MECHANICAL

ESTIMATING AND COSTING

[A TEXT-BOOK FOR ENGINEERING STUDENTS]

(Including Project Planning)

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ESTIMATING AND COSTING

Definition of Estimating. It is an art of finding the cost, which is likely to be incurred on the manufacture of an article, before it is actually manufactured. Thus, it is the calculation of a probable cost of an article before the manufacturing starts. It also includes per determination of the quality of material, labour etc., required.

Estimating is a highly technical knowledge about factory methods and operation times etc.

Importance of Estimating. In all organisations, before starting actual production or filling up the tenders, estimation is done. Therefore accurate estimating is very necessary to compete the market and to be sure whether manufacture of a particular article will be profitable or not. Both over and under-estimating are dangerous. Over-estimating leads to increase the cost and hence tenders may not get suitable response. Under-estimating may lead to heavy losses to the concern. Hence accurate estimating is very essential and therefore staff of the estimating department should be well qualified, experienced and trained in this profession.

For example, a concern wants to start, the manufacturing of Lathe-chucks. The firm finds by market-research that, its market price is approximately Rs. 200. But estimated price of the firm is more than this value. Then the drawings may be sent back to design section, to find out an alternate design, so that price can be reduced If reduction of price is not possible than idea of manufacturing the chucks would be dropped, otherwise it would lead to a greater loss.

Aims of Estimating. The main aims of estimating are as under :

(*i*) To help the factory owner's in deciding the manufacturing and selling policies.

(*ii*) To help in filling up the tender enquiries.

(*iii*) To decide about the amount of overheads, which helps in comparing and checking the actual overheads of the factory.

(*iv*) To decide about the wage rates of the workers after making "Time Study."

(*v*) It helps to decide whether a particular material should be purchased from the market or to be manufactured.

Functions of Estimating. The important functions of estimation are summarised below :

(*i*) To determine material cost, taking into consideration different allowances given for different manufacturing operations.

(*ii*) To determine labour cost considering labour time with the help of wage rates.

(*iii*) To determine the cost of material to be purchased from outside.

(*iv*) To determine the cost of tools, equipment etc., to be purchased from outside.

(*v*) To determine different overhead charges including selling, packing and transportation charges.

(*vi*) To determine selling price after adding due profit in the total cost.

(*vii*) To conduct time and motion study.

(*viii*) To refresh themselves with modern methods and equipment used in manufacturing their products.

(*ix*) To keep the previous records in a systematic way of estimates for future reference.

(*x*) To keep contacts with other departments, regarding methods of operations, quality of material and products etc.

(*xi*) To keep control over selling expenses with the help of sales manager.

(*xii*) To find most economical procedure for the manufacture of products and their design.

(*xiii*) To submit estimates to the sales department for selling products.

(*xv*) To help in modification of design.

ORGANISATION OF ESTIMATING DEPARTMENT

In large concerns, this department functions separately under the planning department ; but for small concerns, the work of estimation is generally performed by production manager with the help of a qualified draftsman.

The person, who prepares the estimates is known as an "Estimator".

Qualities of Estimator. An estimator must possess the following essential qualities :

(*i*) He must be able to read and understand drawings and blue prints well.

(*ii*) He must have a good knowledge of different machines operations and operation timings for the product being manu (*iii*) He should have a good knowledge of the use of proper tools, jigs and fixtures etc.

(*iv*) He must have good knowledge of market prices of different materials required in manufacture.

(*v*) He must have a good knowledge about the wage rates of all types of workers.

(*iv*) He should have good knowledge about different allowances for time *i.e.*, personal allowance, fatigue allowance, tool changing allowance, grinding allowance and checking allowance, etc.

(*vii*) He must have good knowledge about the cutting speeds feeds and depth of cuts for different materials, operations and with different types of tools.

(*viii*) He must be a well qualified and trained technical person and must be able to suggest new methods of production to reduce the production cost.

(*ix*) He must know the official account classification.

(*x*) He must know the procedure for the performance of "Time and Motion Study".

(*ix*) He should also have good knowledge about the business matters.

(*xii*) He must cooperate with the other departments, specially with design, planning and sales deptts.

SOURCE OF ERRORS IN ESTIMATING

There may be some errors in estimating. These errors are of the following two types :

(*i*) Unavoidable errors.

(*ii*) Avoidable errors.

(*i*) *Unavoidable Errors*. These are those, which can not be avoided. Some of the examples of such errors are given below :

(*a*) Machinery breakdown.

(*b*) Power failure.

(*c*) Accidents.

(*d*) Drop in the efficiency of workers.

(*e*) Drop in the efficiency of machines and tools.

(*f*) Strikes.

(*ii*) *Avoidable Errors*. Some of the errors can be avoided by the estimator while preparing the estimates. These errors may occur due to less experience, carelessness and hurry in preparing the estimates.

(*a*) Poor analysis.

(*b*) Omissions of some factors.

(*c*) Not considering up-to date data.

(*d*) Repetition of same factors.

COSTING

Definition. It is the determination of an actual cost of an article, after adding different expenses incurred in various departments.

It may also be defined as a system, which systematically records all the expenditures to determine the cost of manufactured products.

It differs from estimating, that costing is a determination of cost after knowing the expenditures incurred in various departments on the product while estimating is the pre-determination of cost based on the assumptions and previous experiences.

Aims of Costing. The important aims of costing are :

(*i*) To determine the exact cost of each article.

(*ii*) To determine the cost incurred during each operation, to keep control over workers' wages.

(*iii*) To provide information, to ascertain the selling price of the product.

(*iv*) To supply information for detection of wastages.

(*v*) It helps in reducing the total cost of manufacture.

(*vi*) It suggests, changes in design, when the cost is higher.

Standard Cost. It is the pre-determined cost of a product. After compiling different expenses, an estimated cost of a product is forecasted, which is known as standard cost.

It is used as a device to check and lower overhead expenses and improving efficiency.

Generally, standard costs are not flexible but when sudden variation in the material cost or any change in the production method occurs, standard cost should be modified.

Advantages of Standard Cost

(*i*) It provides a check on various expenses.

(*ii*) It helps in deciding the budget.

(*iii*) It helps in budgetary control.

(*iv*) It helps reduction in wastage of material and labour.

(*v*) It helps in price determination.

(*vi*) It is a measure for arriving at the efficiency of the whole concern.

PROCEDURE FOR COSTING

Actual expenditures incurred in various departments for different items are collected by the costing department The expenditures are then categorised under the following main heads :

(*i*) Direct material cost.

(*ii*) Direct labour cost.

(*iii*) Factory overheads.

(*iv*) Administrative overheads.

(*v*) Selling overheads.

To determine the total cost, sum of each of the above heads is added. For detailed description chapter on 'Elements of Cost' should be consulted.

Advantages of Efficient Costing. Efficient costing has got the following advantages :

(*i*) It helps in tracing wastage, leakage and spoiled material.

(*ii*) It gives information regarding profitable and unprofitable activities.

(*iii*) It provides an effective check on wage systems.

(*iv*) Actual causes of reduction in profits can be easily found.

(*v*) It gives information, regarding component parts, whether it is profitable to manufacture them in the factory or to purchase from outside market.

(*vi*) It also helps in the settlement of wage rates with trade unions at the time of dispute.

(*vii*) It provides data for comparison between actual cost and estimated cost of an article.

(*viii*) It provides data for overhead charges etc. to assist in the preparation of estimates for future work.

(*ix*) It helps the management in forming the policies for price determination.

(*x*) It provides information of detailed expenditure, so that, it can be checked, when it is tending to exceed.

(*xi*) It keeps control over selling price.

(*xii*) The main advantage of costing is to compare the output of the persons of same trade and working on same type of machines.

(*xiii*) It helps in determining the efficiency of administrative and operative functions and decides the weak point, where wastage and expenses need check.

(*xiv*) It helps the planning department in deciding about the quantity of material required and the sequence of operations on the job.

Constituents of Estimate

These are :

1. Design time
2. Drafting time
3. Time and Motion Studies, Planning and Production Control Time
4. Design and arrangement of special items
5. Experimental work

6. Materials
7. Labour and
8. Overheads.

1. **Design Time.** It is the time consumed in designing a particular product. In estimating, the wages and other expenditures required to be paid in designing a product are to be considered. For this purpose, the cost can be estimated on the basis of similar products already designed in the past or on the basis of good judgement of designer. In this the remuneration paid to design office staff and other expenditures incurred during designing a product in a particular period are all added.

2. **Drafting Time.** After the design work is over, the drawing is split up in simple parts and drawings of individual component according to the requirement of production shops are prepared by Draftsman.

The estimated time to be consumed by draftsman in preparing such drawings is called "Drafting Time". For calculating, drafting time cost, the remuneration of draftsman is taken as the basis.

3. **Time and Motion Studies, Planning and Production Control Time.** Sufficient time may be consumed for such activities and therefore an estimated time and then costs to be incurred are required to be estimated. These can be recorded separately by several departments by past experience or judgement.

4. **Design and arrangement of special items.** Sometimes certain special items are needed for manufacturing a variety of product. The special Items may be patterns, core boxes, flasks, dies, jigs, fixtures and tools etc. The estimator must take into account their cost, whenever used.

5. **Experimental work.** With the help of experiments the best and cheapest method of production is determined. For this, researches and experiments are performed on old and present methods or sometimes inventions are required to be done The cost incurred on such activities is given due consideration.

6. **Materials.** The material cost is found out with the help of samples or drawings etc. These drawings show only the finished dimensions while estimation must take into account the calculations of quantities to be provided including holding, turning, stamping, moulding. waste or spoilage in cutting and finishing etc. therefore an estimator must have practical knowledge of various allowances.

An estimator first prepares rough drawings with all allowances and calculates the volume. From volume weight is obtained by multiplying density. Thus material cost is obtained by knowing the market rates of material.

While calculating material cost it must be seen that whether or not scrap resulting from the process of manufacture can be utilised for some other work by the concern. Its cost is then deducted from the material cost.

7. **Labour.** Estimation of labour cost is a complicated problem, which requires a large experience and at the same time, it plays big role in estimating total cost of a product. Therefore, to estimate the labour cost, an estimator must have a thorough knowledge of all the operations carried out during the production. Estimator should take the advice of production department while deciding about the exact time of each operation.

Different allowances like personal, fatigue, tool changing and grinding and checking measurement allowance should also be taken into consideration.

8. **Time Allowances.** The classification of "Time Allowances" are as under :—

(*i*) Set up time

(*ii*) Operation time

(*a*) Handling time

(*b*) Machining time

(*iii*) The tear-down time

(*iv*) Miscellaneous allowances.

(*i*) **Set up time.** This is the time required for setting and fixing the job and different tools on the machine. This is also known as "Setting Time". This includes time to study drawings, blue prints, to set machines, to inspect job, setting of gauge etc.

Set up time is independent of the number of jobs to be produced and is the function of two factors.

(*a*) Set up hours and

(*b*) Rate paid per hour

(*ii*) **Operation Time.** This the time taken by the machines for the actual operations on the job. This is also known as "cutting time" or "floor to floor time". Operation time includes (*i*) Handling time and (*ii*) Machining Time.

Handling Time means all the time required in physical movement while performing the machining operations.

Machining Time means time taken by the machines from the start when the tool touches the job to the end when the tool leaves the job.

(*iii*) **Tear-down Time.** This time is counted from when the last element of operation has been completed.

(*iv*) **Miscellaneous Allowances.** An estimator should also consider different allowances for time because it cannot be expected that a worker can work for all the 8 hours without rest. Therefore, he should not completely strict about the time, which he has calculated. The efficiency of the worker decreases with the lapse of time due to fatigue etc. Time for other works such as tool changing, tool sharpening, checking measurement and personal calls etc., should also be considered while calculating the time taken to complete the product. These factors consume generally 10% to 15% of the total time taken.

On the job. This includes the removal of all tools used on the operation or operations. It means the machine should be left in a condition which would not need any additional removel of tools for a new operation. This time is sometimes included in 'Set up' time.

Some of the important miscellaneous allowances are discussed below :

(*a*) Personal allowances

(*b*) Fatigue allowances

(*c*) Tool changing and grinding allowances

(*d*) Measurement checking allowances

(*e*) Other allowances.

(*a*) **Personal allowances.** It is the time consumed to attend his personal needs such as going to lavatories, to take water, to smoke etc. Reduction in efficiency due to headache, cold and other minor diseases also falls in this category. This allowance is nearly 5% of the total working time.

(*b*) **Fatigue allowances.** A worker cannot work for full time with the same speed. After some time, he feels some tiredness due to excessive work, poor lighting, machine noises etc. These all lead to fatigue. This is a well known fact that a fresh man can work quickly than that of a tired man. A suitable allowance for a fatigue should therefore also be considered. This allowance may also be taken as nearly 5% of the total time taken.

(*c*) **Tool changing and grinding allowances.** These include the time required to remove the tool from its holder and to fix another tool. It also includes the time required to sharpen the tool because, it becomes necessary after certain hours of use. For sharpening the tool, worker has to remove the tool, walk up to the grinder to grind the tool, come back to machine and set the tool again or the machine. This allowance may be taken nearly 20% of the total time taken.

(*d*) **Measurement and checking allowances.** These include the time taken for measuring and checking the different dimensions of the product. Rough dimensions require less time; while accurate dimensions require large time. Therefore a due consideration should be allowed for it. This allowance may be taken nearly 2% to 30% of the total time taken.

(*e*) **Other Allowances.** In this, time consumed in activities like periodic cleaning and oiling. getting stocks, delivering jobs, disposing of scraps and surplus stock etc. Due consideration must be given to this while estimating. In some shops, 15% to 20% of the operation time is consumed in these activities.

9. Overheads. These include the expenditure which cannot be definitely charged to some particular product during production. These include the expenses such as :

(*a*) *Indirect material cost.* In this, the cost of greases, coolants, oils, cotton waste, contingencies, power, water etc. are considered.

(*b*) *Indirect labour cost.* In this the pay of supervisors, draftsmen, designers, research workers, helpers, chowkidars and persons working for material handling etc. is included.

(*c*) *Administrative Overheads.* These include salaries of high officials, salaries of persons working in general office, telephone, telegraph and insurance premium etc.

(*d*) *Selling Overheads.* These include salaries of salesman, commission to salesman and advertising expenditure etc.

(*e*) Repairs and maintenance expenses.

(*f*) Insurance premium on building and plants

(*g*) Depreciation of building, furniture and equipment.

Other expenditures if any added in overheads. Then sum of all these expenses is found which will be the total estimated cost of the product. These estimates are then sent to the sales department for necessary action and approval.

2

ELEMENTS OF COST

Introduction. This topic is very useful in the subject "Estimating and Costing". In any factory, the cost of the product manufactured is calculated, so that the exact idea of the amount of profit can be made. We know that there are hundred of different items of expenditures, which are made in the factory and all these are charged on the product manufactured. No items of expenditure should be left, while calculating the total cost of any product, there fore, this total cost is divided into different headings known as "Elements of Cost".

For easy and accurate calculations, the total cost of a product manufactured can be divided into three main "Elements". These are :—

1. Materials.
2. Labour.
3. Expenses.

1. Materials. These can be further classified into :

(*i*) Direct materials, and

(*ii*) Indirect materials.

(*i*) *Direct Materials.* These are those materials which when operated or processed in the factory shops through the various stages form the final useful shape of the main product or component part of the main product. These are also known as "Productive Materials".

(*ii*) *Indirect Materials.* These are those materials which are essentially needed in various shops for helping the materials to be converted into the final useful shapes. Difference between direct and indirect forms of materials can be easily understood by the following example.

Suppose a person continuously working in Milling Machine Shop is cutting gear teeths on cast iron blanks. Now the cast iron blanks, of which the gear is made, will be the direct material while the coolant required for cooling the cutter, grease and lubricating oil needed for lubricating the machine, kerosene oil and cotton waste etc. needed for cleaning the machine are known as Indirect Materials.

2. Labour. Labour employed in any factory may be of two classes.

(*i*) Direct labour, and

(*ii*) Indirect labour.

(*i*) *Direct Labour.* The workers, who actually work or process the different materials manually or with the aid of machines is known as "Direct Labour". This is also called Productive Labour. The nature of their duties is such that their wages can be directly charged to the job, which they are manufacturing.

Workers engaged for operating on various production machines in machine shop welding shop, pattern making shop, electric winding shop and assembly shop etc. is known as Direct Labour.

(*ii*) *Indirect labour.* Any other labour, who help the productive labour in performing their duties is known as Indirect Labour. The nature of their duties is such that their wages can not be charged directly to a particular job but are charged on the total number of products produced in the plant during a particular period.

Foremen, Supervisors, Inspectors, Chowkidars, Gate-keepers, Store-keeper, Crane Driver and Gangmen etc., are classified as Indirect Labour.

Now again consider the above example of Milling Machine Shop. The worker who is producing gears continuously on the milling machine is known as Direct Labour, while the Foreman, supervising in the milling machine shop, the inspector checking the accuracy of gears and helper, who is bringing and taking away the gear blanks from the worker are examples of Indirect Labour.

3. **Expenses.** We have discussed, direct material cost and direct labour cost but apart from this, you will find that, in each factory there are several other expenditures, such as cost of advertisement, building rent, depreciation charges of plant and factory building, cost of packing, cost of transportation, salaries and commission to salesman etc. All these expenditures are known as "Expenses". So, we can say that except direct material and direct labour cost, all other expenses, which occur in the factory are known as "Expenses".

The cost of Indirect material and Indirect labour is also included in the expenses.

Expenses may be of two classes.

(*i*) Direct or chargeable Expenses, and

(*ii*) Indirect Expenses.

(*i*) *Direct Expenses.* These are those expenses, which can be charged directly to a particular job and are done for that specific job only. For example, cost of special jigs and fixtures, cost of some special patterns and cost of experimental work on a particular job etc.

(*ii*) *Indirect Expenses.* These are also known as overhead charges, oncost, burdon or indirect charges. These can be further classified as :

(*a*) Factory expenses.

(*b*) Administrative expenses.

(*c*) Selling expenses and

(*d*) Distribution expenses.

(*a*) **Factory Expenses.** These overheads include all the expenditure made on the actual operation of the product in the plant. Such as Indirect material and Indirect labour. It is also named as works oncost.

(*b*) **Administrative Expenses.** These overheads include all the expenditure made on the salaries of general office staff and executive staff, telegraph and telephone charges, depreciation of office building and equipment etc.

This is also known as establishment on-cost or office expenses.

(*c*) **Selling Expenses.** These overheads include all the expenditure made on the salaries of persons working in sales department, advertising expenses and agency expenses etc.

(*d*) **Distribution Expenses.** These overheads include all the expenses made on holding finished stock, despatching them to the customer and packing cost etc.

Fixed and Variable Overheads. All the overheads described above may be classified into two forms.

(*i*) Fixed overheads and

(*ii*) Variable overheads.

(*i*) *Fixed Overheads.* These are those indirect expenses which remain constant whatever may be the volume of production such as salaries of higher officers, rent of building and insurance charges etc.

(*ii*) *Variable Overheads.* These are those indirect expenses, which vary with the volume of production such as power, fuel, store supplies etc. These are also known as variabie. Fluctuating or Floating over overheads.

Now, from above we can see that variable overheads increase proportionately with the rate of production, but fixed overheads remain almost constant. So by increasing the amount of production, the total cost of the product can be reduced. It is also essential that there should at least be some minimum amount of production which can cover the fixed overheads.

Thus large profits can be earned by increasing the production and lowering fixed overheads.

Components of Cost. The various components of cost are :

1. **Prime cost.**
2. **Factory cost.**
3. **Office cost.**
4. **Total cost.**

1. *Prime Cost.* It consists of direct material cost, direct labour cost and direct expenses.

i.e. Prime cost = Direct material cost + Direct labour cost + Direct expenses.

Prime cost is also named as "Direct Cost".

2. *Factory Cost.* It consists of prime cost and factory expenses.

i.e. Factory cost = Prime cost + Factory expenses.

Factory cost is also named as 'Works Cost'.

3. *Office Cost.* It consists of factory cost and administrative expenses.

i.e. Office cost = Factory cost + Administrative expenses.

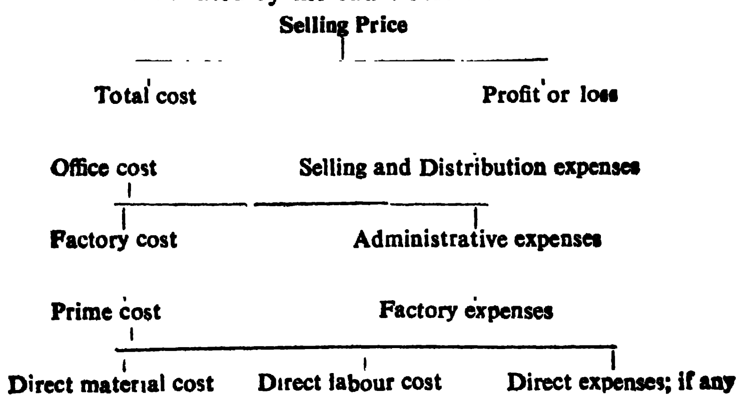
Office cost is also named as manufacturing cost or cost of production.

4. *Total Cost.* It includes office cost and selling and distribution expenses.

i.e. Total cost = Office cost + Selling expenses + Distribution expenses.

Selling Price. If the profit of factory is added, in the total cost of the product it is called selling price. So the customers get the articles, by paying the price which is named as selling price.

The relation between the elements of cost and components of cost can be best illustrated by the chart below :



This can also be illustrated by the block diagram given on next page.

NUMERICALS

1. A certain piece of work is produced by a firm in batches of 100. The direct material cost for that 100 pieces work is Rs. 160·00 and the direct labour cost is Rs. 200·00 Factory on cost is 35% of the total material and labour cost. Overhead charges are 20% of the factory cost. Calculate prime cost, factory cost. If the manage-

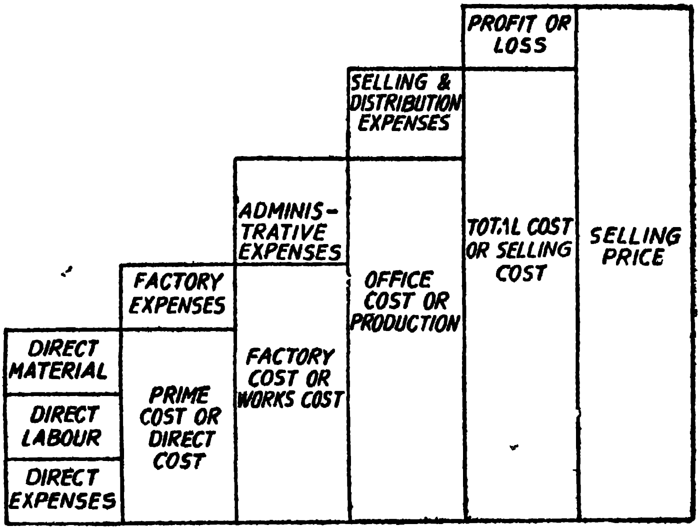


Fig. 2·1. Block diagram to illustrate the relation between "Elements of Cost and Components of Cost".

ment wants to make a profit of 10% on the gross cost. Determine the selling price of each article.

Solution.

No. of products to be manufactured = 100

Direct material cost = Rs. 160·00

Direct labour cost = Rs. 200·00

Hence, Prime cost = Direct material cost + Direct labour cost

= Rs. 160·00 + Rs. 200·00

= Rs. 360·00 only. **Ans.**

As factory on-cost is 35% of the Prime cost,

Factory on-cost $\frac{360 \times 35}{100}$ Rs. 126·00

Factory cost = Prime cost + Factory on-cost

= Rs. 360 + Rs. 126 = Rs. 486·00 only. **Ans.**

As overhead charges are 20% of the factory cost.

∴ Overhead cost $= \frac{20 \times 486}{100} =$ Rs. 97·20

∴ Total cost = Prime cost + Factory oncost + Overheads

= Rs. 360 + Rs. 126 + Rs. 97·20

= Rs. 583·20.

Now, management wants profit of Rs. 10% on the gross cost, *i.e.* total cost.

$$\text{Hence, Selling price of 100 pieces} = \frac{110 \times 583{\cdot}20}{100}$$

$$= \text{Rs. } 641{\cdot}52$$

$$\text{Hence, Selling price of each work piece} = \frac{641{\cdot}52}{100}$$

$$= \textbf{Rs. } \mathbf{6{\cdot}4152}$$

Say, Rs. 6·42 only. Ans.

2. The market price of a lathe is Rs. 5000 and the discount allowed to the distributor is 20% of the market price. It is found that the selling expenses cost is ¼th the factory cost and if the material cost, labour cost and factory overhead charges are in the ratio of 1 : 4 : 2 : what profit is made by the factory on each lathe, if the material cost is Rs. 400 ? Neglect other overheads.

Solution.

Market price of a lathe = Rs. 5000

Discount allowed = 20% on market price

$$= \frac{5000 \times 20}{100} = \text{Rs } 1000.$$

Hence, Selling price of factory = Rs. (5000 − 1000)

= Rs. 4000 ...(1)

Now, Selling price of factory = Factory cost + Selling expenses + Profit

But, Selling expense cost = $\frac{1}{4}$ (Factory cost) ...given

Selling price of factory = $\frac{5}{4}$ Factory cost + Profit ...(2)

Now, Factory cost = Material cost + Labour cost + Overheads

Here material cost = Rs. 400

Labour cost = 4 × 400 = Rs. 1600

and Overhead expenses = 2 × 400 = Rs. 800

∴ Factory cost = 400 + 1600 + 800 = Rs. 2800 ...(3)

Substituting value in equation (2) from equations (1) and (3)

Then, $4000 = \frac{5}{4} \times 2800 + \text{Profit}$

∴ Profit = Rs. 4000 − 3500, or Rs. 500.

Hence profit to factory on each lathe is **Rs. 500 only.**

3. Two workmen engaged on a forgoing Hammer complete 20 connecting rods, each weighing 4 kg. The workmen are paid at the rate of Rs. 5 and Rs. 3 per day and material cost is Rs. 2 per kg. If 140% of direct labour is charged to compensate for both factory overheads and administrative expenses, what will be per unit cost of production of these units.

Solution. No. of workers = 2

Rate of worker No. 1 =Rs. 5/day
Rate of worker No. 2 =Rs. 3/day
No. of connecting rods 20.
Weight of each connecting rod=4 kg.
and overhead charges=140% of direct labour charges.
First find the total cost of 20 pieces.
Total cost consists of labour cost+Material cost+Factory Overheads+Administrative overheads
Labour cost for 20 pieces=Rs. 5+Rs. 3=Rs. 8·00
Material weight =20×4=80 kg.
Material cost =80×2=Rs. 160·00

Factory and administrative overheads

$$=8\times\frac{140}{100}=\text{Rs. }11{\cdot}20$$

∴ Total cost of 20 pieces=8·00+160·00+11·20
=179·20.

$$\therefore \text{ Per unit cost of production}=\frac{\text{Total cost}}{\text{No. of pieces}}=\frac{179{\cdot}20}{20}$$
=Rs. 8·96.

Hence the production cost of each connecting rod will be
=**Rs. 8 96 only. Ans.**

4. A factory is producing 1000 bolts and nuts per hour on a machine. Its material cost is Rs. 375, labour cost Rs. 245 and the direct expense is Rs 80. The factory oncost is 150% of the total labour cost and office on cost is 30% of the total factory cost. If the selling price of each bolt and nut is Rs. 1·30, calculate whether the management is going in loss or gain and by what amount.

Solution.

Material cost =Rs. 375
Labour cost =Rs. 245
Direct expense =Rs. 80

Overhead charges. Factory on cost=150% of total labour

$$\text{cost}=\frac{150\times245}{100}=\text{Rs. }367{\cdot}50$$

Hence total factory cost=375+245+80+367·50
=Rs. 1067·50

Now, office oncost is 30% of total factory cost

$$=\frac{1067{\cdot}50\times30}{100}=\text{Rs. }320{\cdot}25$$

Hence, total cost of production per 1000 bolts and nuts

= Factory cost + Office on-cost

= Rs. 1067·50 + Rs. 320·25 = Rs. 1387·75

∴ Production cost per piece

= 1·38775 say Rs. 1·39 per piece

But selling price of management is Rs. 1·30 per piece.

Hence the management is undergoing at loss of Rs. 1·39 − 1·30

= **Re. 0·09 per piece only. Ans.**

5. A small firm is producing 100 pens per day. The direct material cost is found to be Rs. 160, direct cost Rs. 200 and factory overheads chargeable to it Rs. 250. If the selling on cost is 40% of the factory cost, what must be the selling price of each pen to realise a profit of 14·6% of the selling price.

Solution.

No. of pens to be manufactured = 100
Direct material cost = Rs. 160
Direct labour cost = Rs. 200
Factory overhead charges = Rs. 250.
Selling oncost = 40% of factory cost
Profit = 14·6% of selling price

Let selling price of 100 pens is Rs. R

Hence, profit on selling price of Rs. R

$$= \frac{14 \cdot 6 \times R}{100}$$

Total cost = Selling price − Profit

$$= R - \frac{14 \cdot 6 \times R}{100} \quad \ldots(1)$$

Now, Factory cost = Material cost + Labour cost + Overheads

= Rs. 160 + 200 + 250

= Rs. 610.

Total cost = Factory cost + Selling oncost.

But selling oncost = 40% of factory cost

$$= \frac{610 \times 40}{100} = \text{Rs. } 244$$

Total cost = 610 + 244 = Rs. 854

Hence, substituting in Eqn. (1)

$$854 = R - \frac{14 \cdot 6R}{100}$$

or $R = 1000$.

Hence Selling price of each pen

$$=\text{Rs. } \frac{1000}{100} = \textbf{Rs. 10 only. Ans.}$$

6. Data regarding the expenditure made on a machine during the month of March 1969 are as follows :

(*i*) Cost of machine=Rs. 6,000

(*ii*) Estimated scarp value=Rs. 1,000

(*iii*) Effective working life=20,000 hours.

(*iv*) Power charges=Re. 0·50 per hour

(*v*) Repairs and maintenance cost during the month=Rs. 30

(*vi*) Standing charges (*i.e.* charges for insurance, lighting and rent etc.) for the month=Rs. 60.

(*vii*) Duration of work in March 1969=150 hours.

Calculate (*a*) Hourly rate of depreciation
(*b*) Machine hour rate.

Solution.

(*a*) As, Depreciation

=Cost of machine−Scrap Value

=6,000−1,000

=Rs. 5,000

$\therefore$ Hourly rate of depreciation$=\frac{5000}{20,000}=$**Re. 0·25. Ans.**

(*b*) Hourly rate of depreciation=Re. 0·25

Hourly cost of power consumption

=Re. 0·50

Repairs and maintenance cost for 150 hours.

=Rs. 30

$\therefore$ Cost of repairs and maintenance/hr. $=\frac{30}{150}=$Re. 0·20

Standing charges for 150 hours=Rs. 60.

$\therefore$ Standing charges per hour$=\frac{60}{150}=$Re. 0·40

$\therefore$ Total machine hour rate=Rs. (0·25+0·50+0·20+0·40)

=**Rs. 1·35 Ans.**

7. A factory owner employed 50 workers during the month of April 1969, whose details of expenditure are given below :

(*i*) Material cost =Rs. 30,000.

(*ii*) Rate of wages for each worker

=Re. 0·75/hr.

(*iii*) Duration of work =8 hours/day

(*iv*) No. of holidays in the month
=5 days.

(*v*) Total overhead expenses =Rs. 15,000.

If workers were paid overtime of 400 hours at the rate of Rs. 1·50/hr.

Calculate (*a*) Total Cost.

(*b*) Man hour rate of overheads.

Solution.

(*a*) Material cost =Rs. 30,000

No. of workers =50

No. of working days =30−5
=25 days

Duration of work/day =8 hours

∴ Total No. of hours for the month
$= 50 \times 25 \times 8$
=10,000 hrs.

Rate/hr. =Re. 0·75/hr.

∴ Labour cost $=10{,}000 \times 0{\cdot}75$
=Rs. 7500

∴ Overtime allowance =No. of overtime hours × hourly rate
$=400 \times 1{\cdot}50=$ Rs. 600

∴ Total labour cost =Rs. 7500+Rs. 600
=Rs. 8,100.

Total overhead expenses =Rs. 15,000.

Total cost=Material cost+Labour cost+Overheads.
=Rs. 30,000+8,100+15,000

∴ Total cost=**Rs. 53,100 Ans.**

(*b*) Total Man hours=10,000+Overtime
=10,000+400=10,400 hrs.

∴ Man hour rate of overheads

$$=\frac{\text{Total overheads}}{\text{Total man hours}}$$

$$=\frac{15{,}000}{10{,}400}$$

=**Rs. 1·44. Ans.**

8. An article can be made either by hand or in large quantity by mass production. In the former case, time taken is 3 hours and overheads are 25% of labour cost, while in the latter case time taken for 10 pieces is 8 hours, but overheads are 150% of labour cost. Material cost is Rs. 1·50 per piece and labour charges are Re. 0·80/hr

Compare the total cost in both the cases.

Solution. *First case.* When article is manufactured manually Time taken for manufacturing one article=3 hours.

Material Cost/piece	= Rs. 1·50
Labour rate	=Re. 0·80/hr.
∴ Labour cost	=3×0·80 =Rs. 2·40
Now overhead charges	=25% of labour cost
∴ Overheads	=0·25×2·40
	=Re. 0·60
Hence, Total cost	=Rs. 1·50+Rs. 2·40+Re. 0·60 =**Rs. 4·50 Ans.**

Second case. When the article is manufactured on mass scale. Time taken for 10 pieces=8 hrs.

∴ Time taken/piece $= \frac{8}{10}$ hrs.

As labour rate is Re. 0·80/hr.

∴ Labour cost $= \frac{8}{10} \times 0{\cdot}80 =$ Re. 0·64

Overhead charges = 150% of labour cost

$= \frac{150}{100} \times 0{\cdot}64 =$ Re. 0·96

Now, Total cost=Material cost+Labour cost+Overheads.

=Rs. 1·50+Re. 0·64+Re. 0·96

=**Rs. 3·10. Ans.**

Now, we can see that article produced be second method is much cheaper than the first method.

9. Prepare a statement giving the following information. (*i*) Material cost (*ii*) Prime cost (*iii*) Factory cost (*iv*) Administrative overheads (*v*) Selling overheads (*vi*) Total cost and (*vii*) Profit.

Following data refer to a factory for the financial year ending 31st March, 1971.

1.	Stock of material on 1st April, 1970	=Rs. 50,000
2.	Material purchased	=Rs. 3,40,000
3.	Drawing office salaries	=Rs. 5,000
4.	Rent, taxes and insurance of factory	=Rs. 10,000
5.	Pay and commission to salesmen	=Rs. 10,000
6.	Depreciation of office equipment	=Rs. 200
7.	Wages to labour (Direct labour cost)	=Rs. 2,50,000
8.	General administrative expenses	=Rs. 3,400
9.	Water and power for factory	=Rs. 9,000
10.	Sale of products	=Rs. 90,00,000
11.	Works Manager's salary	=Rs. 15,000

12.	Salary of office staff (including executives)	=Rs. 60,000
13.	Depreciation of the plant	=Rs. 8,000
14.	Material transportation	=Rs. 2,000
15.	Water and lighting for office	=Rs. 3,000
16.	Rent, taxes and insurance of office	=Rs. 1,500
17.	Repairs and maintenance of plant	=Rs. 5,000
18.	Direct Expenses	=Rs. 500
19.	Stock of material on 31st March, 1971	=Rs. 45,000

Solution. *First we have to determine material cost.*

Material cost=Stock of material on 1st April 1970+material purchased−stock of material on 31 March, 1971

=Rs. 50,000+3,40,000−45,000

=Rs. 3,45,000. **Ans.**

(*ii*) *Prime cost*=Direct materials+Direct Labour+Direct Expenses

=3,45,000+2,50,000+500=Rs. 5,95,500. **Ans.**

(*iii*) *Factory overheads are :*

Rent, taxes and insurance of factory	=	Rs. 10,000
Water and power for factory	=	9,000
Works Manager's salary	=	15,000
Depreciation of plant	=	8,000
Material transportation	=	2,000
Repairs and maintenance of plant	=	5,000
Total	=	Rs. 49,000

∴ Factory cost=Prime cost+Factory overheads

=5,95,500+49,000=**Rs. 6,44,500. Ans.**

(*iv*) *Administrative overheads are* :

Drawing office salaries	=	Rs. 5,000
Depreciation of office equipment	=	200
General Expenses	=	3,400
Salaries of office staff	=	60,000
Water and lighting for office	=	3,000
Rent, taxes and insurance of office	=	1,500
Total	=	Rs. 73,100 **Ans.**

(*v*) *Selling overheads are* :

=Pay to salesmen=Rs. 10,000. **Ans.**

(*vi*) *Total cost* =Factory cost+Administrative overhead +selling overhead

=6,44,500+73,100+10,000

=**Rs. 7,27,600. Ans.**

(*vii*) ∴ *Net Profit* = Selling price − Total cost.
= 9,00,000 − 7,27,600 = 1,72,400. **Ans.**

10. (*a*) What are the elements of total cost of a product being manufactured and sold ?

(*b*) How will you try to minimise the total cost of an article, when it is facing heavy competition from other manufacturers ?

Ans. (*a*) *See* chapter on "Elements of Cost".

(*b*) The following are the sources which increase the cost of a product. There should be a reasonable check on them to face competition.

The sources are :

(*i*) Capital

(*ii*) Space and building

(*iii*) Power

(*iv*) Material

(*v*) Man-power

(*vi*) Equipment

(*vii*) Time

The following factors should be used to reduce the cost of product :

(*i*) A definite system of doing work.

(*ii*) Simplification and standardisation of product should be made.

(*iii*) Use of jigs and fixtures.

(*iv*) Use of best gauges in inspection.

(*v*) Best organisation of every department and factory as a whole.

(*vi*) Classification and identification.

(*viii*) Designing of proper tools and equipment etc.

The above facts should be introduced and time and motion study should be made to reduce the cost of product specially when it is facing heavy market competition.

11. The output of an axle factory is 4,000 units per month. Its variable cost is Rs. 5 each and fixed overheads are Rs. 4,000 per month. The selling price of each is Rs. 7. Estimate the minimum, monthly Production that may not cause any loss to the owner.

Let the required minimum Production = P units

Variable cost = Rs. 5 each

∴ Variable cost for P units = Rs. $5 \times P$

Fixed overheads = Rs. 4,000 monthly.

∴ Total cost = Variable cost + Fixed overheads
= $(5P + 4000)$. ...(*i*)

Selling Price of each unit $= Rs. 7.$

$\therefore$ Selling Price of P units $= Rs. 7 \times P$ ...(*ii*)

It there is no profit or loss than the total cost should be equal to selling price.

$\therefore$ Equating (*i*) & (*ii*)

$$5P + 4,000 = 7P$$

or $$2P = 4,000$$

$\therefore$ $$P = 2.000 \text{ units}$$

Therefore monthly minimum production to avoid any loss should not be less than 2000 units.

12. The variable overhead charges for a product are Rs. 2 and the fixed overhead charges per month are Rs. 35,100. It is found that 65,000 products are manufactured per month under normal conditions.

(*a*) Find the normal overhead cost per product.

(*b*) If the production drops to 90%, determine the overhead charges that are unrecovered.

(*c*) If ihe production is increased to 130% by what amount these charges will be over-recovered ?

Solution.

Variable overhead charges

$= Rs. 2/article.$

Fixed overhead charges

$= Rs. 35,100/month.$

Articles produced under normal conditions

$= Rs. 65.000/month.$

(*a*) **Normal overhead cost/article.**

Total overheads = Variable overheads + Fixed overheads.

Per product $= Rs. 2 + Rs. 35,100/6500.$
$= Rs. 2 + Rs. 0{\cdot}54.$
$= Rs. 2\ 54.$ **Ans.**

i.e. Fixed overheads charges/unit
$= Re. 0{\cdot}54.$

(*b*) **Production drops to 90%.**

Now monthly production

$= 65000 \times 0{\cdot}90$
$= 58.500/units.$

$\therefore$ Fixed overheads for 58,500 unit

$= 58,500 \times 0{\cdot}54$
$= Rs. 31,690.$

Fixed overheads under normal conditions.

$= Rs. 35,100.$

∴ Overheads to be unrecovered

= (35,100−31,690)

= Rs. 3410. **Ans.**

(*c*) **Production increases to 130%.**

Now, monthly production

= 65000×1·30

= 84500 units.

∴ Fixed overheads for 84500 units

= 84500×0·54

= Rs. 456·30.

∴ Fixed overheads under normal conditions.

= Rs. 35,100.

∴ Overheads to be over recovered

= 45630−35100

= Rs. 10,530. **Ans.**

13. For manufacturing a turret machine, the expenditure is as given below :—

(*i*)	Material consumed	=Rs. 55,000
(*ii*)	Indirect factory wages	=Rs. 8,000
(*iii*)	Director's fees	=Rs. 3,000
(*iv*)	Advertising	=Rs. 10,000
(*v*)	Net profit	=Rs. 12,500
(*vi*)	Depreciation on sales department car	=Rs. 1,100
(*vii*)	Printing & Stationery	=Rs. 250
(*viii*)	Depreciation on Plant	=Rs. 4,500
(*ix*)	Direct Wages	=Rs. 65,000
(*x*)	Factory rent	=Rs. 6,000
(*xi*)	Telephone & Postage charges	=Rs. 150
(*xii*)	Gas & Electricity	=Rs. 500
(*xiii*)	Office salaries	=Rs. 2,100
(*xiv*)	Office rent	=Rs. 500
(*xv*)	Show room rent	=Rs. 1,500
(*xvi*)	Salesman's Commission	=Rs. 2,650
(*xvii*)	Sales department car expenses	=Rs. 1.500

Find out (*a*) direct cost (*b*) works or factory cost (*c*) total cost of production (*d*) cost of sales and (*e*) selling price.

(*A.M.I.E. Sec. B. Nov. 1969*)

Solution.

(*a*) **Direct Cost**

= Direct material cost+Direct Labour cost +Direct expenses, if any.

= 55,000+65,000

= Rs. 1,20,000. **Ans.**

(*b*) **Factory cost**

= Direct cost+Factory overheads.
= 1,20,000+8000+4500+6000+500
= **Rs. 1,39,000. Ans.**

(*c*) **Cost of Production**

= Factory cost+Office oncost
= 1,39,000+3000+250+150
+2,100+500
= **Rs. 1,45,000. Ans.**

(*d*) **Total cost or cost of sales**

= Cost of Production+Sales overheads
= 1,45,000+10,000+1,100+1,500
+2,650+1,500
= **Rs. 1,75,250. Ans.**

(*e*) **Selling Price**

= Total cost+Profit
= 1,75,250+12,500
= **Rs. 1,87,750. Ans.**

PIPE FITTING

14. Estimate the direct material cost and total cost for a pipe fitting as shown in the layout given below.

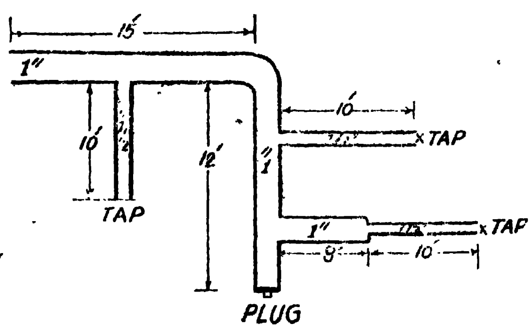


Fig. 2·2

The rates for various items are as follows :

Pipe 1"—Rs. 1·80/ft. ; Pipe ½"—Re. 1·0/ft. Reducer 1" to ½" -Re. 1·00 each ; Tee 1"—Re. 1·00 each ; Reducer Tee 1" to ½" —Re. 0·70 each : Tap ½"—Rs. 4·00 each ; Socket 1"—Re. 0·70 each ; Socket ½"—Re. 0·50 ; Bend 1"—Re. 1·00 ; Plug 1"—Re. 0·40.

Assume consumption of cotton waste and white lead as ½ kg. and 100 gm. respectively and these are available at the rates of Rs. 2/kg. and Rs. 3/kg. respectively. One fitter and one helper are employed for one day @ Rs. 6·00 and Rs. 4·00 per day respectively Overheads may be taken as 20% of the direct labour cost.

Solution. List of Material Consumed :

S.N.	*Material*	*Quantity*	*Rate*	*Amount*
1.	G.I pipe 1″	35′	Rs. 1·80/ft.	Rs. 63·00
2.	G.I. pipe ½″	30′	Re. 1·00/ft.	Rs. 30·00
3.	Reducer 1″ to ½″	1	Re. 1·00 each	Re. 1·00
4.	Reducer Tee 1″×1″×½″	2	Re. 0·70 each	Rs. 1·40
5.	Tee 1″	1	Re. 1·00 each	Re. 1·00
6.	Bend 1″	1	Re. 1·00 each	Re. 1·00
7.	Plug 1″	1	Re. 0·40 each	Re. 0·40
8.	Socket 1″	1	Re. 0·70 each	Re. 0·70
9.	Socket ½″	3	Re. 0·50 each	Rs. 1·50
10.	Tap ½″	3	Rs. 4·00 each	Rs. 12·00
11.	Cotton waste	½ kg.	Rs. 2·00/kg.	Re. 1·00
12.	White lead	100 gm.	Rs. 3·00/kg.	Re. 0·30
			Total	Rs. 113·30

∴ Direct material cost = **Rs. 113·30 Ans.**

Direct labour cost = Rs 6+4 = Rs. 10·00

∴ Prime cost = Rs. 123·30

and Overheads = 20% of labour cost
= 10×0·20 = Rs. 2·00

∴ Total cost = Prime cost + Overheads
= 123·30 + 2·00
= **Rs. 125·30. Ans.**

Unsolved Problems

1. A concern produces bolts and nuts of aluminium and estimated cost is given on the basis of a lot of 1000 bolts with nuts. Length of bolt with head 10 cm. and diameter 2 cm.

(*i*) Material cost = Rs. 700

(*ii*) Labour cost (Direct) :

(*a*) Cutting and setting up = Rs. 150

(*b*) Milling, threading, drilling = Rs. 160

(*iii*) Cost of tools = Rs. 100

(*iv*) Factory overheads = 150% of the total labour cost

(*iv*) Office on cost = 30% of factory cost

(*vi*) Selling price = Rs. 2·00/piece.

Calculate whether the management is making a profit or loss per piece.

Ans. Loss of Re. 0·05 per piece.

2. A certain product is produced by a firm in batches of 100. The direct material cost for them is Rs. 70 and direct labour cost Rs. 50. Factory on cost is assumed to be 40% of the total material and labour cost and other overhead charges as 30% of the factory cost. If the management wants to make a profit of 15% on the gross cost, estimate the selling price of each product.

Ans. Rs. 2·51

3. A businessman purchased a car of Rs. 25,000 and runs it at the rate of 8500 km a month. The car consumes one litre of petrol for 10 km and the owner has to spend Rs. 2500 every year on the car for its repairs. Find out the total cost of running the car as on 2500 km if cost of petrol is Rs. 1·20/litre. Estimate the rate which should be charged/km, if he wants to run the car as a taxi and earn Rs. 1000 per month. Distance covered by the car per month, when it runs as a taxi remains same as in the first case.

Ans. Rs. 361·27 ; Re. 0·26.

4. The catalogue piece of an oil engine is Rs. 7500. The discount allowed to the distributer being 15%, selling expense cost is ½ the factory cost and if the material cost, labour cost and factory overhead charges are in the ratio of 1 : 4 : 3. What profit is to be made by the owner on each engine, if the material cost is Rs. 500.

Ans. Rs. 375.

5. Explain in details the various elements which go to make up the total cost of any product.

6 How would you calculate the cost of a finished product in a factory ? Define and expiain factory cost, manufacturing cost and selling cost.

7. Find out production cost per crank shaft of 22 B.H.P. 4 stoke oil engine from the following figures :

Charges for forgoing per shaft
=Re. 0·25

Wrought iron used/week @ Rs. 1·00/kg.
= 3 tonnes.

Pay of 4 operators =Rs. 24/day
Cartage/day =Rs. 25

Depreciation of machines and tools
=Rs. 500 p.m.

Pay of 4 helpers =Rs. 3·00/day each

Pay of supervisor =Rs. 500 p.m.

Packing charges for 12 shafts
=Rs. 3 00

Electric charges =Rs. 300 p.m.

Pay of manager and maintenance staff
=Rs. 1400/month

If 1500 crank shafts are produced per month and factory runs 26 days a month, what should be the selling price of each shaft so as to earn a profit of 20% on factory cost. Also calculate factory expenses.

Ans. Rs. 10·73 ; Rs. 12·94 ; Re. 0·98.

8. Estimate factory cost, prime cost and overheads of the factory from the data given with respect to production cost.

Shop	*Labour Cost*	*Material Cost*	*Overheads*
Smithy	Rs. 2050	Rs. 9000	Rs. 750
Welding	Rs. 1000	Rs. 200	Rs. 250
Sheet metal	Rs. 1200	Rs. 4000	Rs. 1200
Machine	Rs. 3000	Rs. 700	Rs. 450

Administrative cost for all the shops is Rs. 2500.

9. A factory manufactures two types of electric motors. The following data for the year 1969 are as under :

	1st Type	*2nd Type*
Motor manufactured	250	150
Direct Costs :		
(*i*) Material	Rs. 40,000	Rs. 29,000
(*ii*) Wages	Rs. 12,000	Rs. 8000
(*iii*) Power etc.	Rs. 2500	Rs. 1400
Other Costs :		
(*i*) Supervision	Rs. 3000	
(*ii*) Depreciation	Rs. 280	
(*iii*) Rent	Rs. 700	
Other Expenses :		
(*i*) Management and administrative		Rs. 8900
(*ii*) Selling		Rs. 2000

Estimate the cost of each motor, if factory expenses are to be charged in proportion to direct cost, administrative expenses are to be charged in the ratio of factory costs and factory selling expenses to be charged in proportion to motors manufacturing costs. Assume profit as 20% of total cost.

Ans. Rs. 294 ; Rs. 372

10. The direct material used is Rs. 1000 and direct wages as of Rs. 443 for the manufacture of certain items.

Calculate the factory cost :

(*i*) When the on-cost is to be 60% of prime cost.

and (*ii*) when the on-cost is to be 90% of direct productive labour cost.

Ans. Rs. 2308·80 and Rs. 1841·70

11. A certain article is manufactured in batches of 100. The direct material cost is 250, direct labour cost Rs. 400 and factory

overheads Rs. 290. If the selling on cost is 40% of prime cost, what should be the selling price of each product to obtain a profit of 20% (*i.e.*, profit is 20% of the selling price).

Ans. Rs. 15 each

12. Three workers in a machine shop are engaged on turning of steel pins. They are paid equally. The weekly wages paid to them are Rs. 205 and overhead expenses Rs. 90/week. Find factory cost per piece, if each worker completed 420 pieces per week. Neglect material cost.

Ans. Re. 0·24

13. A certain product can be made either by hand or by mass production. In the first method the time taken is 2 hours and overheads are 40% of labour cost. In the second method, the time taken is 15 hours/100 products and overheads are 140% of the labour cost The material cost of each product is Rs. 1·50 and rate of labour/hour is 80 paisa in each case. Estimate which of the two methods will be more economical.

Ans. (*i*) Rs. 3·74
(*ii*) Rs. 1·79
Second method

14. A factory has a capacity to produce 1000 shapers/annum. But at present it is working at its 70% capacity. The sales income at this level is Rs. 52,50,000. The fixed cost of the factory is Rs. 20,00,000 and variable cost/piece is 2500. There is a proposal for mechanization, but this will increase the fixed cost by Rs 400,000 and will reduce the variable cost by Rs. 500 per unit. Estimate :

(*a*) Whether the proposal is economical ?

(*b*) If a reduction in selling price by Rs. 200/unit makes the factory to run at 85% of its full capacity, would this be a better proposal than the first one. **Ans.** (*a*) No, (*b*) Yes.

15. How the total cost of a product can be divided into different groups ?

16. What are the different products which affect the sales price ?

17. "For the minimum cost of manufacture scrap should not be kept as minimum". Justify the above statement.

3

INDIRECT EXPENSES

Introduction.

These expenses are all the expenses except direct labour, direc material and direct expenses, incurred in the production of a concern It includes repair of plant, power and water charges, depreciatio of building, machines etc , taxes, insurances, compensations, salarie of supervisors, administrative officers and sales agents etc. Becaus there are several types of expenses incurring on a product during year it is difficult to have an account of these expenses. Therefor to have a systematic method of charging them, these expenses ar categorised into certain groups.

Classified statement of different expenses are helpful to kno the upto-date position of these expenses. These expenses are groupe into following major categories.

(*i*) Factory expenses

(*ii*) Administrative expenses

(*iii*) Sales expenses.

In the chapter of elements of cost, different expenses made o a product manufactured in an industry, had already been discussec Direct labour and direct material costs can be calculated with th help of work order, material requisition slip, wages sheets etc.

As regards to oncosts, some of them can easily be known fro various records, examples of such oncosts are, power charges, insu rance, building rent, water charges, fuel charges etc. But som charges require good knowledge and experience of the estimato These charges are discussed as under :

(1) Depreciation

(2) Obsolescence

(3) Interest on capital

(4) Idleness

(5) Repairs and maintenance.

1. *Depreciation.* Whenever any machine or equipment per forms useful work its wear and tear is bound to occur. This can b minimised upto some extent by proper care and maintenance bu can't be totally prevented. Its efficiency also reduces with the laps of time and at one time it becomes uneconomical to be used furthe and needs replacement by another new unit.

Therefore, we can say that efficiency and value of machine or asset contantly reduces with the lapse of time during use, which is known as "Depreciation". So some money must be set aside yearly from the profits, so that when that equipment becomes uneconomical, it can be replaced by the new one. Therefore the initial cost of machine plus installation charges+repair charges−scrap value is charged against overheads and is spread over the machines useful life.

For this purpose depreciation account for the complete plant or individual equipment is opened in the Company's Books and is known as "Depreciation Fund" or "Sinking Fund". This amount is deducted yearly from the profits and kept separate to have sufficient money for replacement at the end of useful life.

2. *Obsolescence.* Suppose a factory owner purchases a machine for his production shop but after some duration a better machine comes in the market, whose production rate is very high and much economical. Although the old machine is efficient but becomes out of fashion and uneconomical due to the new better machine which has come in the market. This is known as "Obsolescence". Consideration of this factor is of much importance and some money should also be set aside from the profits for this cause.

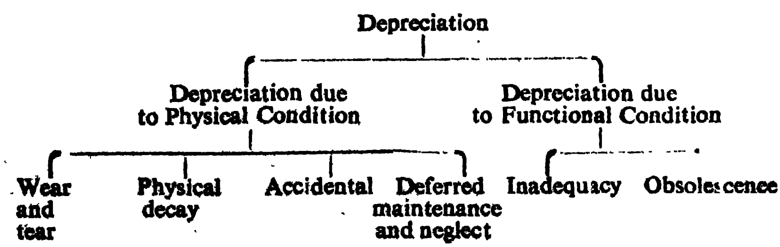
Hence "Obsolescence" is the depreciation of existing machinery or asset due to new and better invention, design, equipment or processes etc.

It is very difficult problem for the estimator to provide for the on-cost on obsolescence, because no body can say when a revolutionary change in the machine is coming in the market. But it is a general practice to reduce the life of a machine so as to account the effect of obsolescence. Now the depreciation and obsolescence charges are calculated in the reduced life.

Suppose an estimator expects the life of machine as 20 years then the depreciation rate will be $100/20=5\%$. By considering obsolescence also, its life may be taken as 15 years. Then the combined depreciation and obsolescence charges will be $100/15=6{\cdot}66\%$ instead of 5%. Therefore, the difference $6{\cdot}66-5{\cdot}00 = 1{\cdot}66\%$ will be obsolescence charges.

The other causes of depreciation are physical decay, accidents, deferred maintenance and neglect, inadequacy etc.

For further understanding depreciation can be classified as under :



Now, each is explained in short below :

(*a*) **Depreciation due to Wear and Tear.** Every body know that when any machinery performs work, wear and tear of certai components takes place, although sufficient precautions are taken *i.e* proper lubricating and cooling is done, which minimises wear an(tear but it can not be totally prevented. So the cost of replacemen because of this cause, is the valve of depreciation due to wear an(tear.

(*b*) **Depreciation due to "Physical decay".** There ar certain items in a factory, such as insulation of material, furniture electric cables, poles. buildings, chemicals and vessels etc., which ge decay, because of climatic and atmospheric effect, with the result th value of these articles goes on reducing with the lapse of time Although every effort is made by the owner to keep them in service able condition, even then because of climatic and atmospheric effec there will be reduction in their costs. This reduction in cost is depre ciation due to physical decay.

(*c*) **"Accidental" Depreciation.** Although, the machin might have installed even few days back and sufficient care is take to prevent accident, even then, accident may occur due to som wrong operation, or some loose component or some other cause which may result in a heavy damage. So the depreciation in machin caused due to this reason is called accidental depreciation.

Nowadays, to cover this risk most of the owners get their equip ment insured with the insurance companys. For that owners hav to pay certian premium yearly. The amount of premium depend upon the estimated cost and life of equipment.

(*d*) **Depreciation due to "Deferred maintenance an(neglect".** Every manufacturer supplies certain instructions for th smooth and efficient running of an equipment. For example, in th case of a vehicle, a manufacturer gave the following instructions :

(*i*) Lubricating oil S A.E. 30 should be used in Engine.

(*ii*) Oil should be drained and new S.A.E. 30 oil should b refilled after 1000 km. running.

(*iii*) All the bolts and nuts should be retighten after 5000 km running.

(*iv*) Decarbonising after 6000 km. running and so on.

Now, if these instructions are not properly followed because o neglect and if proper maintenance is not done as recommended b manufacturer ; then the value of the vehicle may be reduced an depreciation in value because of this, is called Depreciation due t deferred maintenanee and neglect.

(*e*) **Inadequacy.** This is the form of functional depreciatio Inadequacy means reduction in efficiency of an asset. This ma result firstly, even if any equipment is servicing under proper precau tions and sufficient maintenance is provided, there is fall in efficie cy with the lapse of time.

Secondly, suppose after 2-3 years of running, the demand of products manufactured by certain plant is increased. But the plant cannot cope with the increased demand. This needs additional money either to replace with the bigger sized machinery or installation of the similar sized more plants. This is, what is called depreciation due to inadequacy.

(*f*) **Depreciation by Obsolesence.** Nowadays because of much scientific advancement, there are large changes every day. If a new machinery comes in the market, which is much efficient because of new invention and better design than the existing one, manufacturing same type of products and the product produced by the new are much cheaper and better than the exisiting one then the existing machinery has to be replaced to withstand market competition.

This is called depreciation by obsolescence and is of functional type.

Methods of Calculating Depreciation. The following are the various methods of providing for depreciation with solved problems for clear understanding to students :

1. Straight Line Method
2. Diminishing Balance Method
3. Sinking Fund Method
4. Annuity Charging Method
5. The Insurance Policy Method
6. The Revaluation or Regular Valuation Method
7. Machine Hour Basis Method
8. The sum of the Year's Digits Method.

1. **Straight Line Method.** This method assumes that the loss of value of machine is directly proportional to its age. It means one should deduct the scrap value from the original value and divide the remaining value by the number of years of useful life.

Let, C be the Initial cost of a machine.

S be the Scrap value.

N be the Number of years of life of machine.

and D be the depreciation amount per year.

Then, $$D = \frac{C-S}{N} \text{ Rupees.}$$

This method of calculating depreciation fund is also known as "Fixed Instalment" method, because every year same (fixed) amount is deducted and no consideration is made about the maintenance and repair charges, which gradually increases as the machine is getting old.

This will be clear by the following numerical problem.

Problem 1. (*a*) A boiler was purchased in Rs. 45,000 on Ist January, 1946, the erection and installation work cost Rs. 7000. The boiler was replaced by a new one on 31st Dec., 1966. If the Scrap Value was estimated as Rs. 15,000 what should be the rate of depreciation and depreciation fund on 15th June, 1955.

(*b*) If after 12 years of running, some boiler tubes are replaced and the replacement cost is Rs. 1500, what will be the new rate of depreciation.

Solution.

(*a*) Total cost = Boiler cost + Erection and installation charges

$\therefore \quad C = \text{Rs. } 45{,}000 + \text{Rs. } 7{,}000 = \text{Rs. } 52{,}000$

Scrap value, $S = \text{Rs. } 15{,}000$

Life of boiler = From 1st January, 1946 to 31st. Dec., 1966
= 20 years.

$$\therefore \quad \text{Rate of depreciation, } D = \text{Rs. } \frac{C-S}{N}$$

$$= \text{Rs. } \frac{52{,}000-15{,}000}{20}$$

$$= \text{Rs. } \frac{37{,}000}{20} = \text{Rs. } 1850{\cdot}00.$$

$\therefore$ Depreciation in value of boiler per year = Rs. 1850 only.

Now, depreciation fund on 15th June, 1955, *i.e.* 9. Instalments (From 1st January, 1946 to 15th June, 1955) could be accumulated.

$\therefore$ Depreciation fund collected upto 15 June, 1955

$= \text{Rs. } 9 \times 1850 = \text{Rs. } 16650{\cdot}00$ only.

(*b*) As after 12 years tubes have been replaced and cost of replacement is Rs 1500.

Now, book value in 12 years will be Rs. $52000 - 12 \times 1850$

= Rs. 29,800

and replacement cost Rs. 1500.

Hence, new book value Rs. 29,800 + Rs. 1500

= Rs. 31,300.

As, scrap value is same Rs. 15,000, hence the depreciation for the rest 8 years will be (Rs. 31,300 − 15,000)

= Rs. 16,300.

$$\therefore \quad \text{New rate of depreciation} = \text{Rs. } \frac{16{,}300}{8}$$

$= \text{Rs. } 2037{\cdot}50$

$\therefore$ New rate of depreciation per year = **Rs. 2037·50 only.**

2. **Diminishing Balance Method.** This is also called "Reducing Balance" Method. The diminishing value of machine is much greater in the early years. It depreciates rapidly in the early years and later on slowly. Therefore, it is better to depreciate

much during the early years, when the repairs and renewals are not costly.

So under this method, the book value of the machine goes on decreasing as its existence continues. A certain percentage of the current book value is taken as the depreciation. Therefore, this is also called "Percentage on Book Value" method.

In this, let x be the fixed percentage taken to calculate the yearly depreciation on the book value.

Then, $$x = 1 - \left(\frac{S}{C}\right)^{\frac{1}{N}}$$

where, C = Initial cost, S = Scrap value, N = No. of years of life.

It will be more clear by the following solved problem.

Problem 2. A lathe is purchased for Rs. 8,000 and the assumed life is 10 years and scrap value Rs. 2,000. If the depreciation is charged by Diminishing Balance method, calculate the percentage by which value of the lathe is reducing every year and depreciation fund after 2 years.

Solution. Here $C = 8{,}000$

$S = 2{,}000$

$N = 10.$

We know that $$= 1 - \left(\frac{S}{C}\right)^{\frac{1}{N}}$$

Substituting the given values in the above formula

$$x = 1 - \left(\frac{2000}{8000}\right)^{\frac{1}{10}}$$

$$= 1 - (0{\cdot}25)^{\frac{1}{10}}$$

Solving $(0{\cdot}25)^{\frac{1}{10}}$ by log, we get

$$(0{\cdot}25)^{\frac{1}{10}} = 0{\cdot}8706$$

$$\therefore\ x = (1 - 0{\cdot}8706) = 0{\cdot}1294$$

$$= 12{\cdot}94\%$$

$\therefore$ Required % = **12 94. Ans.**

$\therefore$ Value of lathe after 1 year

$= 8000(1-0{\cdot}1294) = 8000-0{\cdot}8706$

$=$ Rs. 6964·80.

$\therefore$ Depreciation fund after 1 year

$=$ Rs. 8000 – Rs. 6964·80

$=$ Rs. 1035·20.

Now, value of lathe after 2 years

$$= 6964{\cdot}80(0{\cdot}8706)$$

$$= \text{Rs. } 6063{\cdot}55$$

$\therefore$ Depreciation of 2nd year

$$= 6963{\cdot}80 - 6063{\cdot}55$$

$$= \text{Rs. } 901{\cdot}25.$$

$\therefore$ Depreciation fund after 2 years

$$= 1035{\cdot}20 + 901{\cdot}25$$

$$= \textbf{Rs. 1936·45. Ans.}$$

3. **Sinking Fund Method.** In this system, a depreciation fund equal to the actual loss in the value of the asset or machine is estimated, taking into account the interest on the so accumulated fund. The rate of depreciation will be constant throughout the life of machine

Let D = Rate of depreciation per year.

R = Rate of interest on accumulated fund in fraction number.

C = Total cost of machine

S = Scrap value

N = No. of years of life of machine.

$$D = \frac{R(C-S)}{(1+R)^N - 1}$$

This will be clear by the following solved problem.

Problem 3. A machine is purchased for Rs. 40,000. The estimated life of machine is 15 years and scrap value Rs 15,000. If the rate of interest on the depreciation fund is charged as 5%, calculate the rate of depreciation by sinking fund method.

The required formula is,

$$D = \frac{R(C-S)}{(1+R)^N - 1}$$

Hence by substitution,

$$D = 0{\cdot}05\,\frac{(40{,}000 - 15{,}000)}{(1+0{\cdot}05)^{15} - 1} = \frac{0{\cdot}05 \times 25{,}000}{(1{\cdot}05)^{15} - 1}$$

$$= \frac{1250}{(2{\cdot}080 - 1)} = \frac{1250}{1{\cdot}08} = \text{Rs. } 1157{\cdot}40.$$

Hence, required depreciation is **Rs. 1157·40 per year. Ans.**

4. **The Annuity Charging Method.** In this, interest is charged on the cost of machine or asset every year on the book value, but the rate of depreciation is constant every year.

Let C = Cost of machine

S = Scrap value

N = No. of years of machine life

R = Rate of interest in fractions.

D = Rate of depreciation.

If the value of machine after 1 year becomes C_1, then

$$D = CR + C - C_1 = C(1+R) - C_1.$$

In the same way, the value of machine after 2 years will be say, C_2.

Then $$D = C_1R + C_1 - C_2 = C_1(1+R) - C_2.$$

Hence, the standard formula will be

$$D = \frac{[C(1+R)^N - S][1-(1+R)]}{[1-(1+R)^N]}$$

Hence, by substituting the different values in the above formula the rate of depreciation can be calculated.

It will be more clear by the following problem.

Problem 4. An industrial plant with initial value of 200,000 and the salvage value of Rs. 20,000 at the end of 20 years but is sold for Rs. 1,45,000 at the end of 10 years. What is the profit or loss if sinking fund depreciation method at 8% compounded annually, was adopted.

(*A.M.I.E. Sec. B, May 1969*)

Solution.

$$D \quad \frac{R(C-S)}{(1+R)^N - 1}$$

Here,

$D = ?$

$R = 0{\cdot}08$

$C =$ Rs. 200,000

$S =$ Rs. 20,000

$N = 20$

So, $$D \quad \frac{0{\cdot}08(200{,}000 - 20{,}000)}{(1+0{\cdot}08)^{20} - 1}$$

= Rs. 4342

That is rate of depreciation

= Rs. 4342/year

∴ Depreciation Fund of 10 years

$= 4342 \times 10$

= Rs. 43,420

He sold the plant for Rs. 1,45,000 at the end of 10 years

The value of plant received at the end of 10 years

= Rs. 1,45,000 + Rs. 43,420

= Rs. 1,88,420

Initial value of plant is Rs. 200,000

Hence loss to the owner

$$= 200{,}000 - 188{,}420$$

$$= \textbf{Rs. 11,580. Ans.}$$

Problem 5. Find the depreciation annuity by the annuity charging method after 3 years, when the cost of machine is Rs. 8000 and scrap value Rs. 4000. Rate of interest is 5%.

Solution. $R = 5\% = 0{\cdot}05$

$C =$ Rs. 8000

$S =$ Rs. 4000

$N = 3$ years.

Hence, by substituting the given values in the formula :

$$D = \frac{[C(1+R)^N - S][1-(1+R)]}{[1-(1+R)^N]}$$

$$= \frac{[8000(1+0{\cdot}05)^3 - 4000][1-(1+0{\cdot}05)]}{[1-(1+0{\cdot}05)^3]}$$

$$= \frac{[8000(1{\cdot}05)^3 - 4000][1-0{\cdot}05]}{[1-(1{\cdot}05)^3]}$$

$$= \frac{(8000 \times 1{\cdot}16 - 4000)(-0{\cdot}05)}{1-1{\cdot}16}$$

$$= \frac{5280 \times 0{\cdot}05}{0{\cdot}16}$$

$$= \text{Rs. } 1650.$$

Hence, depreciation annuity = **Rs. 1650. Ans.**

Now, suppose we have to calculate the reduced value of asset after two years, it can be done in this way :

$$D = \frac{[C(1+R)^N - S][1-(1+R)]}{[1-(1+R)^N]}$$

Hence, now S will become C_2, where C_2 is the reduced value of asset after two years and therefore, $N=2$ years.

Hence by substitution,

$$1650 = \frac{[8000(1+0{\cdot}05)^2 - C_2][1-(1+0{\cdot}05)]}{[1-(1+0{\cdot}05)^2]}$$

or $$1550 = \frac{(8000 \times 1{\cdot}1 - C_2) \times -0{\cdot}05}{-0{\cdot}1}$$

or $$1650 \times 2 = 8800 - C_2$$

or $$C_2 = 8800 - 3300 = \text{Rs. } 5500 \text{ only.}$$

∴ the reduced value of asset after two years will be Rs. 5500 only. Ans

5. **The Insurance Policy Method.** This method covers the risk, if the machine becomes unserviceable before its estimated life.

In this machine is insured with the Insurance Company and premiums are paid on the Insurance Policy. When the policy matures, the company provides sufficient sum to replace the machine.

6. **Revaluation or Regular Valuation Method.** This is not a standard method. In this, every year the value of machine is revalued and the difference between the book value and revalued value is charged as depreciation fund.

7. **Machine Hour Basis Method.** In this, rate of depreciation is calculated, considering the total number of hours a machine runs in a year and therefore a work hour chart of every machine is maintained to know the total number of hours the machine runs in a year.

This will be clear by the following problem.

Problem 6. What are Depreciation Charges ?

A machine is costing Rs. 11,000 and is expected to run for 10 years at the end of which its scrap value is likely to be Rs. 1000. Machine is expected to run 2000 hour/year on the average. Estimate the depreciation charges per hour of the machine.

(*B.T.E., Rajasthan May 1970*)

Solution.

Cost of Machine = Rs. 11,000

Scrap value = Rs. 1000

$\therefore$ Depreciation Fund

= Rs. 11,000 − 1000 = Rs. 10,000

Life of Machine = 10 years

= 10×2000

= 20,000 hours.

$\therefore$ Depreciation charges/hr

$$= \frac{10,000}{20,000}$$

= **50 paise/hr. Ans.**

Problem 7. The estimated life of a lathe is 10 years and it works 16 hours a day. The initial cost of lathe is Rs. 8000 and scrap value after 10 years is Rs. 2500. If the machine works for 5840 hours in a year, calculate the rate of depreciation charged annually under machine hour basis method.

Solution. Here N = 10 years

C = Rs, 8000

S = Rs. 2500.

$\therefore$ $C-S$ = Rs. 8000 − Rs. 2500 = Rs. 5500

Therefore loss in the cost of lathe in 10 year = Rs. 5500

Now, life of machine in hours

$$= 10 \times 365 \times 16$$

∴ Depreciation/hour

$$= \frac{5500}{10 \times 365 \times 16} = \frac{55}{584}$$

∴ Depreciation in one year (In one year lathe works for 5840 hours).

$$= \frac{55}{584} \times 5840 = 550.$$

∴ Rate of depreciation/year

= **Rs. 550. Ans.**

8. **The Sum of the Year's Digits Method.** In this, as the new equipment is installed, the reduction in value will be greater initially and it will go on decreasing gradually. This fact is taken into account and therefore greater amount of depreciation is made during the early years of life and it goes on reducing as the life of equipment decreases. Therefore, for calculating depreciation, the net amount (Total cost—Scrap value) is spread over whole life in a decreasing proportion.

It will be more clear by the following problem.

Problem 8. The cost of a machine is Rs. 16,000 and its scrap value is Rs. 4000. Determine depreciation charges for each year, if the estimated life of machine is 4 years.

Solution. Here $C = 16{,}000$

$S = 4000$

$N = 4$ years.

Then $C - S = 16{,}000 - 4000 = 12{,}000.$

Now, sum of the digits of the years will be

$(1+2+3+4) = 10$

Now, depreciation charges for each year can be calculated as follows :

Depreciation charges for the 1st year

$$= \frac{4}{10} \times 12000$$

= **Rs. 4800. Ans.**

Depreciation charges for the 2nd year

$$= \frac{3}{10} \times 12000$$

= **Rs. 3600. Ans.**

Depreciation charges for the 3rd year

$$= \frac{2}{10} \times 12000$$

= **Rs. 2400. Ans.**

Depreciation charges for the 4th year

$$= \frac{1}{10} \times 12000$$

$$= \textbf{Rs. 1200. Ans.}$$

Therefore, from above it is clear that higher depreciation charges are made during the early years and this is the advantage of this method.

Interest on Capital.

While preparing cost accounts interest on capital invested is also considered The rate of interest is that, which would have been available, if that capital is deposited in some bank. By charging the interest, cost of product increases and thus the profit seems to be lesser.

Interest should be charged on the products produced, because :

(*i*) Real profit is not received until interest on capital is charged. Because manufacturer gets an amount equal to interest even when he does not work.

(*ii*) The stocks of raw and finished products cost more, because of the rent and interest on the blocked money.

(*iii*) If the capital is borrowed for business, then the interest has to be paid. Similarly, if manufacturer himself provides capital, he shoud be credited by a sum equal to the interest.

Some manufacturers do not charge the interest on the invested capital. They use the following points to advocate their views :

(*i*) As interest is also a part of the profit, it should not be charged separately.

(*ii*) It is charged to show less profit to decieve the consumers and to increase the cost of product.

(*iii*) It complicates clerical work.

Idleness.

Idleness in an industry may be of following two kinds :

(*i*) Idleness of machines

(*ii*) Idleness of workers.

These idlenesses are discussed as under :

(*i*) *Idleness of machines.* This is the time, when machines remain without doing any useful work. Idleness of machine may be due to the several reasons. Following are some of them :

(*a*) *Mechanical reasons.* Examples of such reasons are breakdown of machines, power failure, accidents etc.

(*b*) *Bad planning.* Machine may remain idle due to bad planning. Reasons for idleness are—not engaging the machines to their full capacity, providing more machines or lack of supervision.

(*ii*) *Idleness of workers*. In this category worker remains idle, but he is paid for this duration also. The idleness of the worker may be due to some of the following important reasons :

(*a*) *Labour*. In this category workers do not perform useful work due to their personal reasons *e.g.* due to lockouts, strikes, accidents and natural calls etc.

(*b*) *Mechanical*. Examples of mechanical reasons when worker remains free, are power failure, breakdown of machines etc.

(*c*) *Supervisory*. Due to poor supervision, sometimes worker wastes his time for waiting to receive the instructions from supervisor. Sometimes workers waste their time in gossipping or wandering here and there unnecessarily because of poor supervision.

An estimator uses to fix the percentage for the idleness effect, on the basis of his past experience. He should also consider all the above factors causing idleness.

Repairs and maintenance.

Every machine requires maintenance for increasing its life and to keep the machine in good condition to remove unnecessary delays in the production. For maintenance, machines are cleaned, lubricated and checked thoroughly from time to time to replace the worn out parts. Manufacturer's instructions for machine maintenance should be carried out properly.

Repair is the process of bringing the defective machine into efficient working condition. Every machine has to be repaired some time or the other during the course of his useful life. Some money has to be spent on the maintenance and repairs. For determining overheads this expenditure should also be considered. Repairs and maintenance charges can be determined with the help of 'diminishing balance' method, which has already been discussed in the chapter of depreciation.

QUESTIONS

1. What is depreciation ? Discuss the various methods of calculating it.
2. What are the various Indirect Expenses which are essential in estimating the total cost ? Explain.

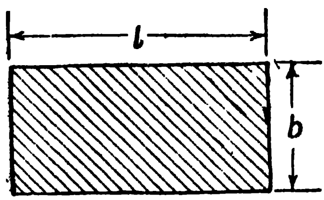
4

MENSURATION

For correct calculation of weights of material an estimator should have good knowledge of mensuration. With the help of knowledge of mensuration, estimator calculates areas, volumes, weights and cost of material. Therefore careful study of mensuration is essential. For the help of estimator some of the important formulae used in mensuration are being given in this chapter. Estimator should always remember these formulae.

AREAS OF PLANE FIGURES

1. **Rectangle.** (Fig. 4·1)



RECTANGLE

Fig. 4·1

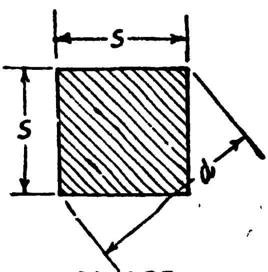
Let, l = length of rectangle

b = breadth of rectangle

then, Area = $l \times b$

Perimeter = $2(l+b)$

2. **Square** (Fig. 4·2)



SQUARE

Fig. 4·2

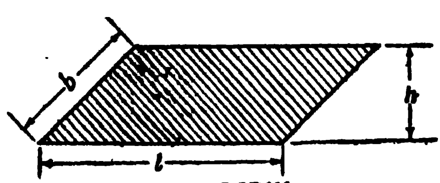
Let s = Length of each side of square

d = Length of diagonal.

then, Area = s^2 or $\frac{d^2}{2}$

Perimeter = $4s$

3. **Parallelogram.** (Fig. 4·3)



PARALLELOGRAM

Fig. 4·3

Let l = Length of one side of parallelogram

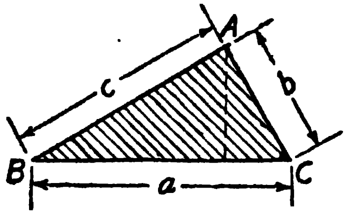
b = „ „ another side of parallelogram

h = heigh of parallelogram

then Area $= l \times h$

Perimeter $= 2(l+b)$

4. **Triangle.** (Fig. 4·4)



TRIANGLE

Fig. 4·4

Let a, b and c are the lengths of the sides of the triangle.

h = height of A from base BC

then, Area $= \frac{1}{2}\, a \times h$

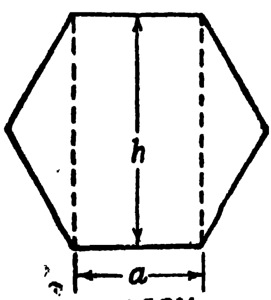
$= \frac{1}{2} \times \text{Base} \times \text{Perpendicular}$

Perimeter $= a+b+c$

and if $s = \frac{a+b+c}{2}$

then, area $= \sqrt{s(s-a)(s-b)(s-c)}$

5. **Hexagon.** (Fig. 4·5)



HEXAGON

Fig 4 5

Let a = Length of each side of hexagon

h = height.

then, Perimeter $= 6a$

Height $h = \sqrt{3}a$.

Area $= \frac{3\sqrt{3}}{2}a^2$.

6. **Any regular Polygon.**

General formulae for any regular polygon having n sides of length 'a' units each, are :

Perimeter $= n.a$

Anea $= \frac{1}{2} \times \text{Perimeter} \times \text{Inner radius}$.

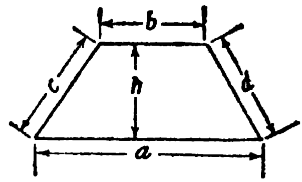
7. **Trapezium.** (Fig. 4·6)

Let, a, b, c, and d are the lengths of four sides.

h = prependicular distance between parallel sides

Perimeter $= a+b+c+d$

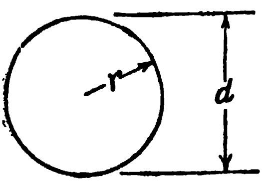
Area $=\left(\frac{a+b}{2}\right)\times h$



TRAPEZIUM

Fig. 4·6

8. **Circle.** (Fig. 4·7)



CIRCLE

Fig. 4·7

Let r = Radius of circle.

d = Diameter of circle.

Area $= \frac{\pi}{4}d^2 = \pi r^2$

Perimeter $= \pi d = 2\pi r$

9. **Sector.** (Fig. 4·8)

Let r = Radius of circle

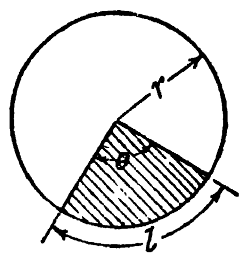
θ = angle in radians

l = length of arc

∴, $l = r\theta$

Area $\frac{\text{Angle of sector}}{2\pi}\times$ Area of circle

$= \frac{\theta}{2\pi}\times\pi r^2 = \frac{1}{2}\theta r^2 \quad \frac{l.r}{2}.$



SECTOR

Fig. 4·8

10. **Fillet.** (Fig. 4·9)

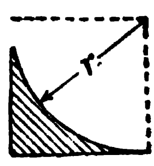
r = radius of the fillet

then,

Area of fillet $= r^2 - \frac{\pi}{4}r^2$

$^2\left(1-\frac{\pi}{4}\right) = 0{\cdot}215r^2$

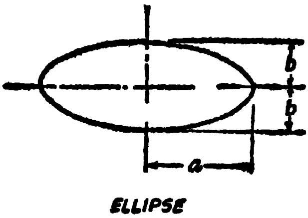
$= \frac{1}{5}r^2$ (approx.)



FILLET

Fig. 4·9

11. **Ellipse.** [Fig. 4·10 (*a*)]



Let a = semi-major axis

b = semi-minor axis

Area $= \pi a b$

Perimeter $= \pi(a+b)$.

Fig. 4·10 (*a*)

12. **Segment of a Circle.** [Fig. 4·10 (*b*)]

$$\text{Area} = \frac{2}{3} h \times l$$

$$= \frac{4}{3} h \sqrt{\frac{l^2}{4} + \frac{2}{5} h^2}$$

where, $h = BD$; $l = AC$.

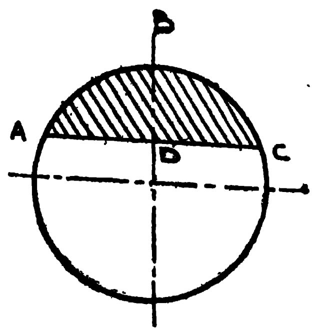


Fig. 4·10 (*b*)

AREAS OF IRREGULAR FIGURES

There are various methods of calculating area of irregular figures. These methods give only approximate results. Some of the important methods are given below :

1. **By Simpson's Rule.** (Fig. 4·11)

Divide the base of figure into even number of equal parts and errect ordinates on each part as shown in the Fig. 4·11.

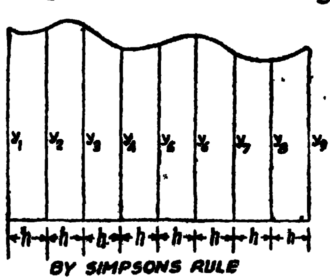


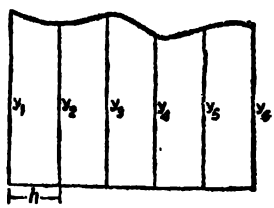
Fig. 4·11

Let h = distance between each ordinate

then, Area $= \frac{h}{3}\{(y_1+y_9)+2(y_3+y_5+y_7)+4(y_2+y_4+y_6+y_8)\}$

2. **By Trapezoidal Rule.** (Fig. 4·12)

Divide the base of the figure in equal number of parts and draw ordinates from each of these points as shown in the Fig. 4·12.



BY TRAPE ZOIDAL RULE

Fig. 4·12

If $y_1, y_2 \ldots\ldots y_6$ are the lengths of ordinates and h = distance between each ordinate

then Area $= h[\frac{1}{2}(y_1+y_6)+y_2+y_3+y_4+y_5]$

3. **By Planimeter.**

With the help of an instrument known as planimeter, accurate areas can be found very quickly.

VOLUME AND SURFACE AREAS OF SOLIDS

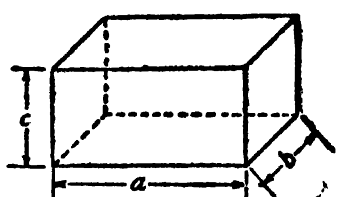
1. **Rectangular Solids.** (Fig. 4·13)

Let a, b and c are the length, breadth and height of the solids

then, Volume $= abc$

Length of diagonal $= \sqrt{a^2+b^2+c^2}$

Surface area $= 2\,(ab+bc+ca)$



RECTANGULAR SOLID

Fig. 4·13

2. **Prisms.** (Fig. 4·14)

Let, h = height of prism

a = breadth of one side

$\therefore$ Volume of Prism
= Area of base × Height

Surface area = No. of surfaces × ah
+ Area of the ends

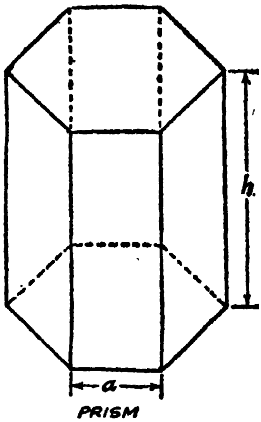


Fig. 4·14

3. **Cylinders.** (Fig. 4·15)

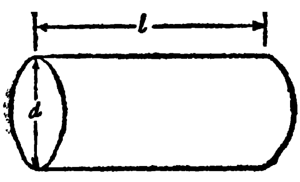


Fig. 4·15

Let d = dia. of cylinder

l = length of cylinder

$\therefore$ Volume of cylinder $= \frac{\pi}{4} d^2 l$

and Surface area $= \pi dl + \frac{\pi}{2} d^2$

4. **Pyramids and Cones.** (Fig. 4·16)

Volume = Area of base × $\frac{\text{Perpendicular height } H}{3}$

Surface Area = Area of base + Perimeter of base × ½ length of slant side L.

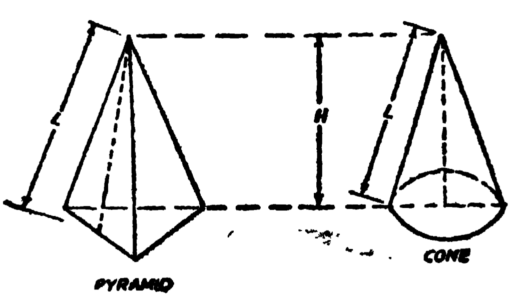


Fig. 4·16

5. **Frustum of Pyramid and Cone.**

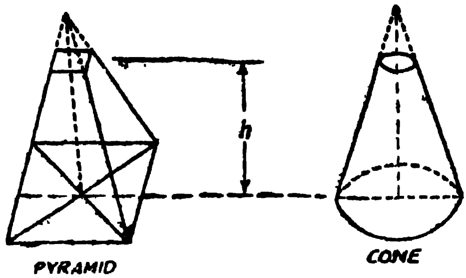


Fig. 4·17

$$\text{Volume} = \frac{h}{3}\left(a_1 + a_2 + \sqrt{a_1 a_2}\right)$$

where, a_1 and a_2 are the areas of the two ends, but for frustum of cone,

$$a_1 = \pi R_1^2\,; \qquad a_2 = \pi R_2^2$$

$$\therefore \quad \text{Volume} = \frac{\pi h}{3}(R_1^2 + R_2^2 + R_1 R_2)$$

6. **Spheres.** (Fig. 4·18)

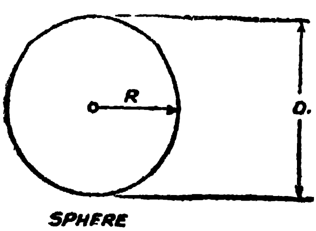


Fig. 4·18

$$\text{Surface area} = \pi D^2.$$
$$= 4\pi r^2$$
$$\text{Volume} = \frac{\pi}{6} D^3$$
$$= \frac{4}{3}\pi r^3.$$

7. **Hollow Sphere.** (Fig. 4·19)

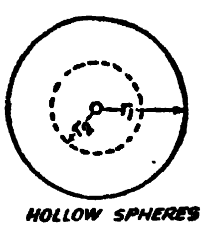
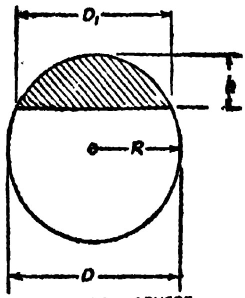


Fig. 4·19

$$\text{Volume} = \frac{4}{3}\pi\,(r_1^3 - r_2^3)$$

8. **Segment of a sphere.** (Fig. 4·20)



SEGMENT OF A SPHERE

Fig. 4·20

$$\text{Volume} = \frac{\pi h^2}{3}(3R-h)$$

$$= \frac{\pi}{6}h^2(3D-2h)$$

or Volume is also $= \frac{\pi}{6}\,h\left(\frac{3}{4}D_1^2+h^2\right)$.

9. **Circular Ring.** (Fig. 4·21)

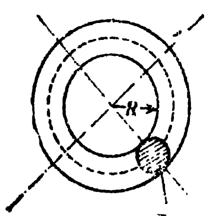


Fig. 4·21

Volume = Area of cross-section × Mean length

$$= 2\pi R \times \pi r^2$$

$$= 2\pi^2 Rr^2$$

where $a = \pi r^2$, r is the radius of the circular cross-section
R is the mean radius of ring.

10. **Spherical Sector.** (Fig. 4·22)

Volume of sector

$ACBD$ $\frac{2}{3}\pi rh$

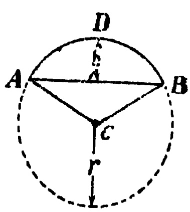


Fig. 4·22

11. **Spherical Zone.** (Fig. 4·23)

$$\text{Volume} = \frac{\pi h}{6}\left\{\frac{3}{4}(a_1^2+a_2^2)+h^2\right\}$$

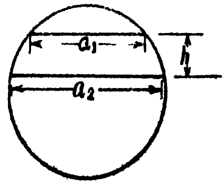


Fig. 4·23

4. **Method of Counting Squares.** Draw the actual irregular diagrams on a graph paper to some scale and count the number of squares covered by this diagram, taking those squares greater than one half as one and neglecting those having less than one-half of them as covered by the diagram. This gives approximate areas and used where much accuracy is not desired.

Area of figures = No. of square × Area of one square

Trapezium

= Distance between successive ordinates × Sum of half the first and last ordinates, together with all the remaining ordinates.

The Midordinate Method. (Fig. 4·24)

Divide the base line of the figure into any number of small equal parts and at the centre of each of these parts draw ordinates as shown in Fig 4·24. Calculate the average length of these ordinates and multiply by the length of base line.

This method also gives approximate areas.

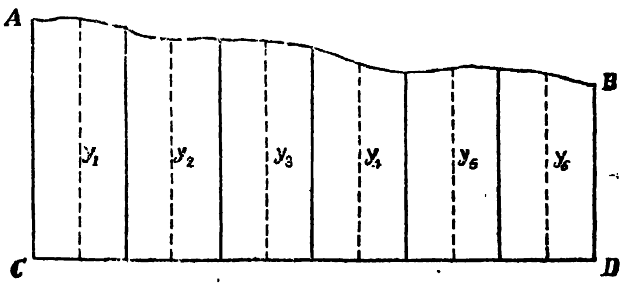


Fig. 4·24

$$\text{Area} = \frac{(y_1+y_2+y_3+y_4+y_5+y_6)\times CD}{6}$$

= Average of length of mid-ordidates × *CD*.

Position of Centroid

The positions of centroid for some essential figures are given below. This position of centroid is useful in calculating surface areas and volumes of solids of revolution.

1. **Triangle.**

$$OG = \frac{1}{3}h$$

$GD = \frac{1}{3} AD$ where AD is the median

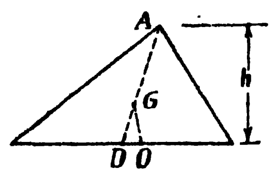


Fig. 4·25

2. Square. (Fig. 4·26)

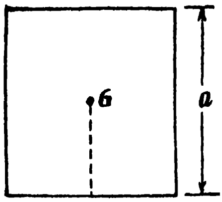


Fig. 4 26

$$OG \quad \frac{a}{2}$$

$\frac{1}{2}$ the side of square.

3. Trapeziod. (Fig. 4·27)

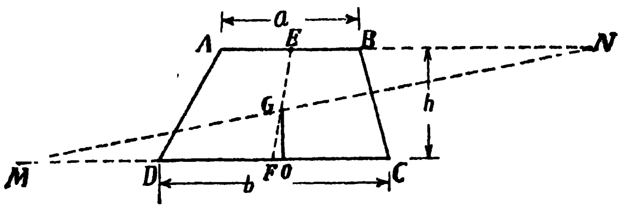


Fig. 4·27

Bisect AB at E and DC at F. Join EF. Set off $BN = DC$ and $DM = AB$. Inter-section of EF and MN is at G. So c.g. will be at G.

$$OG = \frac{h}{3}\frac{(2a+h)}{(a+b)}$$

4. Quadrant of a Circular Arc. (Fig. 4 28)

Here $xG = YG$

$= 0·637R$

$BG = 0·9R$

R = Radius of circular arc

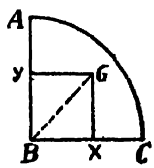


Fig. 4·28

5. Semi-circular Arc. (Fig. 4·29)

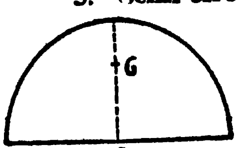


Fig. 4·29

$OG = 0·637R$

where R = radius of arc.

6. Area of Quadrant of a Circle. (Fig. 4·30)

$xG = YG$

$= 0·424R$

where R = radius of the circle.

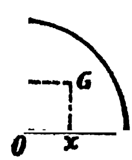


Fig. 4·30

7. Semicircle. (Fig. 4·31)

$$OG = \frac{4}{3\pi}R$$

$$= 0{\cdot}424R.$$

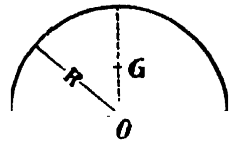


Fig. 4·31

where R is the radius of the circular area.

8. Fillet. (Fig. 4·32)

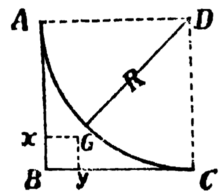


Fig. 4·32

$$xG = yG$$

$$= 0{\cdot}223R$$

from AB or BC

9. Parabolic Segment. (Fig. 4·33)

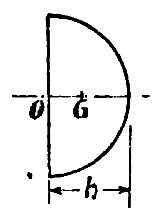


Fig. 4·33

$$OG = \frac{4}{5}h$$

10. Quadrant of an ellipse. (Fig. 4·34)

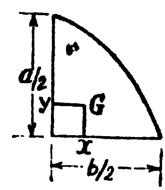


Fig. 4·34

$$xG = 0{\cdot}212\,a$$

$$yG = 0{\cdot}212\,b$$

Here a = Minor axis

b = Major axis

11. Half ellipse. (Fig. 4·35)

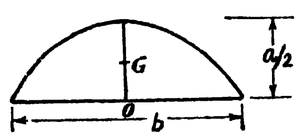


Fig. 4·35

$$OG = 0{\cdot}212\,a$$

Here, a = Minor axis

12. Segment of a Circle. (Fig. 4·36)

$$OG = \frac{1}{2}\left[\frac{c^2}{4h} - \sqrt{4R^2 - C^2}\right]$$

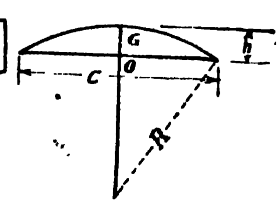


Fig. 4·36

where c is the chord length

and h is the height of chord.

Guldinus Rules

With the help of Guldinus rules the estimation of surface areas and volumes of solids of revolution can be determined.

Estimation of Surface Areas

According to Guldinus Rules, surface area of solid of revolution

= Perimeter of revolving figure × path of its centroid

For example :

(a) Determine the surface area of a straight line parallel to the axis of revolution.

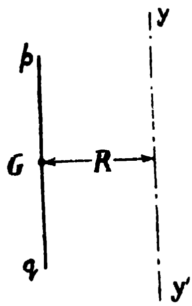


Fig. 4·37

The straight line pq revolving about yy traces out a cylinder. If G is the c.g. of the straight line at a distance R from the axis of revolution.

Then, surface area of cylinder generated by pq revolving about yy

$$= 2\pi R \times pq$$
$$= 2\pi R \times h$$

where $pq = h$.

(b) Determine surface area of solid of revolution of a semi-circle as shown in Fig. 4·38.

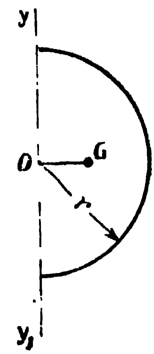


Fig. 4 38

The semi-circle-revolving about its diameter yy_1 will trace out a sphere.

Let r be the radius of the semi-circle then the length of the arc of semi-circle $= \pi r$.

If G is the c.g. of the semi-circle, then distance OG

$$= \frac{2r}{\pi} \text{ from } yy_1.$$

∴ Surface area of solid of revolution by Guldinus rule

= Length of arc of semi-circle × Length path of its c.g. revolving about yy_1.

$$= \pi r \times 2\pi \left(\frac{2r}{\pi}\right)$$
$$= 4\pi r^2.$$

∴ Surface area of a sphere generated by the revolution of semi-circle about yy_1

$$= 4\pi r^2$$

Estimation of Volumes of solids of revolution

According to Guldinus Rules, volumes of solids of revolution.

= Area of revolving figure × path of centroid.

(*a*) Determine volume of solid of revolution of a triangular area.

The right angled triangle revolving about perpendicular side *BC* will trace out a right circular cone.

The area of the △ *ABC*

$$= \frac{1}{2} AB \times BC$$

$$= \frac{1}{2} bh$$

The length of the path of its centroid revolving about *XX*

$$= 2\pi \times OG$$

$$= 2\pi \times \frac{h}{3}$$

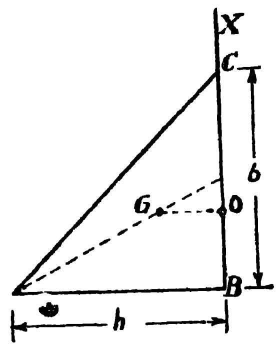


Fig. 4·39

Volume of solid of revolution

$$= \frac{1}{2} \times h \times b \times \frac{2\pi h}{3}$$

$$= \frac{1}{3} \pi b h^2$$

(*b*) Determine volume of solid of revolution of a rectangular area.

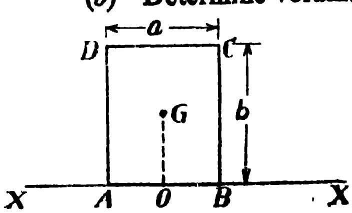


Fig. 4·40

The rectangle revolving about *XX* will trace out a cylinder.

The volume of that cylinder by Guldinus rule

= Area of the rectangular figure × path of its centroid.

Let *G* be the c.g. of rectangular *ABCD* then length of path of c.g.

$$= 2\pi \times OG = 2\pi \times \frac{b}{2} = \pi b.$$

∴ Volume of solid revolution

$$= (a \times b) \times \pi b$$

$$= \pi a b^2.$$

(c) Determine volume of solid of revolution of a semi-circular area when Revolving about its diameter

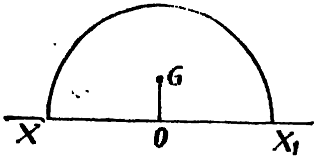


Fig. 4·41

Let the semi-circular area of radius R revolves about its diameter XX_1. It will then trace out a sphere. By Guldinus rule the volume of that sphere is the product of the area of the semi-circle and the path of its c.g.

(i) If G is the c.g. of the semi-circle then distance OG

$$= \frac{4r}{3\pi} \text{ from its base.}$$

∴ Volume of sphere generated

$$= \frac{\pi r^2}{2} \times 2\pi \left(\frac{4r}{3\pi}\right)$$

$$= \frac{4}{3} \pi r^3.$$

(ii) If the semi-circle revolves about the axis XX at a distance R from c.g.

In this case it will trace out a rib

The volume of rib by Guldinus rule

$$= \frac{\pi}{2} r^2 \times 2\pi R$$

where R is the distance of c.g. of the body from the axis of rotation.

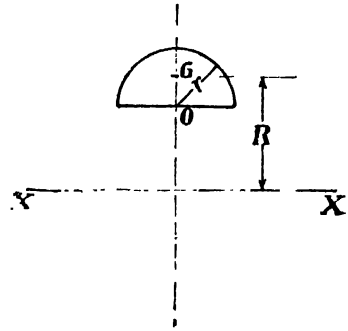


Fig. 4·42

(d) Determine the volume of solid of revolution of a trapezoid about axis XX at a distance R from c.g.

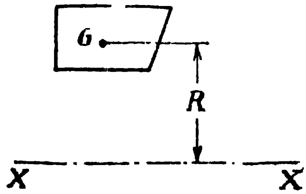


Fig. 4·43

A trapezoid revolving about the axis XX will generate a ring of trapeziodal section.

The volume of the ring so generated by Guldinus rule

Area of trapezium × path of c.g.

$A \times 2\pi R$

where R is the distance of centroid from the axis of rotation.

5

ESTIMATION OF MATERIAL COST

Procedure

For calculating the material cost of a product, following procedure should be adopted :—

(*i*) Break up the product into simple parts so that their volumes can be easily calculated.

(*ii*) Neglect rounded corners and small fillets and take suitable approximation wherever necessary.

(*iii*) By applying the formulae of mensuration, calculate the volume of each part.

(*iv*) Add volumes of the parts to give, volume of complete product.

(*v*) Calculate weight of material by multiplying the volume by its density.

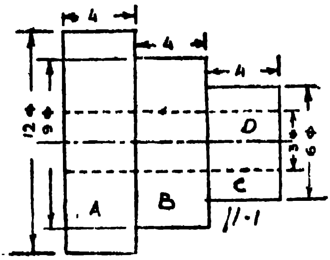
(*vi*) Lastly, calculate the material cost by multiplying the cost per unit weight to the weight of material.

Following table gives the densities of different materials required for estimating the weight of material.

No.	*Materials*	*Wt. in gm./c.c.*
1.	Cast Iron	7·2
2.	Aluminium	2·685
3.	Brass	8·081
4.	Bronze	8·496
5.	Mild Steel	7·85
6.	Teak wood	0·657—0·882
7.	Tin	7·420

Examples for estimating weights and material costs are being given under :—

Example 1. Estimate the weight of C.I. used in manufacturing step pulley as shown in Fig. 5·1. Assume density of C.I. as 7·2 gm./c.c.



All dimensions are in cm
Fig. 5·1

Solution.

Break up this step pulley into 4 following simple part *A*, *B*, *C* and *D*.

Part A :

$$\text{As volume} = \frac{\pi}{4} d^2 l$$

$$= \frac{\pi}{4} \times (12)^2 \times 4$$

$$= 144\pi \text{ cm.}^3$$

Part B :

$$\text{As volume} = \frac{\pi}{4} d^2 l = \frac{\pi}{4} (9)^2 \times 4 = 81\pi \text{ cm}^3.$$

Part C :

$$\text{As volume} = \frac{\pi}{4} (d)^2 \times l = \frac{\pi}{4} (6)^2 \times 4 = 36\pi \text{ cm.}^3$$

Part D :

$$\text{As volume} = \frac{\pi}{4} (d)^2 \times l = \frac{\pi}{4} (3)^2 \times 12 = 27\pi \text{ cm.}^3$$

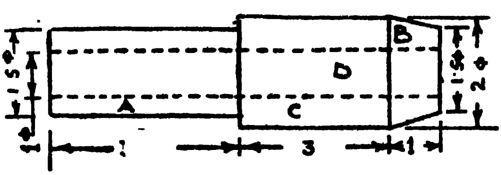
$$\therefore \text{ Total volume} = 144\pi + 81\pi + 36\pi - 27\pi$$
$$= 234\pi \text{ cm.}^3$$

Hence, weight of step pulley

$$= 234 \times \frac{22}{7} \times 7{\cdot}2 \text{ gm.}$$

$$= \mathbf{5{\cdot}3 \text{ kg.}} \quad \textbf{Ans.}$$

Example 2. Find out the weight of 10 M.S. spindles, the shape and size of which are given in Fig. 5·2. Also calçulate the weight of scrap, if they are turned out from a M.S. rod of 25 mm. dia. and facing and parting off allowances can be taken as 1 mm. and 5 mm., respectively. Assume that 15 mm. length of rod is requir-ed for grip in the chuck. Desity of M.S. is 7·8 gm./c.c.



All dimensions are in cm.
Fig. 5·2

Solution. Break up this spindle into 4 parts, namely *A*, *B*, *C* and *D*.

Now, volume of $A = \frac{\pi}{4}(1{\cdot}5)^2 \times 2{\cdot}5 = 4{\cdot}4$ cm.^{3}

Volume of $C = \frac{\pi}{4}(2{\cdot}0)^2 \times 3 = 9{\cdot}4$ cm.^{3}

Volume of $D = \frac{\pi}{4}(1{\cdot}0)^2 \times 6{\cdot}5 = 5{\cdot}1$ cm.^{3}

Volume of B = Volume of frustum of cone dia. 1·5 cm. and 2 cm. and height as 1 cm.

$$= (a_1 + a_2 + \sqrt{a_1 a_2}) \times \frac{\text{height}}{3}$$

$$= \frac{\pi}{4}(d_1^2 + d_2^2 + \sqrt{d_1^2 . d_2^2}) \times \frac{h}{3}$$

$$= \frac{\pi}{4}(2{\cdot}25 + 4 + 3) \times \frac{1}{3}$$

$$= 2{\cdot}4 \text{ cm.}^3$$

$\therefore$ Volume of finished spindle $= A + B + C - D$
$= 4{\cdot}4 + 2{\cdot}4 + 9{\cdot}4 - 5{\cdot}1$
$= 11{\cdot}1$ cm.^{3}

$\therefore$ Weight of 10 spindles $= 10 \times 11{\cdot}1 \times 7{\cdot}8$ gm.
= **866 gm. Ans.**

To calculate the weight of scrap, weight of M.S. rod is first calculated :—

Length of one spindle = 65 mm.

Total length of 10 spindles = 650 mm.

Length required for facing 20 faces $= 20 \times 1 = 20$ mm.

Length required for parting off 10 times $= 10 \times 5 = 50$ mm.

Length required for holding (For last job) = 15 mm.

$\therefore$ Total length of rod required
$= 650 + 20 + 50 + 15$
$= 735$ mm. $= 73{\cdot}5$ cm.

$\therefore$ Volume of rod required $= \frac{\pi}{4} D^2 \times 73{\cdot}5$

$= \frac{\pi}{4}(2{\cdot}5)^2 \times 73{\cdot}5 = 360$ cm.^{3}

$\because$ Weight of rod $= 360 \times 7{\cdot}8 = 2808$ gm.

$\therefore$ Weight of scrap $= 2808 - 866 = 1932$ gm.
= **1·932 kg. Ans.**

Example 3. Calculate the weight of a "Lathe Centre" shown in Fig. 5·3 given below, if the material weighs 7·8 gm./c.c. Also determine the cost of material, if its rate is Rs. 1·20/kg.

Solution.

Break up the article in 4 simple parts

Part A. From $\triangle XYZ$,

$$\tan 30^\circ \quad \frac{YZ}{XZ}$$

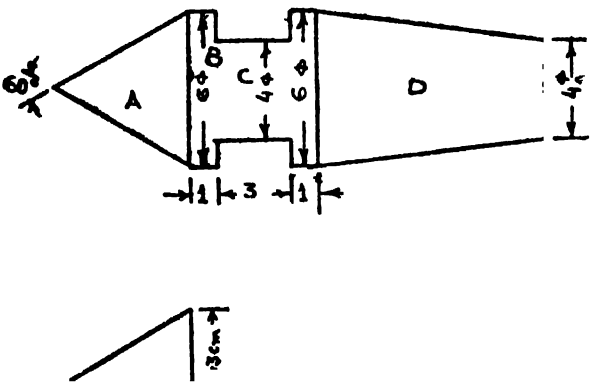
or
$$\frac{1}{\sqrt{3}} = \frac{3}{h}$$

$\therefore$
$$h = 3\sqrt{3} = 5{\cdot}2 \text{ cm.}$$

$\therefore$ Height of cone $A = 5{\cdot}2$ cm. and Base redius $r = 3$ cm.

Now, volume of cone

$$A = V_1 = \tfrac{1}{3}\pi r^2 h$$
$$= \tfrac{1}{3}\pi\,(3)^2 \times 5{\cdot}2 = 49 \text{ cm.}^3$$



All dimensions in cm.
Fig. 5·3

Part B. 2 circular discs, 1 cm. thick and 6 cm dia.

Volume of one disc, $V_2 = \frac{\pi}{4} d^2 l = \frac{\pi}{4} \times (6)^2 \times 1$
$$= 28{\cdot}25 \text{ cm.}^3$$

Part C. One circular disc, 3 cm. thick and 4 cm. dia.

$$\text{Volume, } V_3 = \frac{\pi}{4}(4)^2 \times 3 = 37{\cdot}68 \text{ cm.}^3$$

Part D. Frustum of cone with diameters 4 cm. and 6 cm. and height 8 cm.

$$\text{Volume, } V_4 = (a_1 + a_2 + \sqrt{a_1 a_2}) \times \frac{h}{3}$$
$$= \frac{\pi}{4}(16+36+24) \times \frac{8}{3} = 159 \text{ cm.}$$

∴ Total volume of lathe centre

$$= V_1 + 2V_2 + V_3 + V_4$$
$$= (49 + 2 \times 28{\cdot}25 + 37{\cdot}68 + 159)$$
$$= 302{\cdot}18 \text{ cm.}^3$$

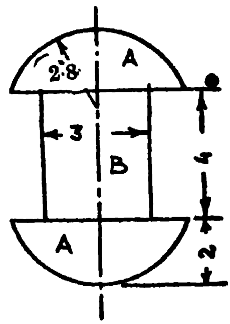
∴ Weight of material $= 302{\cdot}18 \times 7{\cdot}8$

$$= 2357 \text{ gm.} = 2\,357 \text{ kg.}$$

Hence, material cost for lathe centre $= 2{\cdot}357 \times 1{\cdot}20$

$=$ **Rs. 2 83. Ans.**

Example 4. Calculate the number of rivets of dimensions shown in Fig 5·4 which can be manufactured from 4 kg. of M.S. Assume that there is no wastage of material. Density of M.S. is 8 gm./c.c.



All dimensions are in cm.
Fig. 5·4

Solution. Break up the artical into simple parts *A*, *A* and *B*.

Volume of head *A* (Two in Nos).

$$= \frac{\pi}{6} h^2 (3D - 2h)$$

For a segment of sphere.

where $h = 2$ cm., $D = 2R = 5{\cdot}6$

∴ Volume of $A = \frac{\pi}{6} \times 4(3 \times 5{\cdot}6 - 2 \times 2)$

$$= 26{\cdot}5 \text{ cm.}^3$$

Volume of cylindrical part *B*

$$= \frac{\pi}{4} D^2 \times l = \frac{\pi}{4} (3)^2 \times 4$$
$$= 28{\cdot}26 \text{ cm.}^3$$

Total volume $= 2A + B$

$2 \times 26{\cdot}5 + 28{\cdot}26 \quad 81{\cdot}26 \text{ cm.}^3$

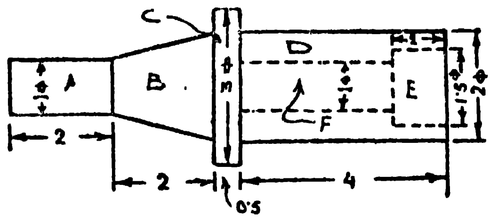
Weight of one rivet $\frac{81{\cdot}26 \times 8}{1000} = 0{\cdot}65$ kg.

∴ No. of rivets which can be manufactured from 4 kg. M.S. (Neglecting wastage)

$$= \frac{4}{0\,650} = 6 \text{ (say)}$$

$=$ **6 rivets. Ans.**

Example 5. Estimate the volume of material required for manufacturing a component, as shown in Fig. 5·5. Calculate also the weight of 10 such components, if it is made up of M.S. of density 8 gm./c.c.



All dimensions are in cm.
Fig. 5·5

Solution. Break up the component into simple parts *A, B, C, D, E* and *F*.

$$\text{Volume of } A = \frac{\pi}{4}(1)^2 \times 2 = \frac{\pi}{2} \text{ cm.}^3$$

$$\text{Volume of } B = \frac{\pi}{3} \times h(R_1^2 + R_2^2 + R_1 R_2)$$

(For frustum of cone)

$$= \frac{\pi}{3} \times 2\{(0{\cdot}5)^2 + (1)^2 + 0{\cdot}5 \times 1)\}$$

$$= \frac{7}{6}\pi \text{ cm.}^3$$

$$\text{Volume of } C = \frac{\pi}{4}(3)^2 \times 0{\cdot}5 = \frac{9}{8}\pi \text{ cm.}^3$$

$$\text{Volume of } D = \frac{\pi}{4}(2)^2 \times 4 = 4\pi \text{ cm.}^3$$

$$\text{Volume of } E = \frac{\pi}{4}(1{\cdot}5)^2 \times 1 = \frac{9}{16}\pi \text{ cm}^3$$

$$\text{Volume of } F = \frac{\pi}{4}(1)^2 \times 3 = \frac{3}{4}\pi \text{ cm.}^3$$

$$\therefore \quad \text{Total volume} = A + B + C + D - E - F$$

$$= \pi\left(\frac{1}{2} + \frac{7}{6} + \frac{9}{8} + 4 - \frac{9}{16} - \frac{3}{4}\right)$$

$$= 17{\cdot}2 \text{ cm.}^3 \quad \textbf{Ans.}$$

Hence, weight of 10 such articles

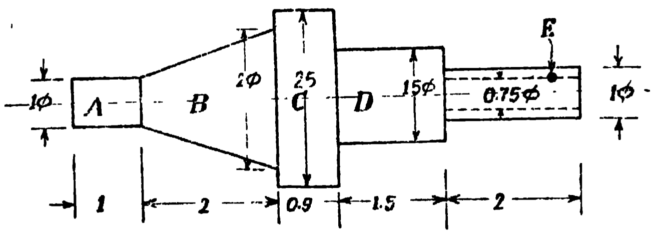
$$= \frac{10 \times 17{\cdot}2 \times 8}{1000}$$

$$= 1{\cdot}376 \text{ kg.} \quad \textbf{Ans.}$$

Example 6. Estimate the volume of material required for manufacturing 100 pieces of shaft as shown in Fig. 5·6. The shafts are made of m.s. which weighs 8 gm./c.c. and costs Re. 1/kg. Calculate also the material cost for 100 such shafts.

(*B.T.E. Rajasthan, May 1967*)

Solution. Break up the component into simple parts *A*, *B*, *C*, *D* and *E*.



All dimensions are in cm.

Fig. 5·6

$$\text{Volume of } A = \frac{\pi}{4} d^2 \times l$$

$$= \frac{\pi}{4}(1)^2 \times 1 = 0{\cdot}7854 \text{ cm.}^3$$

$$\text{Volume of } B = \frac{\pi h}{3}(R_1^2 + R_2^2 + R_1 R_2)$$

$$= \frac{\pi}{3} \times 2\left[(0{\cdot}5)^2 + (1)^2 + 0{\cdot}5 \times 1\right]$$

$$= 3{\cdot}667 \text{ cm.}^3$$

$$\text{Volume of } C = \frac{\pi}{4}(2{\cdot}5)^2 \times 0{\cdot}9 = 4{\cdot}39 \text{ cm.}^3$$

$$\text{Volume of } D = \frac{\pi}{4}(1{\cdot}5) \times 1{\cdot}5 = 2{\cdot}65 \text{ cm.}^3$$

$$\text{Volume of } E = \frac{\pi}{4}\left[(1)^2 - (0{\cdot}75)^2\right] \times 2$$

$$= 0{\cdot}343 \text{ cm.}^3$$

$\therefore$ Total volume = volume of *A* + volume of *B* + volume of *C* + volume of *D* + volume of *E*

$$= 0{\cdot}7854 + 3{\cdot}667 + 4{\cdot}39 + 2{\cdot}65 + 0{\cdot}343$$

$$= 11{\cdot}8354 \text{ cm.}^3$$

$\therefore$ **Weight of material/shaft**

$$= 11{\cdot}8354 \times 8 \text{ gm.}$$

$$= 94{\cdot}6832$$

$$= 94{\cdot}7 \text{ gm.}$$

∴ Weight of 100 shafts

$= 94{\cdot}7 \times 100$ gm.

$= 9{\cdot}47$ **kg.**

∴ Cost of material

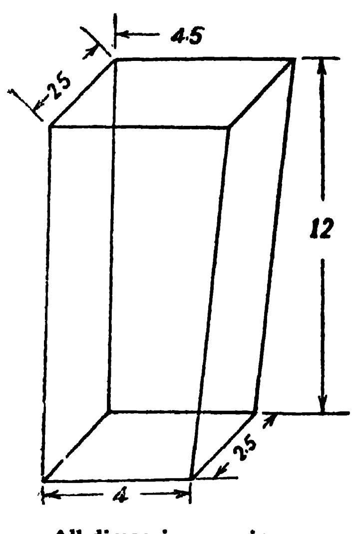
$= 9{\cdot}47 \times 1$

= **Rs.** 9·47. **Ans.**

Example 7. An iron wedge has been made by forging cut of a 3 cm. diameter round bar. The length and breadth of the base of the wedge being 4·5 cm and 2·5 cm. respectively. the length of edge being 4 cm and the height 12 cm. If the density of metal remains unchanged after forging, what length of bar is required for making the wedge ?

(B.T.E., Rajasthan Nov. 1970)

Solution.



All dimensions are in cm.
Fig. 5·7

The wedge is like the frustum of pyramid

Vol. of pyramid

$$= \frac{h}{3}\left(a_1 + a_2 + \sqrt{a_1\, a_2}\right)$$

Here $h = 12$ cm.

$a_1 = 2{\cdot}5 \times 4{\cdot}5$

$= 11{\cdot}25 \text{ cm}^2$

$a_2 = 2{\cdot}5 \times 4 = 10 \text{ cm}^2$

$$\therefore \text{Vol.} = \frac{12}{3}\left(11{\cdot}25 + 10 + \sqrt{11{\cdot}25 \times 10}\right)$$

$= 4(21{\cdot}25 + 10{\cdot}6)$

$= 127{\cdot}4 \text{ cm.}^3$

Let l cm. length of bar is required

Then $\frac{\pi}{4}(3)^2 \times l = 127{\cdot}4$

or $l = \frac{127{\cdot}4 \times 4}{9\pi}$

$= 18$ cm.

Length of bar required **18 cm. Ans.**

Example 8. A wedge guide is shown in Fig. 5·8. Estimate its volume.

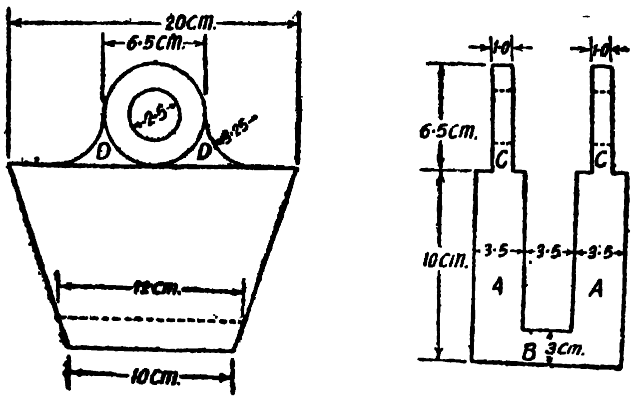


Fig. 5·8

Solution. Break up the component into simple parts A, B, C and D.

$$\text{Volume of trapezium } A = \frac{(20+10)}{2} \times 10 \times 3{\cdot}5 = 525 \text{ cm.}^3$$

$$\text{Volume of trapezium } B = \frac{12+10}{2} \times 3 \times 3{\cdot}5 = 115{\cdot}5 \text{ cm.}^3$$

Volume of each hollow cylindrical portion C

$$= \frac{\pi}{4}\{(6{\cdot}5)^2-(2{\cdot}5)^2\} \times 1$$

$$= 28{\cdot}26 \text{ cm.}^3$$

Volume of fillets D :

Total No. of fillets on both the sides of both hollow cylindrical portion

$C = 4 \times 2$

$= 8$

$\therefore$ Total volume of 8 fillets

$= 0{\cdot}215\, R^2 \times \text{thickness} \times 8$

$= 0{\cdot}215 \times (3{\cdot}25)^2 \times 1 \times 8$

$= 18{\cdot}2 \text{ cm.}^3$

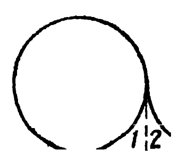


Fig. 5·9

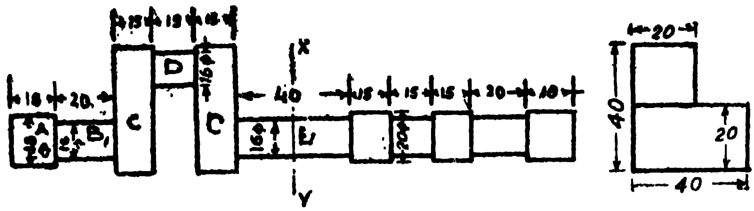
$\therefore$ Total volume of component

$$= 2A+B+2C+D$$

$$= 2 \times 525 + 115{\cdot}5 + 2 \times 28{\cdot}26 + 18{\cdot}2$$

$$= \mathbf{1240{\cdot}22 \text{ cm.}^3 \text{ Ans.}}$$

Example 9. Calculate the weight of forged crank shaft shown in the Fig. 5·10. Steel weighs 0·0075 kg/cm³.



All dimensions are in cm.
Fig. 5·10

Solution. As crank shaft is similar in dimensions on both the side of line *XY*. Therefore volume on one side can be calculated and the total volume will be twice of that on one side.

Breaking the drawing into simple parts *A*, *B*, *C*, *D* and *E*.

$$\text{Volume of } A = \frac{\pi}{4} \times (18)^2 \times 18 = 1458\pi \text{ cm.}^3$$

$$\text{Volume of } B = \frac{\pi}{4} (16)^2 \times 20 = 1280\pi \text{ cm.}^3$$

$$\text{Volume of } C = 40 \times 20 \times 15 = 12000 \text{ cm.}^3$$

$$\text{Volume of } D = \frac{\pi}{4} (16)^2 \times 15 = 960\pi \text{ cm.}^3$$

$$\text{Volume of } E = \frac{\pi}{4} (16)^2 \times 20 = 1280\pi \text{ cm.}^3$$

∴ Volume of half crank shaft

$$= A + B + 2C + D + E$$
$$= \pi[1458 + 1280 + (2 \times 12000) + 960 + 1280]$$
$$= 39642 \text{ cm.}^3$$

∴ Total volume of crank shaft

$$= 2 \times 39642 \text{ cm.}^3 = 79284 \text{ cm.}^3$$

Hence, weight of crank shaft

$$= 79284 \times 0{\cdot}0075$$
$$= \mathbf{594{\cdot}6 \text{ kg.}} \quad \textbf{Ans.}$$

Example 10. Find the volume of stuffing box gland shown in Fig. 5·11. Dimensions are given in cm.

Solution. Break up the drawing into simple parts *A*, *B*, *C*, *D* and *E*.

(*a*) *Elliptical portion.*

$$\text{Volume of } A = \pi \times a \times b \times h$$

(where *a* and *b* are semi-major and minor axes)

$$= \pi \times 10 \times 5 \times 2 = 100\pi \text{ cm.}^3$$

(*b*) Cyclindrical portion (without hole)—

$$\text{Volume of } B = \frac{\pi}{4}(10)^2 \times 6 = 150\pi \text{ cm.}^3$$

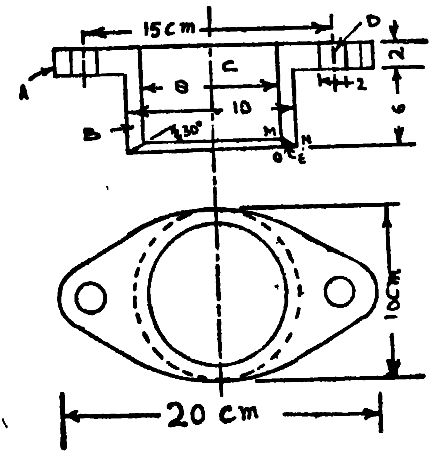


Fig. 5·11

(*c*) Volume of hollow portion

$$C = \frac{\pi}{4}(8)^2 \times 8 = 128\pi \text{ cm.}^3$$

(*d*) Volume of 2 bolt holes (*D*)

$$= \frac{\pi}{4} \times (2)^2 \times 2 \times 2 = 4\pi \text{ cm.}^3$$

(*e*) Volume of triangular portion *MNO* by Guldinus Rule.

= Circumference through C.G. × Area of triangle *MNO*

(As C.G. lies at $\frac{1}{3}h$ from base ∴ dia. through C.G. will be

$$= \text{Inner dia} + \frac{\text{Difference of dia.}}{3}$$

$$= 8 + \frac{10-8}{3} = 8\ 66 \text{ cm.}^3$$

∴ Volume of triangular portion *MNO*

$$= \pi \times 8{\cdot}66 \times \left(\frac{MO \times ON}{2}\right)$$

$$= 8{\cdot}66\pi \times \left(\frac{0{\cdot}58 \times 1}{2}\right)$$

$$\left\{\because \frac{MO}{ON} \quad \tan 30^\circ\right\}$$

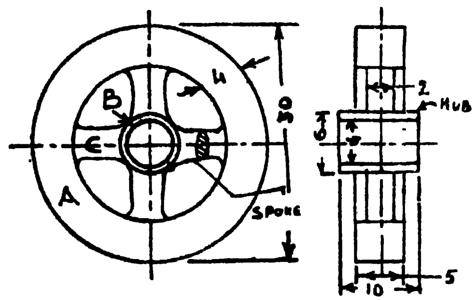
$2{\cdot}51\pi$ cm.^{3}

$\therefore$ Total volume of gland

$$= A+B-C-D-E$$
$$= \pi(100+150-128-4-2{\cdot}51)$$
$$= 115{\cdot}49\pi \text{ cm.}^3$$
$$= 363 \text{ cm.}^3 \quad \textbf{Ans.}$$

Example 11. Calculate the weight of gear blank of C.I. taking its density as 5·12 gm./c.c.

Spokes
4×2 elliptical



All dimensions are in cm.
Fig. 5·12

Solution. Break up the drawing into simple parts *A*, *B* and *C*.

Volume of rim A = Mean circumference × thickness × width
$$= \pi(26)\times5\times4 = 520\pi \text{ cm.}^3$$

(This volume can also be calculated by assuming this rim as a cylindrical disc.

$$\therefore \quad \text{Volume} = \frac{\pi}{4}\{(30)^2-(22)^2\}\times5 = 520\pi$$

$$\text{Volume of hub } B = \frac{\pi}{4}\{(6)^2-(4)^2\}\times10 = 50\pi \text{ cm.}^3$$

Volume of each arm C = Area of cross-section × length of each arm

$= \pi ab\times l$ (where a and b are semi-major and minor axes)

$$= \pi\times2\times1\times8 = 16\pi \text{ cm.}^3$$

$\therefore$ **Total volume of gear blank**

$$= A+B+4C$$
$$= (520+50+4\times16)\pi$$
$$= 634\pi = 1993 \text{ cm.}^3$$

$\therefore$ **Weight of gear blank**

$$= \frac{1993\times7{\cdot}4}{1000} \text{ kg.}$$
$$= 14{\cdot}75 \text{ kg.} \quad \textbf{Ans.}$$

Example 12. Find the weight of a C.I. bracket shown in Fig. 5·13. Density of C.I. may be taken as 7·5 gm./c.c. Assume all dimensions in cm.

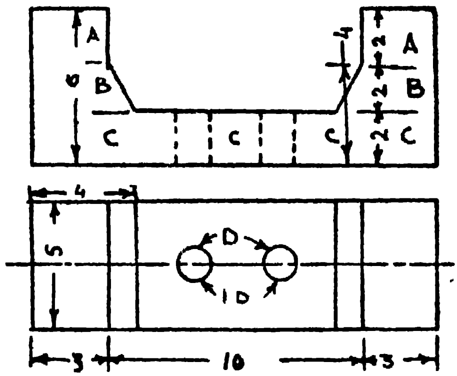


Fig. 5·13

Solution. Split up the drawing into simple parts *A*, *B*, *C* and *D* as shown in Fig. 5·13.

Volume of each part *A*

$$= \text{Area of cross-section} \times \text{width}$$

$$= (3\times2)\times5 = 30 \text{ cm.}^3$$

Volume of each part *B*

$$= \text{Area of trapezoidal section} \times \text{width}$$

$$\left\{\left(\frac{3+4}{2}\right)\times2\right\}\times5 = 35 \text{ cm.}^3$$

Volume of part $C = 16\times2\times5 = 160 \text{ cm.}^3$

Volume of each hole *D*

$$= \frac{\pi}{4}\times(1)^2\times2 = 1{\cdot}57 \text{ cm.}^3$$

∴ Volume of complete bracket

$$= 2A+2B+C-2D$$

$$= 60+70+160-3{\cdot}14 = 286{\cdot}86 \text{ cm.}^3$$

∴ Weight of bracket $= \dfrac{286{\cdot}86\times7{\cdot}5}{1000}$ kg.

$= 2{\cdot}15$ **kg. Ans.**

Example 13. Calculate the weight of a "Dovetailed Bracket", shown in Fig. 5·14. It is made of C.I. having density 7·5 gm./c.c. Assume all dimensions in cm.

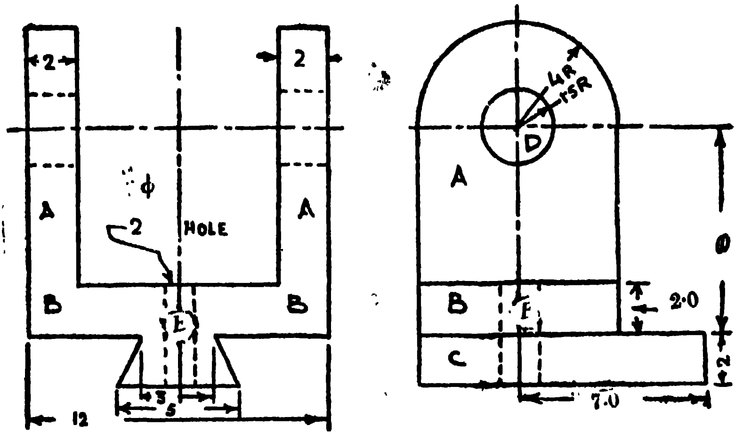


Fig. 5·14

Solution. Break up the component into simple parts *A, B, C, D* and *E*.

Volume of each part *A*

$= $ Volume of semi-circular part+Lower rectangular part.

$$= \left(\frac{\pi}{4}d^2 \times \frac{1}{2} \times t\right) + (6 \times 8 \times 2)$$

$$= \frac{\pi}{4} \times (8)^2 \times \frac{1}{2} \times 2 + 96$$

$$= 146{\cdot}24 \text{ cm.}^3$$

Volume of part *B* $= 12 \times 8 \times 2 = 192$ cm.^{3}

Volume of part *C* $=$ Area of trapezoidal sec. $\times$ Length

$$\left(\frac{3+5}{2}\right) \times 2 \times 11 \qquad \text{cm.}^3$$

Volume of each hole *D*

$$\times (3)^2 \times 2 = 14{\cdot}13 \text{ cm.}^3$$

Volume of hole *E* $= \frac{\pi}{4}(2)^2 \times 4 = 12{\cdot}56$ cm.^{3}

Total volume of bracket

$$= 2A + B + C - 2D - E$$

$$= (2 \times 146{\cdot}24 + 192 + 88 - 2 \times 14{\cdot}13 - 12{\cdot}56)$$

$$= 531{\cdot}66 \text{ cm.}^3$$

Therefore, weight of bracket

$$\frac{531{\cdot}66\times7{\cdot}5}{1000}\text{ kg.}$$

$= 4{\cdot}00$ **kg.** (Approx). **Ans.**

Example 14. Calculate the weight of C.I. bracket shown in the sketch 5·15. Assume density of C.I. as 7·5 gm./c.c.

Solution. Break up the bracket into simple parts *A*, *B*, *C* and *D*.

Volume of part *A*

= Volume of semi-circular part+Volume of rectangular part.

$$=\left\{\frac{1}{2}\times\frac{\pi}{4}\times(7)^2\times2\right\}+7\times15\times2$$

$= 248{\cdot}5$ cm.^{3}

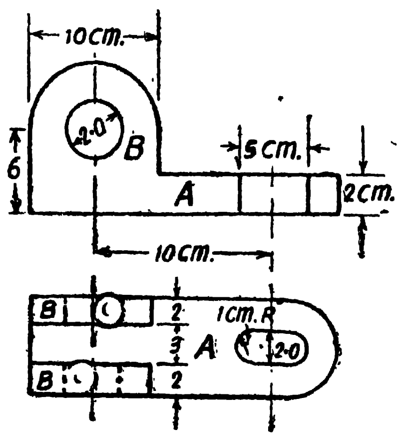


Fig. 5·15

Volume of each Part *B*

Volume of semi-circular part +Volume of rectangular part.

$$=\left\{\frac{1}{2}\times\frac{\pi}{4}\times(10)^2\times2\right\}+(4\times10\times2)$$

$= 158{\cdot}5$ cm.^{3}

Volume of each hole $C = \frac{\pi}{4}(2)^2\times2 = 6{\cdot}28$ cm.^{3}

Volume of hole *D* Volume of 2 semi-circular holes of 1 cm. radius+Volume of rectangular hole

$$=\left\{\frac{\pi}{4}\times(2)^2\times2\right\}+(3\times2\times2)$$

$18{\cdot}28$ cm.^{3}

∴ Total volume of bracket

$$= A+2B-2C-D$$
$$= 248{\cdot}5+2\times158{\cdot}5-2\times6{\cdot}28-18{\cdot}28$$
$$= 248{\cdot}5+317-12{\cdot}56-18{\cdot}28$$
$$= 534{\cdot}66 \text{ cm.}^3$$

Hence, weight of C I. bracket

$$= \frac{534{\cdot}66\times7{\cdot}5}{1000}$$
$$= 4 \text{ kg (nearly). } \textbf{Ans.}$$

Example 15. Calculate the volume of the component shown in Fig. 5·16.

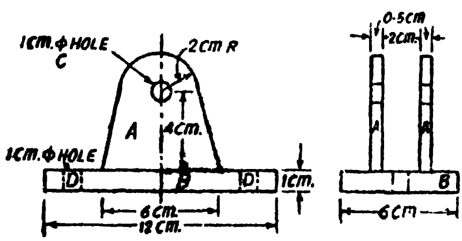


Fig. 5·16

Solution. Break up the drawing into simple parts *A*, *B*, *C* and *D*.

Volume of each part A = Volume of semi-circular part + Volume = of trapezoidal part

$$= \left\{\frac{1}{2}\times\frac{\pi}{4}(4)^2\times0{\cdot}5\right\} + \left\{\left(\frac{4+6}{2}\right)\times4\times0{\cdot}5\right\}$$
$$= 13{\cdot}14 \text{ cm.}^3$$

Volume of base $B = 12\times6\times1 = 72 \text{ cm.}^3$

Volume of each hole $C = \frac{\pi}{4}(1)^2\times0{\cdot}5 = 0{\cdot}4 \text{ cm.}^3$, nearly

Volume of each hole $D = \frac{\pi}{4}(1)^2\times1$

$$= 0{\cdot}8 \text{ cm.}^3 \text{ (nearly).}$$

∴ Total volume $= 2A+B-2C-2D$

$$= 2\times13{\cdot}14+72-2\times0{\cdot}4-2\times0{\cdot}8$$
$$= 95{\cdot}88 \text{ cm.}^3 \quad \textbf{Ans.}$$

Example 16. Calculate the material cost of 20-gun metal bushes. The drawing is given as under. Assume the density of gun metal as 8·3 gm./c.c. and its cost is Rs. 10/kg. Consider 10% material loss during process. All dimensions are in mm.

Solution. Break up Fig. 5·17 into simple parts, *A*, *B*, *C* and *D*.

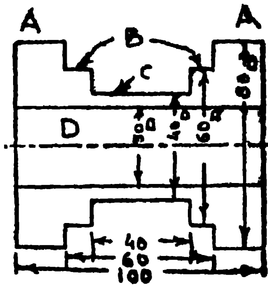


Fig. 5·17

Volume of each part $A = \frac{\pi}{4}(8)^2 \times 2$
$= 32\pi$ cm.^{3}

Volume of each part $B = \frac{\pi}{4}(6)^2 \times 1$
$= 9\pi$ cm.^{3}

Volume of part $C = \frac{\pi}{4}(4)^2 \times 4$
$= 16\pi$ cm.^{3}

Volume of hole $D = \frac{\pi}{4}(3)^2 \times 10 = 22{\cdot}5\pi$ cm.^{3}

$\therefore$ Volume of bush $= 2A + 2B + C - D$
$= \pi(2 \times 32 + 2 \times 9 + 16 - 22{\cdot}5)$
$= 237{\cdot}6$ cm.^{3}

$\therefore$ Weight of bush $= \frac{237{\cdot}6 \times 8{\cdot}3}{1000}$
$= 1{\cdot}97$ kg.

Hence, weight of material required for 20 bushes
$= 1{\cdot}97 \times 20 \times 1{\cdot}1$ (considering 10% loss)
$= 43{\cdot}34$ kg.

$\therefore$ Material cost $= 43{\cdot}34 \times 10$
$=$ **Rs. 433·40. Ans.**

Example 17. Estimate the weight of C.I. plumber block. The density of C.I. is 7·2 gm./c.c. (Fig. 5·18).

Solution. Break up the block into simple parts *A*, *B*, *C*, *D*, *E* and *F*.

Volume of base $A = 20 \times 5 \times 2 = 200$ cm.^{3}

Volume of each part $B = 4 \times 5 \times 1{\cdot}5$
$= 30$ cm.^{3}

Volume of each inner fillet $C = 0{\cdot}215\, r^2 \times 5 = 4{\cdot}30$ cm^3.

Volume of each outer fillet $D = 0{\cdot}215\, (1)^2 \times 5 = 1{\cdot}075$ cm.^{3}

Volume of each hole $E = 3 \times 2 \times 2 = 12$ cm.^{3}

Volume of each base projection F

$$= 1 \times 5 \times 0.5 = 2.5 \text{ cm.}^3$$

$$\therefore \quad \text{Total volume} = A+2B+2C+2D-2E+3F$$

$$= (200+2\times30+2\times4.30+2\times1.075 -2\times12+3\times2.5)$$

$$= 254.25$$

$$\therefore \text{ Weight of the block} = \frac{254.25\times7.2}{1000}$$

$$= 1.83 \text{ kg.} \quad \textbf{Ans.}$$

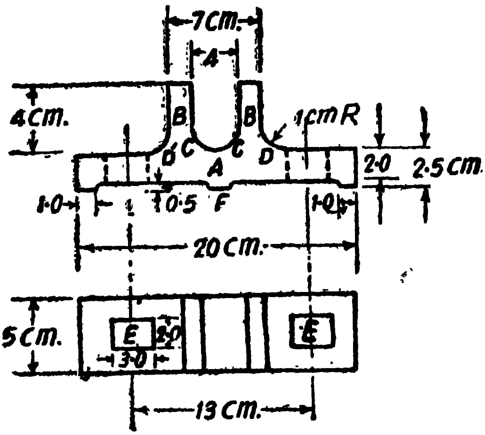


Fig. 5·18

Example 18. Calculate the weight of C.I. pedestal shown below. Assume the density of C.I. as 7·2 gm./c.c. [Fig. 5·20].

Solution. Break up the component into simple parts A, B, C, D, E and F as shown in Fig. 5·17.

$$\text{Volume of part } A = (15-XX)\times7\times3$$

where $\quad XX = 4\sqrt{3}$ as explained in Fig. 5·19.

$$= (15-4\sqrt{3})\times21$$

$$= 169.5 \text{ cm.}^3$$

$$\text{Volume of part } B = XX\times\text{height}\times7$$

$$= 4\sqrt{3}\times1\times7$$

$$= 48.5 \text{ cm.}^3$$

$$\text{Volume of each fillet } C = 7\times0.215\, r^2$$

$$= 0.215\,(4)^2\times7$$

$$= 24.08 \text{ cm.}^3$$

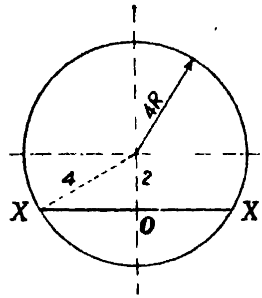


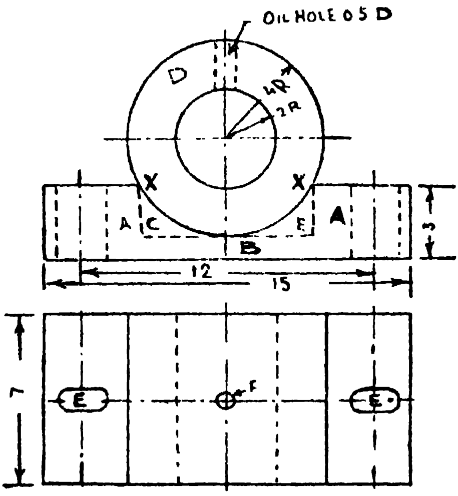
Fig. 5·19

From this figure

$$OX = \sqrt{4^2-2^2}$$
$$= 2\sqrt{3}$$
$$\therefore \quad XX = 2\times2\sqrt{3}$$
$$= 4\sqrt{3}.$$

Volume of hollow cylindrical part D

$$= \frac{\pi}{4}\{(8)^2-(2)^2\}\times7$$
$$= 84\pi = 264 \text{ cm.}^3$$



All dimensions are in cm.

Fig. 5·20

Volume of each elliptical hole E

$$= \pi\, ab \times \text{thickness}$$

(where a and b are semi-major and minor axes)

$$= \pi\times1\times\tfrac{1}{2}\times3 = 4{\cdot}71 \text{ cm.}^3$$

Volume of oil hole $F = \frac{\pi}{4}\left(\frac{1}{2}\right)^2 \times 2$

$= 0.40$ cm.³ (nearly)

$\therefore$ Total volume $= A+B+2C+D-2E-F$

$= (169.5+48.5+2\times24.08+264-2\times4.71-0.4)$

$= 520.34$ cm.³

Hence, weight of component

$= \frac{520.34\times7.2}{1000}$

$= 3.75$ **kg. Ans.**

Example 19. Estimate the volume of material required for an engine flywheel shown in Fig. 5·21

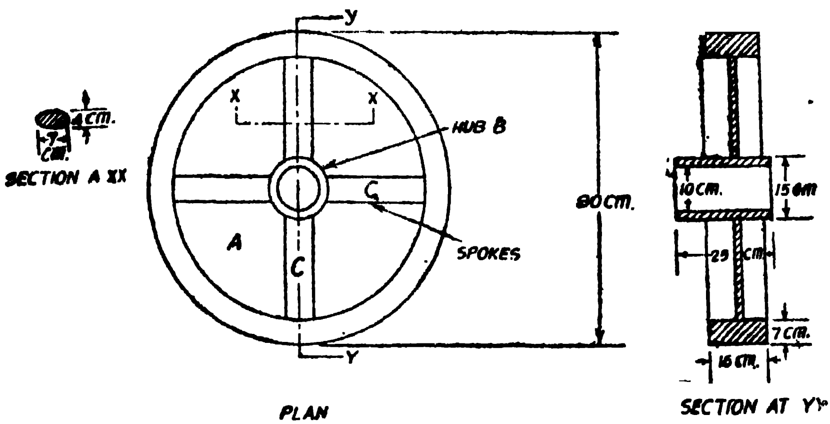


Fig. 5·21

Solution. Break up the drawing into simple parts *A*, *B* and *C*.

Volume of rim $A = \frac{\pi}{4}\{(80)^2-(66)^2\}\times 15$

$= 7665\pi$ cm.³

Volume of hub $B = \frac{\pi}{4}\{(15)^2-(10)^2\}\times 25$

$= 781\pi$ cm.³

Volume of each arm $C = \pi ab \times l$

(where a and b are semi-major and semi-minor axes of an elliptical section and l is the length of each arm.

$\therefore$ Volume of $C = \pi\times3.5\times2\times25.5$

$= 178.5\pi$ cm.³

$\therefore$ Total volume of material

$$= A+B+4C$$
$$= (7665+781+4\times178{\cdot}5)\pi$$
$$= 28762 \text{ cm.}^3 \quad \textbf{Ans.}$$

Example 20. Estimate the weight of 100 I.C. engine valves, sketch of which is shown in Fig. 5·22. Assume the weight of material as 8 gm./c.c.

Solution. Break the drawing into simple parts *A, B, C, D, E* and *F*.

$$\text{Volume of part } A = \frac{\pi}{4}(1)^2\times2 = 1{\cdot}57 \text{ cm.}^3$$

$$\text{Volume of part } B = \frac{\pi}{4}(0{\cdot}7)^2\times1$$
$$= 0{\cdot}39 \text{ cm.}^3$$

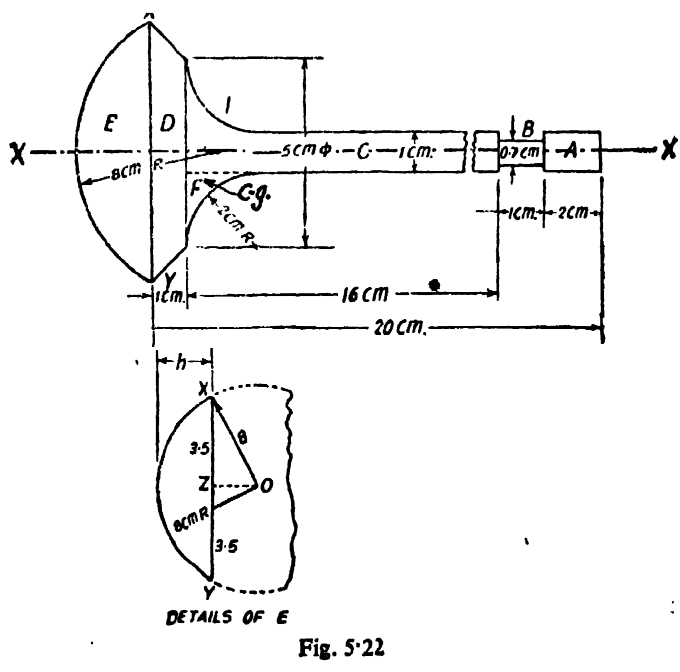


Fig. 5·22

$$\text{Volume of part } C = \frac{\pi}{4}(1)^2\times16 = 12{\cdot}56 \text{ cm.}^3$$

Volume of frustum of cone D

$$= \frac{\pi}{3}h\,(R_1^2+R_2^2+R_1R_2)$$

where $R_1 = 2{\cdot}5$ cm., $R_2 = 3{\cdot}5$ cm., $h = 1$ cm.,

$$\therefore \quad \text{Volume of } D = \frac{\pi}{3}\times 1\left\{\left(\frac{5}{2}\right)^2+\left(\frac{7}{2}\right)^2+\frac{35}{4}\right\}$$

$$= 28{\cdot}55 \text{ cm.}^3$$

Volume of spherical portion E

$$= \frac{\pi}{3}\, h^2(3R-h)$$

where, $$OZ = \sqrt{(8)^2-3{\cdot}5)^2}$$

$$= 7{\cdot}18$$

$$h = (8-OZ) = (8-7{\cdot}18)$$

$$= 0{\cdot}82 \text{ cm.}$$

$$\text{Volume of } E = \frac{\pi}{3}\times(0{\cdot}82)^2(3\times 8-0{\cdot}82)$$

$$= 16 \text{ cm.}^3 \text{ (nearly)}$$

$$\text{Area of fillet } F = 0{\cdot}215\, r^2 = 0{\cdot}215\times(2)^2$$

$$= 0{\cdot}86 \text{ cm.}^2$$

Peripheral length of fillet F (By Guldinus Rule)

$$= 2\pi x,$$

where x = distance of C.G. of fillet from XX axis

$$\therefore \text{ Volume of fillet } F = 0{\cdot}86\times\pi\times 1{\cdot}892 = 5{\cdot}10 \text{ cm.}^3$$

$$\therefore \quad \text{Total volume} = A+B+C+D+E+F$$

$$= (1{\cdot}57+0{\cdot}39+12{\cdot}56+28{\cdot}55+16+5{\cdot}10)$$

$$= 63{\cdot}17 \text{ cm.}^3$$

$\therefore$ Volume of 100 such valves

$$= 63{\cdot}17\times 100 = 6317 \text{ cm.}^3$$

$\therefore$ Weight of 100 such valves

$$\frac{6317\times 8}{1000} = \mathbf{50{\cdot}54 \text{ kg.}} \quad \textbf{Ans.}$$

Example 21. Calculate the weight of 50 metres of a steel chain, one link of which is shown in the Fig. 5·23. Assume weight of steel rod of 1 cm. dia. as 6·6 gm./cm. length.

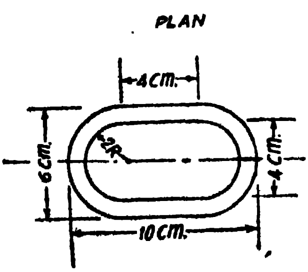


Fig. 5·23

Solution. Effective length of the link is the inner length which determines the length of chain and is equal to 10−2 (dia. of steel rod).

$$= 10-2\times 1 = 8 \text{ cm.}$$

$\therefore$ No. of such links required for 50 m. chain

$$= \frac{50\times 100}{8} = 625$$

Mean length of one link $= 4+4+2\pi r$

(where r = mean radius of link)

$= 4+4+2\times\pi\times2{\cdot}5 = 23{\cdot}7$ cm.

$\therefore$ Total length of steel rod required for 50 m. chain

$= 23{\cdot}7\times625$ cm.

$\therefore$ Weight of 50 m. chain

$$= \frac{23{\cdot}7\times625\times6{\cdot}6}{1000}\text{ kg.}$$

$= 97{\cdot}76$ **kg. Ans.**

Example 22. Estimate the weight of m.s. sheet block as shown in the figure. The base and top of the block are eliplical in cross-section. Density of C.I. may be taken as 8 gm/c.c. All dimensions are in cm. (See Fig. 5·24).

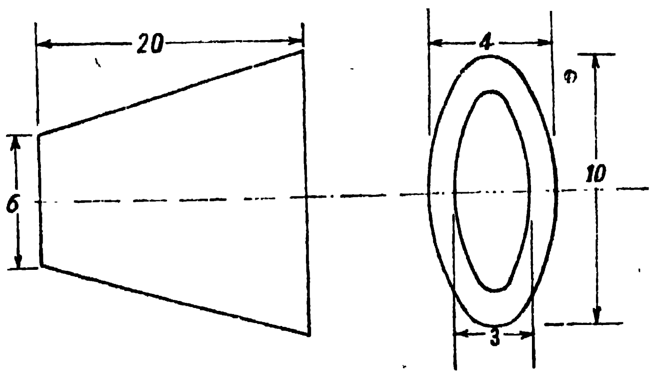


Fig. 5·24

This block is like a frustum of cone

$$\text{Volume} = \frac{h}{3}(a_1+a_2+\sqrt{a_1a_2})$$

here h = 20 cm.

$a_1 = \pi\times a\times b$, where a and b are semi major and minor axes.

$$a = \frac{10}{2},\ b = \frac{4}{2}$$

$a_1 = \pi\times5\times2$

$= 31{\cdot}4$ cm.^{2}

Similarly $a_2 = \pi\times\frac{6}{2}\times\frac{3}{2}$

$= 14$ cm.^{2}

∴ Volume of M.S. sheet

$$= \frac{20}{3}(31 \cdot 4 + 14 + \sqrt{31 \cdot 4 \times 14})$$

$$= 442 \text{ cm.}^3$$

∴ Wt. of M.S. block

$$= 442 \times 8$$

$$= 3536 \text{ gm.}$$

$$= \mathbf{3 \cdot 536 \ kg.} \quad \textbf{Ans.}$$

Example 23. Find out the weight of the overhung crank as shown in the Fig. 5·25, if the weight of steel is 7·8 gm./cm³. All dimensions are in cm.

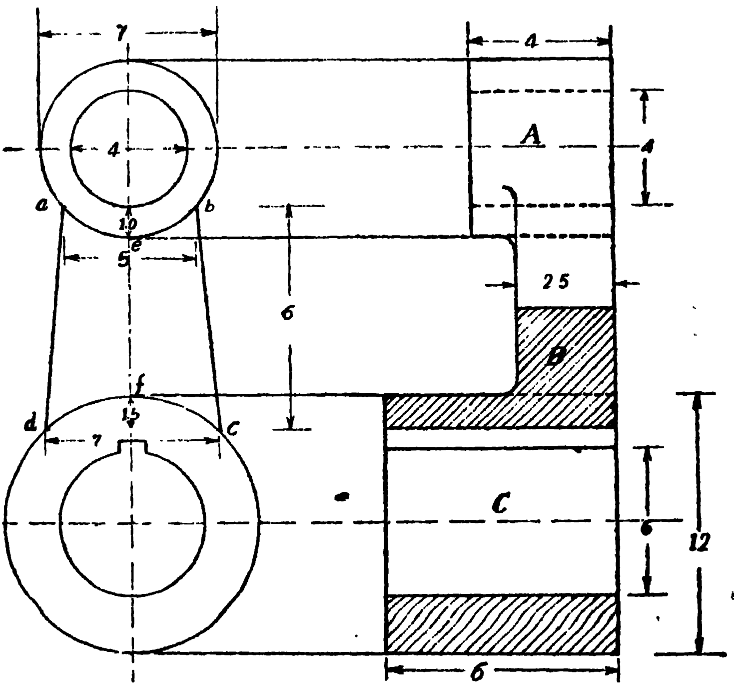


Fig. 5·25

Total volume of overhung crank

= Volume of A+volume of B+volume of C.

$$\text{Volume of } A = \left[\frac{\pi}{4}(7)^2 - \frac{\pi}{4}(4)^2\right] \times 4$$

$$= \frac{\pi}{4} \times 4\left[(7)^2 - (4)^2\right] = 33\pi$$

$$= 104 \text{ cm.}^3$$

Volume of B = Vol. of trapezium *abcd*—vol. of segment *abe*—vol. of segment *cdf*

$$= \frac{(5+7)}{2}\times 6\times 2{\cdot}5-\frac{2}{3}h_1l_1-\frac{2}{3}h_2l_2$$

$$= 90-\frac{2}{3}\times 1\times 5-\frac{2}{3}\times\frac{3}{2}\times 7$$

$$= 90-3{\cdot}34-7$$

$$= 90-10{\cdot}34$$

$$= 79{\cdot}66\ \text{cm.}^3$$

$$\text{Vol. of } C = \frac{\pi}{4}\left[(12)^2-(6)^2\right]\times 6-\text{vol. of keyway}$$

$$= \frac{\pi}{4}\left[108\right]\times 6-1\times 1{\cdot}5\times 6$$

$$= \pi\times 27\times 6-9$$

$$= 162\times\pi-9$$

$$= 500\ \text{cm.}^3$$

$$\text{Total volume} = 104+79{\cdot}66+500$$

$$= 683{\cdot}66\ \text{cm.}^3$$

$$\text{Weight} = 683{\cdot}66\times 7{\cdot}8\ \text{gm.}$$

$= 5{\cdot}33$ kg. **Ans.**

Example 24. It is proposed to provide an angle Iron frame around an opening 450 mm. square and cover the opening by a chequered plate 6 mm. thick as shown in Fig 5·25. Find out the weight of steel used if angle iron 75 mm. × 7 mm. × 6 mm. weighs as 7 kg. per metre, bar 25 mm × 6 mm. weighs 1·0 kg/metre, chequered plate 6 mm. thick weighs 60 kg./square metre and bar 12 mm. dia. weighs 1 kg. per metre. *(B.T.E. Punjab)*

Solution.

(*a*) Length of angle iron 75 mm. × 75 mm. × 6 mm

= 4 × 450 mm = 1800 mm.

= 1·8 metre.

∴ Weight of angle iron

= 1·8 × 7 = 12·6 kg.

(*b*) Length of iron bar 25 mm. × 6 mm.

= (551 − 1) × 4

= 2200 mm.

Allowing 1 mm length for welding.

∴ Weight of iron bar

$$\frac{2200}{1000}\quad 2{\cdot}20\ \text{kg.}$$

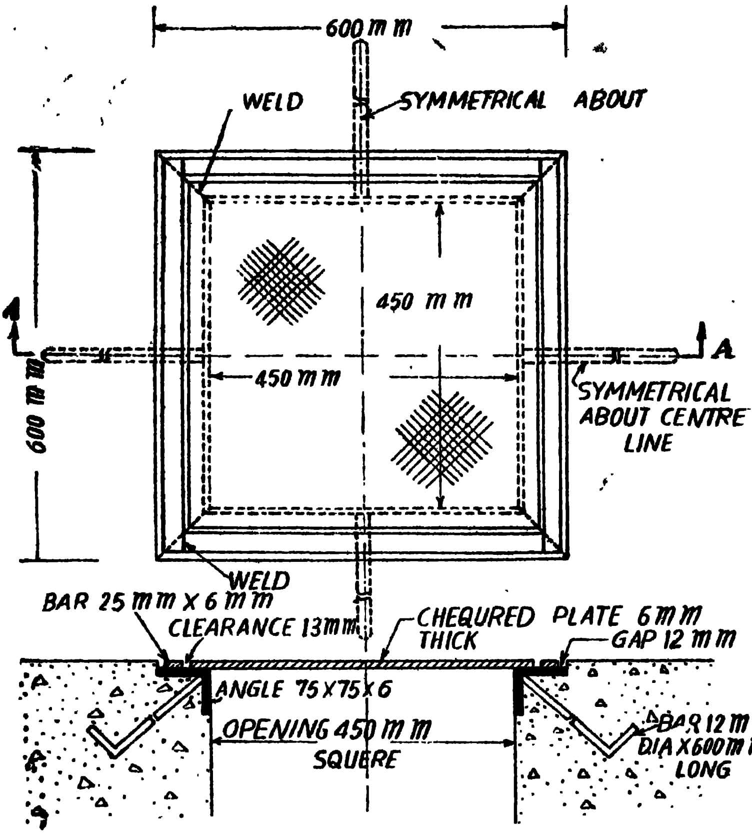


Fig. 5·26

(c) Area of chequered plate

$$= 500 \times 500$$

$$\frac{250000}{10^6} \text{ m}^2 = 0{\cdot}25 \text{ m}^2$$

∴ Weight of chequered plate

$$= 0{\cdot}25 \times 60$$

$$= 15 \text{ kg.}$$

(d) Length of bar 12 mm. dia.

$$= 4 \times 600 = 2400 \text{ mm}$$

$$= 2{\cdot}4 \text{ metre.}$$

∴ Weight of bar $= 2{\cdot}4 \times 1{\cdot}0$

$$= 2{\cdot}4 \text{ kg.}$$

∴ Total steel used $= 12{\cdot}6 + 2{\cdot}20 + 15 + 2{\cdot}4$

$= 32{\cdot}2$ kg. Ans.

Unsolved Problems

1. A C.I. muff coupling has 17 cm. external and 7 cm. internal diameters and length is 22 cm , find its weight. What length of wrought iron shaft having 6 cm. diameter, would have the same weight. Assume density of both the materials as 7·2 gm./c.c.

(Ans. 29·8 kg. ; 146 7 cm.)

2. The length of one edge of a C.I. cube is 30 cm. Estimate its volume.

(Ans. 0·027 cu. m.)

3. Fig. 5·27 shows a wedge forged from M.S. bar of 4 cm. diameter. Estimate, what length of bar shall be needed, if the volume of the metal remains unchanged.

(Ans. 5·25 cm.)

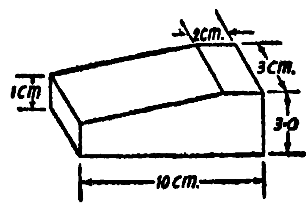


Fig. 5·27

4. A spherical oil tank is 15 m. in dia. and oil is allowed to be filled in it upto a height of 12 m. Find in litres, the quantity of oil, stored in it. Take density of oil as 0·86.

(Ans. 13,61,000 litres)

5. Fig. 5·28 shows three views of a C.I. V-block. Calculate its weight, if the density of material is 7·8 gm/c.c.

(Ans. 93·75 cm.^{3})

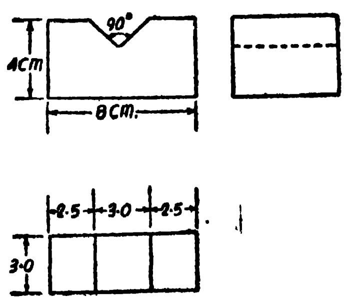


Fig. 5·28

6. Estimate weight of a C.I. block shown in Fig. 5·29. Take density of material as 7·2 gm./c.c.

(Ans. 0·7 kg.)

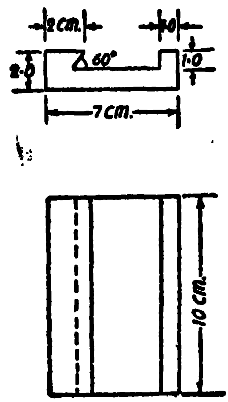


Fig. 5·29

7. Assume density of cast steel as 7·4 gm/c.c. Estimate the weight of the casting shown in Fig. 5·30. (Ans. 3 13 kg.)

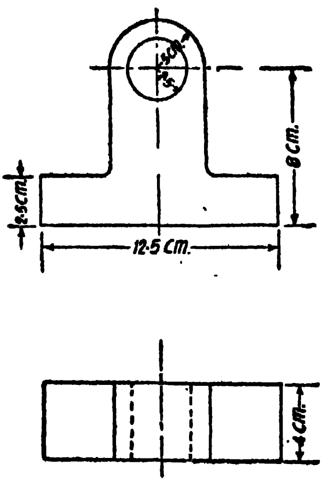


Fig. 5·30

8. Fig. 5·31 shows an ink blotting block of aluminium of density 5·8 gm./c.c. Find the weight of block. (Ans. 1·65 kg)

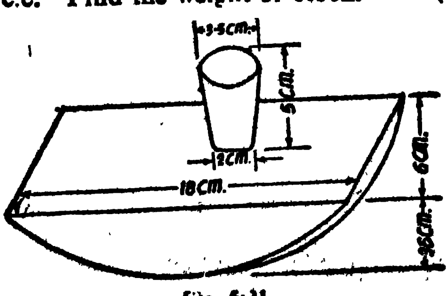


Fig. 5·31

9. Estimate the weight of M.S. spindle for a spring compressor as shown in Fig. 5·31. Assume density of steel as 7 8 gm./c.c.

(Ans. 0·46 kg)

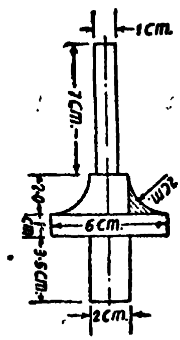


Fig. 5·32

10. Estimate the weight of brass required for preparing a handle shown in Fig. 5·33. Take density of C.I. as 7·2 gm /c.c.

(Ans. 0·635 kg

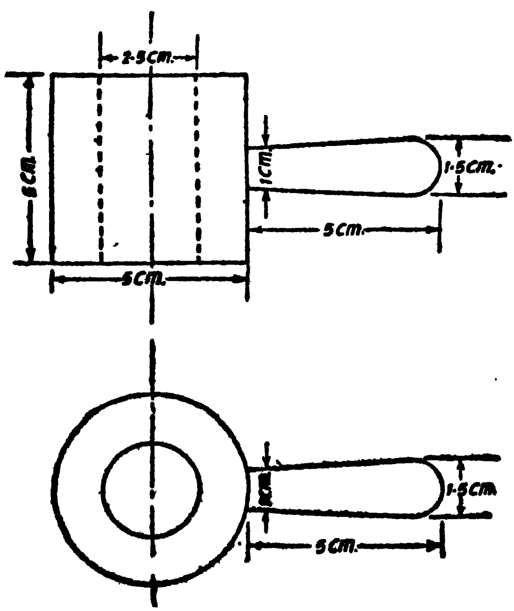


Fig. 5·33

11. Calculate the wt. of M.S. bell crank lever. Density of M.S. may be taken as 8 gm./c.c. (Fig. 5·34).

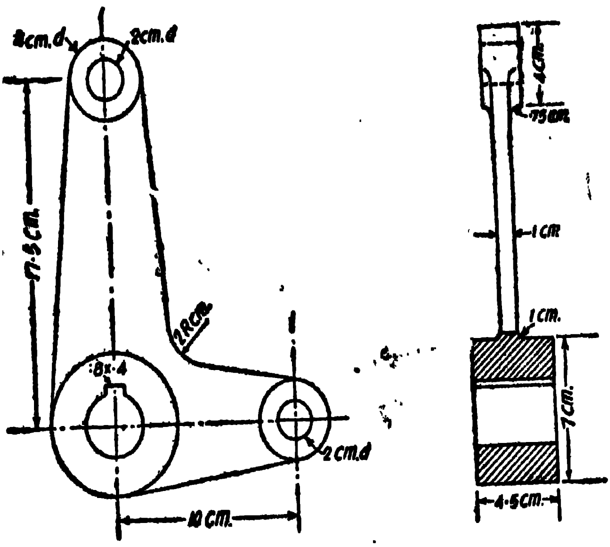


Fig. 5·34

6

ESTIMATION IN MACHINE SHOP

Procedure

For estimation purposes, machining cost is calculated after finding the material cost. Machining is done, to get the exact size and shape of the product on castings, on forgings and on bar stocks etc.

We shall discuss in the chapter on 'Estimation of castings' that certain amount of material is included as machining allowance. For this purpose, we took slightly bigger dimensions than that from finished drawings on the sides which are to be machined.

Generally following different operations are performed in the machine shop, on different machines :—

(1) Turning, (2) Knurling, (3) Facing, (4) Drilling, (5) Boring, (6) Reaming, (7) Threading, (8) Tapping (9) Milling, (10) Grinding, (11) Shaping, (12) Planing.

In estimating, our aim is to find out the time, which a labour takes for performing the machining operation, for calculating their wages. In addition to this machining time (also known as operation time), following time considerations are taken :

(*i*) Setting up the job.

(*ii*) Setting up the tool or cutters.

(*iii*) Inspection of job.

(*iv*) Fatigue allowance.

In the study of the machining operation time following terms are generally used :

(*a*) *Cutting Speed.* It is the distance at which tool travels along the material in one minute. Its unit is metres/min.

Let us consider an example, in which a job of D cm. dia. is revolving at a speed of N r.p.m. Then, distance travelled by the tool point in one min. = Distance moved in one rev. × Revolutions performed in one min.

$$\therefore \quad \text{Cutting speed} = \frac{\pi DN}{100} \text{ m./min.}$$

Cutting speed depends on the following factors :—

(*i*) Hard material requires a lower cutting speed than that of soft and ductile materials.

(*ii*) High speed tools, and tools of special cutting alloys can cut at higher cutting speeds than carbon steel tools.

(*iii*) If the depth of cut and feed is more, then less cutting speed is taken and *vice versa*.

(*iv*) By using good cutting fluids, cutting speeds may be increased.

An estimator should consider above factors while selecting a suitable cutting speed.

Table on next page gives the cutting speeds for different materials on different operations. The cutting speeds are with H.S.S. tools.

Note. (*i*) Cutting speeds for grinding in Table show the speed of the work at which it travels against the grinding wheel, while grinding wheel has its speed for external grinding as 1800 m./min., for internal grinding as 1200 m./min. and for surface grinding as 1500 m./min.

(*ii*) When the Tungsten carbide tools are used, the cutting speeds are 2 to 3 times the above speed.

(*b*) **Feed.** It is the distance, through which the tool advances into the work piece during one revolution of the work piece or the tool or cutter. Its unit is mm/rev.

As the feed depends on the depth of cut, cutting speed and power of the machine, hence no specific values for this can be mentioned.

(*c*) **Depth of cut.** It is the amount by which a tool or cutter is inserted into the metal during one cut. In other words, it is the thickness of the metal removed in one cut. It is generally measurep in mm.

LATHE OPERATIONS

Now we shall discuss about the estimation of time on different operations to be performed on lathe.

1. **Turning.** It is the operation of metal removal in which job is rotated against a tool.

Let S = Cutting speed in m./min.

D = Dia. of job to be turned in cm.

N = Rev. of the job/min.

TABLE

Material	Operations (cutting speeds are in M/min)							
	Turning and Boring	Drilling	Reaming	Threading	Tapping	Milling	Shaping, slotting and planing	Grinding
Aluminium	300	120	120	30	45	200	25	20
Brass	50	50	25	30	20	40	12	22
Mild steel	30	25	12	25	5	20	20	15
Cast Iron	20	15	10	20	7	50	10	12
Copper	30	50	15	30	20	40	10	22

and F = Feed/rev.

as $$S = \frac{\pi DN}{100} \text{ m./min.}$$

$$\therefore \quad N = \frac{100\, S}{\pi D} \text{ r.p.m.}$$

As we know that feed/min.

$$= \text{r.p.m.} \times \text{feed/rev.}$$

and. Time taken to turn unit length

$$= \frac{1}{\text{Feed/min}} \text{ min.}$$

∴ Time taken to turn L metre length

$$= \frac{L}{\text{Feed/min.}}$$

$$= \frac{L}{\text{Feed/rev.} \times \text{r.p.m.}}$$

Hence $$T = \frac{\text{Length of the job to be turned}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

$$\therefore \quad T = \frac{L}{F \times N} \text{ min.}$$

Example 1. Estimate the machining time to turn a M.S. bar of 3 cm. dia. down to 2·5 cm. for a length of 10 cm. in a single cut. Assume cutting speed=30 m./min. and feed=0·4 mm./rev.

Solution. To estimate the time required to turn the M.S. bar, first step is to find out the r.p.m. at which this bar should be rotated to give the cutting speed as 30 m./min. approximately.

Now, using the formula

$$N = \frac{100\, S}{\pi D} \text{ r.p.m.}$$

where S = 30 m./min.

D = 3 cm.

$$\therefore \quad N = \frac{100 \times 30}{\pi \times 3} = \frac{1000}{\pi} = 318 \text{ r.p.m.}$$

Now, second step is to find the machining time. As we know that

$$\text{Time } T = \frac{\text{Length}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

where L = 10 cm.

Feed = 0·04 cm./rev.

N = 318 r.p.m.

$$\therefore \quad \text{Time } T = \frac{10}{0{\cdot}04 \times 318} = 0{\cdot}79 \text{ min.} \quad \textbf{Ans.}$$

Example 2. A m.s. bolt 2 cm. diameter is rotating at 500 R.P.M. How much machining time is required to make 45° chamfer by 0·5 cm. Assume feed as 0·2 mm/rev. (Fig. 6·1).

Solution. Let AB is the length of cut required for chamfering.

$$\frac{0.5}{AB} = \sin 45°$$

$$= \frac{1}{\sqrt{2}}$$

or $$AB = 0.5 \times \sqrt{2}$$

$$= 0.707 \text{ cm.}$$

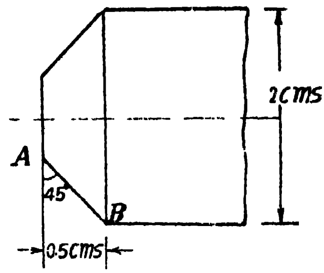


Fig. 6·1

∴ Now, Time for chamfering,

$$T = \frac{\text{Length of cut}}{\text{Feed} \times \text{r.p.m.}}$$

$$= \frac{L}{F \times N}$$

$$= \frac{0.707}{0.02 \times 500} \text{ min.}$$

$$= 0.07 \text{ minute}$$

$$= \mathbf{4.2 \text{ seconds.}} \quad \textbf{Ans.}$$

Example 3. Estimate the total time taken to turn a 10 cm. long 2 5 cm diameter m.s. rod to a diameter of 2·3 cm. in a single cut. Assuming cutting speed to be 25 m/min, feed to be 0·1 mm/rev. and the mounting time in a shelf centring 3 jaw chuck to be 40 seconds. Neglect time taken for setting up tools etc.

(*B.T.E., Rajasthan Nov. 1969*)

Solution. Here $L = 10$ cm.

$S = 25$ m/min.

$F = 0.01$ cm/rev.

As $$N = \frac{100\,S}{\pi D}$$

$$N = \frac{100 \times 25}{\pi \times 2.5} = 318 \text{ r.p.m.}$$

$$T = \frac{10}{0.01 \times 318} = 3.14 \text{ min.}$$

Now, it is given that job mounting time is 40 sec.

∴ **Total machining time**

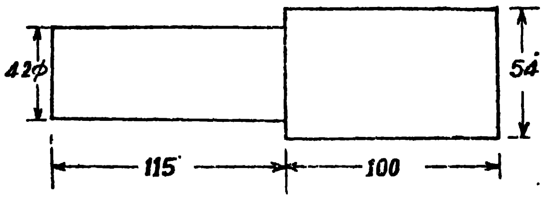
$$= 3.14 + \frac{40}{60}$$

$$= \mathbf{3.80. \text{ minute.}} \quad \textbf{Ans.}$$

Example 4. Find the time required to turn a 60 mm. diameter rod to the dimensions shown in Fig. 6·2. Take cutting speed as 20 m/minute, feed as 1·2 mm. All cuts are 3 mm deep. (Fig. 6·2).

(S.B.T.E. Rajasthan May 71)

Solution. *First step.*



All dimensions are in mm.

Fig. 6 2

Reducing the diameter from 60 mm. to 54 mm. for a length of 215 mm. by turning. As depth of cut is 3 mm. hence one cut is required.

∴ Time for turning,

$$T_1 = \frac{L_1}{F_1 \times N_1}$$

Here $$T_1 = \frac{215}{1 \cdot 2 \times \frac{100 \times 20}{\pi \times 6 \cdot 0}}$$

or $$T_1 = 1 \cdot 7 \text{ min.}$$

Second step.

Reducing the diameter from 54 mm. to 42 mm. by turning. As depth of cut is 3 mm., therefore

$$\frac{54-42}{6} \quad 2 \text{ will be the number of cuts.}$$

1st cut

Here $$N_2 \quad \frac{100\, S}{\pi\, D_2}$$

$$\frac{100 \times 20}{\pi \times 5 \cdot 4}$$

118 r.p.m.

$$\frac{115}{1 \cdot 2 \times 118} = 0 \cdot 8 \text{ min.}$$

2nd cut

$$N_2 = \frac{100\,S}{\pi\,D_2}$$

$$= \frac{100\times 20}{\pi\times 4{\cdot}8} = 132{\cdot}7 \text{ r.p.m.}$$

$$T_2 = \frac{115}{1{\cdot}2\times 132{\cdot}7}$$

$$= 0{\cdot}7 \text{ min.}$$

∴ Total turning time

$$= 1{\cdot}7+0{\cdot}8+0{\cdot}7$$

$$= 3{\cdot}2 \text{ minute. Ans.}$$

Example 5. What do you mean by step turning ? Calculate the time required to turn a stepped shaft of the dimensions shown in Fig. 6·3 from m s. stock of approximate length and 4 cm. diameter. Neglect facing and setting up time The depth of cut should not exceed 0·25 cm. Assume the cutting speed to be 20 m/min. and feed to be 0 3 mm/rev. for each cut. (*B.T.E., Rajasthan, May 1967*)

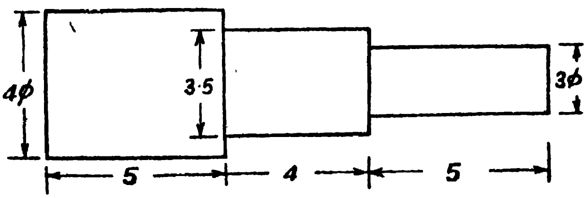


Fig. 6·3
'All dimensions are in cm.

Solution. *First step.*

Reducing the diameter from 4 cm to 3·5 cm. for a length of 9 cm. in single cut as depth of cut is 0·25 cm.

$$\therefore \quad N_1 = \frac{100\,S}{\pi D_1}$$

$$= \frac{100\times 20}{\pi\times 4} = 159{\cdot}2 \text{ r.p.m.}$$

$$\therefore \quad T_1 = \frac{L}{F/\text{rev.}\times \text{r p.m.}}$$

$$\frac{9}{0\;03 \cdot 159{\cdot}2}$$

or $\quad T_1 \quad 1\;9$ min.

Second step.

Reducing the diameter from 3·5 cm. to 3 cm. for a length of 5 cm. in single cut as depth of cut is 0 25 cm.

$$\therefore \quad N_2 = \frac{100\,S}{\pi D_2}$$

$$= \frac{100\times 20}{\pi\times 3\;5} = 182 \text{ r.p.m.}$$

$$\therefore \qquad T_2 = \frac{5}{0.03 \times 182} = 0.9 \text{ min.}$$

$\therefore$ Total turning time

$$= T_1 + T_2 = 1.9 + 0.9$$
$$= \mathbf{2.8 \text{ minute.}} \quad \textbf{Ans.}$$

Example 6. A circular aluminium rod is to be reduced from 5 cm. to 4 cm. for a length of 8 cm. in two cuts. Assuming cutting speed as 300 m./min. and feed as 0.01 cm./rev., estimate the time required for turning.

Solution. As we are required to turn the above rod in two cuts, therefore considering first cut

As $$N = \frac{100\,S}{\pi D}$$

$\therefore$ Speed for the first cut

$$N_1 = \frac{100 \times 300}{\pi \times 5} = \frac{6000}{\pi} \text{ r.p.m.}$$

and Time taken by first cut,

$$T_1 = \frac{L}{F \times N}$$
$$= \frac{8}{0.01 \times \frac{6000}{\pi}} = \frac{8\pi}{60} = \mathbf{0.42 \text{ min.}}$$

Now considering second cut,

As diameter is to be reduced by 1 cm. in two cuts, therefore after first cut dia. will be 4.5 cm.

Speed of rod for second cut,

$$N_2 = \frac{100\,S}{\pi D}$$

here, $S = 300$ m./min.

$D = 4.5$ cm.

$$\therefore \qquad N_2 = \frac{100 \times 300}{\pi \times 4.5} = 2120 \text{ r.p.m.}$$

$\therefore$ Time for second cut,

$$T_2 = \frac{L}{F \times N}$$
$$= \frac{8}{0.01 \times 2120} = 0.38 \text{ min.}$$

$\therefore$ **Total time,** $T = T_1 + T_2 = 0.42 + 0.38$

$$= \mathbf{0.8 \text{ min.}} \quad \textbf{Ans.}$$

Example 7. A 15 cm. long m.s. bar is to be turned from 4 cm. dia. in single cut in such a way that for 5 cm. length its dia. is reduced to 3·8 cm. and remaining 10 cm. length is reduced to 3·4 cm. Estimate the total time required for turning it, assuming cutting speed as 30 m/min., feed as 0·02 cm./rev. and time required for setting and mounting of the job in a three jaw chuck is 30 secs. Neglect the tool setting time.

Solution. *Step I.* For turning the entire length of the jobs it will be mounted twice in the chuck, therefore time for setting the job $T_1 = 2 \times 30$ sec. $= \mathbf{1}$ **min.**

Step II. For turning the job to reduce the dia. from 4 cm. to 3·8 cm. in single cut for a length of 5 cm. time required

$$= T_2 = \frac{L}{F \times N} \text{ min.}$$

where. $L = 5$ cm. ; $F = 0{\cdot}02$ cm.

and $N = \dfrac{100\,S}{\pi D} = \dfrac{100 \times 30}{\pi \times 4} = 240$ r.p.m.

$\therefore$ $T_2 = \dfrac{5}{0{\cdot}02 \times 240} = \mathbf{1{\cdot}04}$ **min.**

Sept. III. Turning time required for reducing the dia. from 4 cm. to 3·4 cm. for remaining length,

$$T_3 = \frac{L}{F \times N} \text{ min.}$$

where, $L = 10$ cm. ; $F = 0{\cdot}02$ cm. and

$N = 240$ r.p.m.

$\therefore$ $T_3 = \dfrac{10}{0{\cdot}02 \times 240} = 2{\cdot}08$ min.

$\therefore$ Total time required

$$= T = T_1 + T_2 + T_3$$
$$= 1 + 1{\cdot}04 + 2{\cdot}08$$
$$= \mathbf{4{\cdot}12 \text{ min.}} \quad \textbf{Ans.}$$

2. **Knurling.** Knurling is the process used for making diamond shaped impressions on the surface of a component to produce a rough surface to facilitate easy grip. This is done with the help a knurling tool also known as knurl. This process is performed on a lathe machine.

Time required for knurling operation can be calculated by the same formula as that for turning.

i.e. Time for for knurling

$$= \frac{\text{Length of cut}}{\text{Feed/rev.} \times \text{r.p.m.}} \text{ min.}$$

Cutting speed for knurling should be little less than that for turning.

Example 8. A componet, as shown in Fig. 6·4 is to be knurled on the surface. Find the time required for knurling it, if cutting speed is 20 m./min. and feed is 0·03 cm./rev.

Solution.

As $N = \frac{100\,S}{\pi D}$

where, S = 20 m./min.

D = 3 cm.

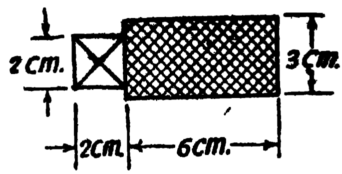


Fig. 6·4

$\therefore\ N = \frac{100\times 20}{\pi\times 3} = 212$ r.p.m.

Now, as,

Length of cut = 6 cm.

Feed = 0·03 cm./rev.

$\therefore$ Time for turning

$= \frac{\text{Length of cut}}{\text{Feed/rev.}\times\text{r.p.m.}}$

$= \frac{6}{0\cdot03\times 213}$ min. = 56·6 sec. **Ans.**

3. **Facing.** It is the process of material removal, from the surface at right angles to the axis of rotation of the job. Fig. 6·5 shows how the facing is done.

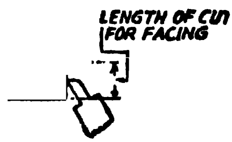


Fig. 6·5

In this process tool is feed cross-wise, while in turning, tool is feed longitudinally.

Time required for facing

$= \frac{\text{Length of cut}}{\text{Feed/rev.}\times\text{r.p.m.}}$

where, length of cut

= ½ (Dia. of job.)

Example 9. Find the time required to face both ends of a component, shown in Fig. 6·6 in one cut. Assume speed of rotation of the job as 100 r.p.m. and cross-feed as 0·03 cm./rev.

Solution.

As we know that,

Time for facing

$= \frac{\text{Length of cut}}{\text{Feed/rev.}\times\text{r.p.m.}}$

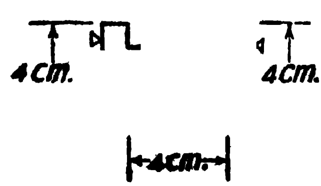


Fig. 6·6

where, Length of cut

$= \frac{D}{2} = \frac{4}{2} = 2$ cm.

Feed/rev. = 0·03 cm./rev.

and N = 100 r.p.m.

∴ Time for facing on one end

$$\frac{2}{0{\cdot}03 \times 100} = \frac{2}{3} \text{ min.}$$

∴ Time for facing both ends.

$$= 2 \times \frac{2}{3} = \mathbf{1{\cdot}33 \text{ min.}} \quad \textbf{Ans.}$$

4. **Drilling.** It is the process of producing a hole in an object. Time required for drilling hole can be calculated by using the following formula :

$$\text{Time for Drilling} = \frac{\text{Depth of hole to be produced}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

5. **Boring.** It is the process of enlarging a hole, which has already been drilled or casted or punched. Time required for boring can be obtained by using the similar formula *i.e.*

Time required for boring

$$= \frac{\text{Length to be bored}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

6. **Reaming.** It is the process of removing very small amount of material, to make the drilled holes in very accurate size. This process is carried out by a tool known as reamer.

$$\text{Time for reaming} = \frac{\text{Depth of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

Example 10. Find the time required to drill 6 holes in a casted flange, each of 1 cm. depth, if the hole dia. is 1½ cm. Assume cutting speed as 20 m./min. and feed as 0 02 cm./rev.

Solution. As we know that,

$$\text{Time for drilling} = \frac{\text{Depth of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

where, Depth of hole = 1 cm.

Feed = 0·02 cm.

and $N = \frac{100\, S}{\pi D} = \frac{100 \times 20}{\pi \times 1{\cdot}5} = 424$ r.p.m.

∴ Time for drilling one hole

$$= \frac{1}{0{\cdot}02 \times 424} \text{ min.}$$

Time for drilling 6 holes

$$= \frac{6 \times 60}{0{\cdot}02 \times 424} \text{ sec.}$$

$$= \mathbf{42{\cdot}7 \text{ secs.}} \quad \textbf{Ans.}$$

Example 11. Calculate the time required for drilling a component as shown in Fig. 6·7. Assume the cutting speed as 22 m./min. and feed as 0·02 cm./rev.

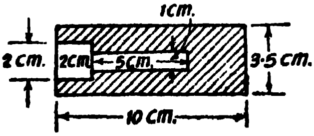


Fig. 6·7

Solution. In this case drilling will be done in two steps.

Step I. Drilling the hole with 1 cm. drill for a depth of 7 cm.

$$\text{Time } T_1 = \frac{\text{Depth of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

where, Depth of hole = 7 cm.

Feed/rev. = 0·02 cm./rev.

$$\text{r.p.m. } N_1 = \frac{100\,S}{\pi D_1} = \frac{100 \times 22}{\pi \times 1} = 700 \text{ r.p.m.}$$

$$\therefore \quad T_1 = \frac{7}{0{\cdot}02 \times 700} = 0{\cdot}5 \textbf{ min.}$$

Step II. Now drilling the hole with 2 cm. drill up to 2 cm. depth.

$$\text{In this case,} \quad N_2 = \frac{100\,S}{\pi D_2} = \frac{100 \times 22}{\pi \times 2} = 350 \textbf{ r.p.m.}$$

$$\text{Time } T_2 = \frac{\text{Depth of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

$$= \frac{2}{0{\cdot}02 \times 350} = \frac{2}{7} = 0{\cdot}29 \textbf{ min.}$$

$\therefore$ Total time for drilling $T = T_1 + T_2$

$= 0{\cdot}5 + 0{\cdot}29$

$= 0{\cdot}79$ **min. Ans.**

Example 12. Estimate the time for reaming a 2 cm. dia. hole having 3 cm. depth to make it 2·05 cm. dia. hole. Assume the cutting speed as 10 m./min. and feed as 0·03 cm./rev.

Solution. As,

$$\text{Time for reaming} = \frac{\text{Depth of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

where, Depth of hole = 3 cm.

Feed = 0·03 cm./rev.

$$\text{and} \quad \text{r.p.m.} = \frac{100S}{\pi D} = \frac{100 \times 10}{\pi \times 2} = \frac{500}{\pi} \text{ r.p.m.}$$

$$\therefore \quad \text{Time } T = \frac{3}{0{\cdot}03 \times \frac{500}{\pi}} = 0{\cdot}63 \textbf{ min. Ans.}$$

Example 13. A hollow spindle is bored to enlarge its hole diameter from 2 cm. to 2·5 cm. upto 10 cm. depth in single cut. Estimate the boring time, if cutting speed is 22 m./min. and feed is 0·02 cm./rev.

Solution. As we know that,

$$\text{Boring time} = \frac{\text{Length of hole to be bored}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

Here,

Length of hole = 10 cm.

Feed/rev. = 0·02 cm.

and $$\text{r.p.m.} = \frac{100\,S}{\pi D} = \frac{100 \times 22}{\pi \times 2} = 350 \text{ r.p.m.}$$

$\therefore$ $$\text{Boring time } T = \frac{10}{0{\cdot}02 \times 350} = \mathbf{1{\cdot}43\ min.\ Ans.}$$

7. **Threading** (*Screw cutting*) :

It is the removal of material to produce helix on external and internal circular surfaces for fastening purposes.

Formula for calculating the time required in threading is nearly similar to that for turning, only the change is to replace the feed by pitch or lead.

$$\text{Time for threading } T = \frac{L + 0{\cdot}7}{\text{Pitch or lead} \times \text{r.p.m.}} \text{ min./cut}$$

where L is the length of thread in cm. and 0·7 is taken as additional distance for tool travel.

Pitch for single start thread

$$= \frac{1}{\text{Threads/cm.}}$$

Lead for multi-start thread

$$= \frac{\text{No. of start}}{\text{Threads/cm.}}$$

Number of cuts. As threading upto full depth requires several cuts, therefore total time for producing threads up to full depth can be found by multiplying the number of cuts to the time required in one cut.

There is no hard and fast rule, for calculating the number of cuts, but for general guidance, following two systems are used.

First system. Number of cuts can be calculated by using the following relation.

No. of cuts = 25 × pitch (for external threads)

= 32 × pitch (for interual threads)

Second system. Number of cuts can also be found by using the following table :

TABLE—Metric Screw Threads (I.S.I.)

Basic Diameter in mm.	10	12	14	16	18 to 22	24	25	27	30	35	42 to 45	46 to 52	56 to 60	64 to 80
Pitch in mm.	1·5	1·75	2		2·5	3	3	3	3·5	1·5	4·5	5	5·5	6
	1·25		1·5	2					3		4	4	4	4
		1·5		1·5	2	2		2	2		3	3	3	3
	1	1·25	1·25		1·5	1·5		1·5	1·5		2	2	2	2
	0·75	1	1	1	1	1		1	1		1·5	1·5	1·5	1·5

Pitches are generally used diameters for coarse, medium and fine thread ranges.

S.No.	Material	No. of cuts
1.	Aluminium	4
2.	Brass	3
3.	Copper	5
4.	Cast Iron	6
5.	Mild steel	7

8. **Tapping.** It is the process of making internal thread with the help of a tool known as tap. Tapes are generally used for small works.

Time required for tapping

$$= \frac{\text{Length travelled by tap}}{\text{Pitch} \times \text{r.p m.}}$$

$$= \frac{L + \frac{D}{2}}{\text{Pitch} \times \text{r.p.m.}} \text{ min./cut}$$

where,

L = Length of threaded portion

D = Dia. of tap used

The above formula gives the time required to push the tap inside the job. Time for returning the tap is taken at ½ of the time required for pushing it in the job. Therefore, total time for cutting threads

$$T = \frac{\frac{3}{2}\left(L + \frac{D}{2}\right)}{\text{Pitch} \times \text{r.p.m.}} \text{ min.}$$

Example 14. Estimate the time required for cutting 3 mm. pitch threads on a mild steel bar of 2·8 cm. dia. and 8 cm. long. Assume the cutting speed for threading as 15 m./min.

Solution. As, Pitch = 3 mm. = 0·3 cm.

Bar dia. D = 2·8 cm.

Length L = 8 cm.

Cutting speed S = 15 m/min.

$$N = \frac{100\ S}{\pi D} = \frac{100 \times 15}{\pi \times 2{\cdot}8} = 170 \text{ r.p.m.}$$

and Threading time $T = \frac{L}{\text{Pitch} \times N} = \frac{8}{0{\cdot}3 \times 170}$

= **0·16 min.**

This is the time required for making one cut but in mild steel full depth of threads can be produced in 7 cuts. Hence time for threading up to full depth

$$= 0{\cdot}16 \times 7 = \mathbf{1{\cdot}12\ min.\ Ans.}$$

Example 15. Find out the time for threading on a 3 cm. dia. spindle for a length of 10 cm. by single point tool. If 3 threads per cm. are to be cut and speed of spindle is 66 r.p.m. Assume suitable approach and overtake for the tool.

Solution. Spindle dia. = 3 cm.

Length of threads = 10 cm.

No. of threads to be cut = 3/cm.

∴ Pitch of threads = $\frac{1}{3}$ cm.

N = 66 r.p.m.

The movement of the tool will have to be started certain distance before the commencement of threads, which is known as approach lenght. Let it be 0·5 cm. In the same way tool will go ahead by a certain distance after completion of the threads, till tool stops. This distance is known as overtake for the tool, let it be 0·5 cm.

Therefore, length of tool travel

$$= 10+0{\cdot}5+0{\cdot}5 = 11 \text{ cm.}$$

∴ Time required for threading/cut

$$= \frac{\text{Length of tool travel}}{\text{Pitch} \times N}$$

$$= \frac{11}{\frac{1}{3} \times 66} = \mathbf{0{\cdot}5\ min.}$$

To get full depth of threads 7 cuts are necessary.
Therefore,

Total time required for threading

$$= 7 \times 0{\cdot}5 = \mathbf{3{\cdot}5\ min.\ \ Ans.}$$

Example 16. Calculate the time required for cutting 2 threads/cm. on an aluminium bar stock of 3·5 cm. dia. and for a length of 10 cm. Assume cutting speed for aluminium bar as 11 m./min. Neglect approach and overtake for the tool.

Solution. Pitch = 0·5 cm.

Bar dia. D = 3·5 cm.

Length of threads L = 10 cm.

Cutting speed S = 11 m./min.

$$\therefore \quad N = \frac{100\,S}{\pi D} = \frac{100 \times 11}{\pi \times 3{\cdot}5} = 1000 \text{ r.p.m.}$$

and time required for one cut

$$= \frac{L}{\text{Pitch} \times N}$$

$$= \frac{10}{0{\cdot}5 \times 100} = 0{\cdot}2 \text{ min.}$$

To cut the threads upto full depth in aluminium 4 cuts are required. Hence total time required, will be

$$= 0{\cdot}2 \times 4 = \mathbf{0{\cdot}8\ min.}\quad \textbf{Ans.}$$

Example 17. Estimate the time required for tapping a 2 cm. dia. hole with a 3 mm. pitch tap, in a mild steel plate up to a depth of 3 cm. Assume cutting speed as 10 m./min. and also assume that return speed of tap is 2 times the cutting speed.

Solution. As,

$$\text{Speed of rotation } N = \frac{100\,S}{\pi D}$$

where, Cutting speed S = 10 m./min.

Hole dia. D = 2 cm.

$$\therefore \quad N = \frac{100 \times 10}{\pi \times 2} = 159 \text{ r.p.m.}$$

$$\text{Time for tapping/cut} = \frac{L + \frac{D}{2}}{\text{Pitch} \times N}$$

Here $L + \frac{D}{2} = 3 + \frac{2}{2} = 4$ cm.

Pitch = 0·3 cm.

$$\therefore \text{ Tapping time/cut} = \frac{4}{0{\cdot}3 \times 159} = 0{\cdot}08 \text{ min.}$$

$$\text{Time for return} = \tfrac{1}{2} \times \text{tapping time} = \frac{0{\cdot}08}{2} = 0{\cdot}04 \text{ min.}$$

$$\therefore \quad \text{Time/cut} = T_1 + T_2 = 0{\cdot}08 + 0{\cdot}04 = \mathbf{0{\cdot}12\ min.}$$

This the time for one cut, but for getting threads up to full depth, let the total cuts required be 6. Then the total time required for tapping = 6×0·12 = **0·72 min. Ans.**

Example 18. Estimate the time required for internal threading on a mild steel nut of 2 cm. bore dia. and 2 cm. length. Pitch of the thread is 2·5 mm. Assume cutting speed as 12 m./min. Also consider approach and overtravel.

Solution. As we know that,

$$\text{Time for threading/cut} = \frac{\text{Length of travel}}{\text{Pitch} \times \text{r.p.m.}}$$

Let approach and overtravel be 0·5 cm. each

$\therefore$ Length of travel L = 2+0·5+0·5 = 3 cm.

Pitch = 0·25 cm.

and Speed $N = \frac{100\,S}{\pi D} = \frac{100 \times 12}{\pi \times 2}$

$= 190$ r.p.m. (nearly)

∴ Time for threading/cut

$= \frac{3}{0{\cdot}25 \times 190} = 0{\cdot}063$ min.

To get full depth of threads in mild steel 7 cuts are necessary.

∴ Total time required for threading

$= 7 \times 0{\cdot}063$

$=$ **0·44 min. Ans.**

Example 19. You are required to cut 4 threads/cm on a steel shaft 3 cm in diameter and 10 cm long. Calculate time required for this, assuming the speed of thread cutting to be 33 m/min. and no. of cuts taken to be 4.

(B.T.E., Rajasthan 1969)

Solution. Time for threading,

$$T = \frac{L + 0{\cdot}7}{\text{Pitch} \times \text{r.p.m.}} \times \text{No. of cuts/minute}$$

Here $L = 10$ cm

$$\text{Pitch} = \frac{1}{4 \text{ threads/cm.}}$$

$= 0{\cdot}25$ cm.

No of cuts $= 4$.

$$\text{R.P.M.}, N = \frac{100\,S}{\pi D}$$

$$= \frac{100 \times 33}{\pi \times 3}$$

$= 350$ r.p.m.

$$T = \frac{(10 + 0{\cdot}7)}{0{\cdot}25 \times 350} \times 4$$

$=$ **0·48 minutes. Ans.**

Example 20. An operator is required to cut 2 threads/cm on a 4·5 cm. diameter job for a length of 9 cm. This work is to be done on a lathe with a tool. The lathe spindle is turning at 45 r.p.m. and 10 cuts are required to complete the thread. How much time will be taken to cut the threads ? *(B.T.E., Rajasthan Nov. 1970)*

Solution. $T = \frac{L + 0{\cdot}7}{\text{Pitch} \times \text{r p.m.}}$ min/cut × No. of cuts

$L = 9$ cm.

$$\text{Pitch} = \frac{1}{2 \text{ threads/cm}} = \frac{1}{2} \text{ cm.}$$

R.P.M. = 45

No. of cuts = 10

$$\frac{9+0{\cdot}7}{\times 45} \times 10$$

= **4·3 minutes. Ans.**

Some Advanced Problems

Example 21. The comparative tooling up time and turning time for a particular job when made on ordinary lathe and automatic lathe respectively is as follows :

Machine	*Tooling up time*	*Turning Time*
Ordinary Lathe	20 minute	15 minute
Automatic Lathe	120 minute	3 minute

Determine the number of pieces of job for which it would be more economical to use the automatic lathe instead of the ordinary lathe. (*B.T.E., Rajasthan, Nov. 1969*).

Solution. (*i*) Total time for the completion of one job
= 20+15 = 35 minutes.

(*ii*) On Automatic Lathe. Tooling up time is 120 minutes and Turning time is 3 minutes. On automatic lathe tooling up is done only once, after this a large number of pieces at the rate of one piece in every 3 minutes can be produced.

∴ Minimum pieces to be manufactured on automatic lathe

$$= \frac{\text{Total time on ordinary lathe/job}}{\text{Turning time on automatic lathe/job.}}$$

$$= \frac{35}{3}$$

= 11·66. Say 12 pieces. **Ans.**

Example 22. In a C.I. component having a 35 mm cored hole, an internal relief is to be provided over a length of 15) mm. Determine the total time to machine the bore (in two passes) and turning the relief (in one cut) in the component. Cutting speed is 15 m/min. and a feed of 0·10 mm/rev. (Fig. 6·8).

(*B.T.E., Rajasthan May 1970*).

First Step.

Solution. Enlarging (boring) the dia. from 35 mm. to 40 mm. for a length of 200 mm.

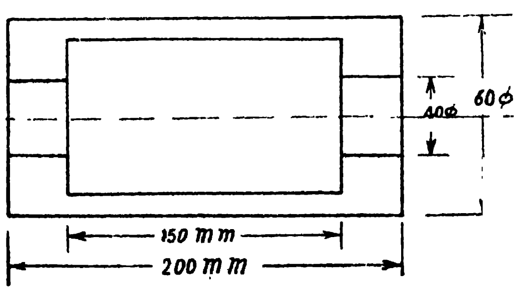


Fig. 6·8

Here $$N_1 \quad \frac{100\ S}{\pi D_1}$$

$$= \frac{100 \times 15}{\pi \times 3{\cdot}5}$$

$$= 136{\cdot}4 \text{ r.p.m.}$$

$\therefore$ Time for enlarging the dia. from 35 mm. to 40 mm. for a length of 200 mm. in two cuts

$$T_1 = \frac{20{\cdot}0}{0{\cdot}01 \times 136\ 4} \times 2$$

$$= 14{\cdot}7 \text{ Min.}$$

Second Step.

Time for providing a relief for a length of 150 mm. in one cut

$$N_2 = \frac{100 \times S}{\pi D_2}$$

$$= \frac{100 \times 35}{\pi \times 4{\cdot}0}$$

$$= 119{\cdot}4 \text{ r.p.m.}$$

$$\therefore \quad T_2 = \frac{15{\cdot}0}{0\ 01 \times 119{\cdot}4}$$

$$= 12{\cdot}5 \text{ min.}$$

$$\therefore \quad \text{Total time, } T = 14{\cdot}7 + 12{\cdot}5$$

$$= \mathbf{27\ 2 \text{ minutes.}} \quad \textbf{Ans.}$$

Example 23. Find the time taken to prepare a job according to the dimensions shown in Fig. 6 9 from a bar 3·5 cm diameter and 6 cm. long. Assume following data :

(1) Cutting speed for turning and boring
= 20 m/min.

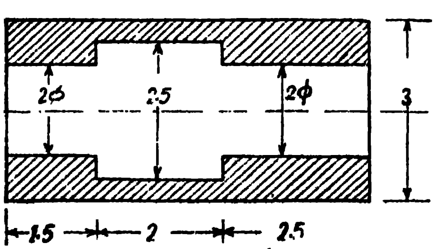
(2) Cutting speed for drilling
= 30 m/min.

(3) Feed for turning and boring
= 0·2 mm/rev.

(4) Feed for drilling = 0 23 mm/rev.

(5) Depth of cut not to exceed
= 3 mm.

(B.T.E., Rajasthan, May 1972)



All dimensions are in cm.

Fig. 6·9

First Step.

Solution. In this problem the dia. of bar stock is 3·5 cm. First it has to be reduced to 3 cm. by turning in single cut as depth of cut is 3 mm.

Here
$$D_1 = 3{\cdot}5 \text{ cm.}$$
$$S_1 = 20 \text{ m/min.}$$
$$F_1 = 0{\cdot}02 \text{ cm./rev.}$$
$$N_1 = \frac{100\, S_1}{\pi D_1} = \frac{100 \times 20}{\pi \times 3{\cdot}5} = 182 \text{ r.p.m.}$$
$$T_1 = \frac{\text{Length of cut}}{\text{Feed/rev.} \times \text{r.p.m.}}$$
$$T_1 = \frac{6}{0{\cdot}02 \times 182} = 1{\cdot}6 \text{ min.}$$

Second Step.

Drilling a hole of 2 cm. diameter to a length of 6 cm.

Time for Drilling,
$$T_2 = \frac{\text{Length to be drilled}}{\text{Feed/rev.} \times \text{r.p.m.}} = \frac{}{F_2 \times N_2}$$

Here
$$N_2 = \frac{100\, S_2}{\pi D_2} = \frac{100 \times 300}{314 \times 2} = 477 \text{ r.p.m.}$$
$$\therefore \quad T_2 = \frac{6 \times 10}{0{\cdot}23 \times 477} = 0{\cdot}547 \text{ min.}$$

3rd Step.

Enlarging a hole from 2 cm diameter to 2·5 cm. diameter for a length of 2 cm.
$$N_3 = \frac{100\, S_3}{\pi D_3} = \frac{100 \times 20}{\frac{22}{7} \times 2} = 318 \text{ r.p.m.}$$
$$\therefore \quad T_3 = \frac{2{\cdot}5}{0{\cdot}02 \times 3{\cdot}} = 0{\cdot}314 \text{ min.}$$

$\therefore$ Total machining time
$$= 1{\cdot}6 + 0{\cdot}547 + 0{\cdot}314$$
$$= \mathbf{2{\cdot}461 \text{ minutes.}} \quad \textbf{Ans.}$$

Example 24. Find the machining time to complete the job as shown in Fig. 6 10 from the basic raw material of 50 mm. diameter and 100 mm. length.

Assume :

Cutting speed for turning 30 m/min.

Feed = 1 mm/rev.

Depth of cut = 2·5 mm.

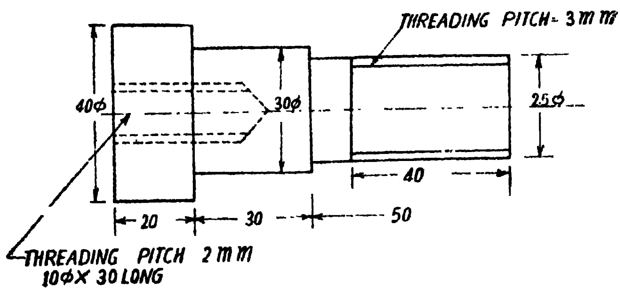
Cutting speed for thread cutting

= 9 m/min.

Cutting speed for drilling

= 30 m/min.

and feed for drilling = 0·2 mm/rev.



All dimensions are in mm.
Fig. 6·10

First Step.

Solution. Reducing the dia. from 50 mm to 40 mm. for a length of 100 mm in two cuts as depth of cut is 2·5 mm.

$$\therefore \quad \text{No. of cuts} = \frac{50-40}{2 \cdot 5 \times 2} = \frac{10}{5} = 2 \text{ cuts.}$$

∴ First dia. will be reduced from 50 mm. to 45 mm. in first cut and then 45 mm. to 40 mm. in second cut.

$$\therefore \quad T_1 = \frac{L}{F \times N_1}$$

$$= \frac{100}{1 \times \frac{100 \times 30}{\pi \times 5 \cdot 0}}$$

$$= \mathbf{0 \cdot 53 \text{ min.}}$$

$$\text{Similarly} \quad T_2 = \frac{L}{F \times N_2}$$

$$= \frac{100}{1 \times \frac{100 \times 30}{\pi \times 4 \cdot 5}}$$

$$= \mathbf{0 \cdot 47 \text{ min.}}$$

Second Step.

Reducing the dia. from 40 mm. to 30 mm. for a length of 80 mm. in two cuts. As depth of cut is 2·5 mm. Therefore no. of cuts

$$= \frac{40-30}{2·5\times2}$$

$$= 2 \text{ cuts.}$$

$$\therefore \quad T_3 = \frac{80}{1\times\frac{100\times30}{\pi\times4}} \text{ for 1st cut}$$

$$= \frac{80\times\pi\times4}{100\times3} = \mathbf{0·33 \text{ minute}}$$

$$\therefore \quad T_4 = \frac{80}{1\times\frac{100\times30}{\pi\times3·5}} = \mathbf{0\ 31 \text{ minute}}$$

3rd Step.

Reducing the dia. from 30 mm. to 25 mm. for a length of 50 mm. in single cut.

$$\therefore \quad T_5 = \frac{L}{F\times\text{r.p.m.}}$$

$$\frac{50}{1\times\frac{100\times30}{3·14\times3·0}}$$

$$= \mathbf{0·157 \text{ minute.}}$$

4th Step.

Drilling for a length of 30 mm and dia. 10 mm.

$$\therefore \quad T_6 = \frac{30}{0·2\times\frac{100\times30}{\pi\times1·0}} = \mathbf{0·157 \text{ min.}}$$

5th Step.

Threading for a length of 30 mm. dia. 10 mm. pitch 2 mm. Let No. of cuts = 7.

$$\therefore \quad T_7 = \frac{30}{20\times\frac{100\times9}{3·14\times1·0}}\times7$$

$$= \mathbf{0·36 \text{ min.}}$$

6th Step

Threading for a length of 40 mm, dia. 25 mm pitch 3 mm. Let no. of cuts = 7.

$$\therefore \quad T_8 = \frac{40}{3\times\frac{100\times9}{\pi\times2·5}}\times7$$

$$= \mathbf{0·81 \text{ min.}}$$

$$\therefore \quad T = T_1+T_2 \text{.........} T_8$$

$$= 0·53+0·47+0\ 33+0·31+0·157+0·157+0·36+0·81$$

$$= 3·124 \text{ minutes.} \quad \textbf{Ans.}$$

Example 25. A 30 mm. dia. 200 mm. long rod of aluminium is to be machined on a lathe to make a component as shown below in Fig. 6·11. Calculate the mechining time. Assume cutting speed for turning 30 m./min. and for threading as 10 m./min. and feed as 3 mm./rev. for turning and 1 mm./rev. for facing.

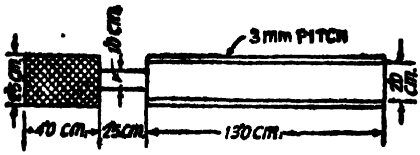


Fig. 6·11

This question is solved in the following steps.

Step I. Turning the job from 30 mm. dia. to required size :

(*i*) First the job is turned from 30 mm. to 25 mm. for the 200 mm. length.

$$\text{Time required, } t_1 = \frac{\text{Length of job}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

$$= \frac{200}{3 \times \dfrac{100 \times 30}{\pi \times 3}}$$

$$= \frac{20\pi}{300} = \mathbf{0{\cdot}21\ min.}$$

(*ii*) Now the dia. is reduced from 25 mm. to 20 mm. for a length of 157·5 mm (considering, that 2·5 mm. length will be reduced in facing on each side).

$$\therefore \text{Time required, } t_2 = \frac{157{\cdot}5}{3 \times \dfrac{100 \times 30}{\pi \times 2{\cdot}5}} = \frac{157{\cdot}5\pi}{3600}$$

$$= \mathbf{0{\cdot}14\ min.}$$

(*iii*) Now the dia. is reduced from 20 mm. to 10 mm. in two cuts for a length of 25 mm., assuming that each cut takes same time.

$$\therefore \text{Time required, } t_3 = \frac{25}{3 \times \dfrac{100 \times 30}{\pi \times 20}} \times 2 = \mathbf{0{\cdot}035\ min.}$$

$$\therefore \text{Turning time } T_1 = t_1 + t_2 + t_3 = 0{\cdot}210 + 0{\cdot}140 + 0{\cdot}035$$

$$= \mathbf{0{\cdot}385\ min.}$$

Step II. *Facing.*

(*i*) First of all facing is done on 25 mm. dia. on one end.

$$\text{Time } t_1 = \frac{\text{Length for facing}}{\text{Feed/rev.} \times \text{r.p.m.}} = \frac{\dfrac{25}{2}}{1 \times \dfrac{100 \times 30}{\pi \times 2{\cdot}5}}$$

$$= \mathbf{0{\cdot}032\ min.}$$

(*ii*) Now facing is done on 20 mm. dia. side,

$$\therefore \text{ Time required, } t_2 = \frac{\frac{20}{2}}{1 \times \frac{100 \times 30}{\pi \times 2}} = \mathbf{0{\cdot}021 \text{ min.}}$$

$\therefore$ Total facing time, T_2

$$= t_1 + t_2$$
$$= 0{\cdot}032 + 0{\cdot}021 = \mathbf{0{\cdot}053 \text{ min.}}$$

Step III. *Knurling.*

Cutting speed during knurling is assumed to be same as that for turning.

$$\text{Time, } T_3 = \frac{\text{Length for knurling}}{\text{Feed/rev.} \times \text{r.p.m.}} = \frac{40}{3 \times \frac{100 \times 30}{\pi \times 2{\cdot}5}}$$

$$\mathbf{0{\cdot}034 \text{ min.}}$$

Step IV. *Threading.*

Threading time for one cut

$$= \frac{\text{Length for threading}}{\text{Pitch} \times \text{r.p.m.}}$$

$$\frac{130}{3 \times \frac{100 \times 10}{\pi \times 2}} = 0{\cdot}28 \text{ min.}$$

Let 4 cuts be required to get full threads, then

Total time $T_4 = 0{\cdot}28 \times 4 = \mathbf{1{\cdot}12 \text{ min.}}$

$\therefore$ Total machining time required for the component,

$$T = T_1 + T_2 + T_3 + T_4$$
$$= 0{\cdot}385 + 0{\cdot}053 + 0{\cdot}034 + 1{\cdot}120$$
$$= \mathbf{1{\cdot}592 \text{ min.}} \quad \mathbf{Ans.}$$

Example 26. A product, as shown in Fig. 6·12, is to be turned from 3·5 cm. dia. to 10 cm. long mild steel bar stock. Calculate the mechining time required, if depth of cut is not to exceed 5 mm., and cutting speed for turning, facing and drilling is 20 m./min.

Solution. This question is solved in the following steps :

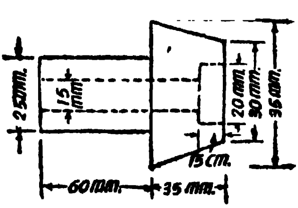


Fig. 6·12

Step I. *Drilling.* Drilling the hole of 15 mm. dia. for a length of 100 mm. will require.

$$\text{Time } T_1 = \frac{\text{Depth of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

$$\frac{100}{1 \times \frac{100 \times 20}{\pi \times 1{\cdot}5}}$$

(assuming feed as 1 mm./rev.)

0·24 mm.

Step. II. *Turning.*

(*i*) Time required for taper turning from 35 mm. to 30 mm. for a length of 35 mm., assuming feed as 3 mm./rev.

$$t_1 = \frac{35}{3 \times \frac{1\ 0 \times 20}{\pi \times 3 \cdot 5}} = 0 \cdot 064 \text{ min.}$$

(*ii*) Time required for turning to reduce the dia. from 35 mm. to 25 mm. in 2 cuts for a length of 60 mm. and assuming that each cut requires same time,

$$t_2 = \frac{60}{3 \times \frac{100 \times 20}{\pi \times 3 \cdot 5}} \times 2 = 0 \cdot 22 \text{ min.}$$

$\therefore$ Total time for turning T_2

$$= t_1 + t_2 = 0 \cdot 064 + 0 \cdot 220 = 0 \cdot 284 \text{ min.}$$

Step III. *Facing.*

(*i*) Facing time required for facing on 30 mm. dia. side, assuming feed as 1 mm./rev. is

$$t_1 = \frac{\left(\frac{30-15}{2}\right)}{1 \times \frac{100 \times 20}{\pi \times 3 \cdot 0}} = 0 \cdot 04 \text{ min.}$$

(*ii*) Facing time required for facing on 25 mm. dia. side

$$t_2 = \frac{\left(\frac{25-15}{2}\right)}{1 \times \frac{100 \times 20}{\pi \times 2 \cdot 5}} = 0 \cdot 02 \text{ min.}$$

$\therefore$ Total facing time

$$T_3 = t_1 + t_2 = 0 \cdot 04 + 0 \cdot 02 = 0\ 06 \text{ min.}$$

Step. IV. *Boring.* Time required for enlarging the hole from 15 mm. to 20 mm. for a length of 15 mm.

$$T_4 = \frac{15}{3 \times \frac{100 \times 20}{\pi \times 1 \cdot 5}} = 0 \cdot 012 \text{ min.}$$

$\therefore$ Total time required

$$T = T_1 + T_2 + T_3 + T_4$$
$$= 0 \cdot 240 + 0 \cdot 284 + 0 \cdot 060 + 0 \cdot 012$$
$$= 0 \cdot 596 \text{ min. } \textbf{Ans.}$$

Example 27. Calculate the cost of machining the casted wheel, as shown in Fig. 6·13, if the rate of machining is Re. 0·10/sq. cm. of mechined surface.

Solution. Calculation of machining area :

(*i*) Machining area of the suface *A*

$$= \frac{\pi}{4}\left\{(25)^2-(15)^2\right\}$$

$$= \frac{\pi}{4}\times 400 = 100\ \pi\ \text{mm.}^2$$

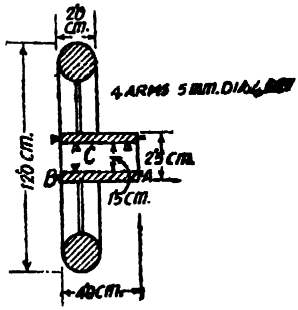


Fig. 6·13

(*ii*) Machining area of the surface *B*

$$= \frac{\pi}{4}\left\{(25)^2-(15)^2\right\}$$

$$= 100\ \pi\ \text{mm.}^2$$

(*iii*) Machining area of the hollow surface

$$C = \pi \times 15 \times 40 = 600\pi\ \text{mm.}^2$$

∴ Total machining area

$$= 100\pi + 100\pi + 600\pi$$

$$= 800\pi\ \text{mm.}^2 = 8\pi\ \text{cm.}^2$$

$$= \mathbf{25{\cdot}12\ cm.^2}$$

Therefore,

Machining cost @ Re. 0·10 per cm.²

$0{\cdot}10 \times 25{\cdot}12 =$ **Rs. 2·512. Ans.**

Example 28. A gun metal bush is to be made from a 5 cm. dia. and 8 cm. long stock, diagram of which is shown in Fig. 6·14. Calculate the machining time per piece, if cutting speed is 20 m./min and feed 2 mm./rev. Boring is done after drilling the hole of 1·5 cm. dia.

Solution.

Step I. First of all facing is done on stock on both the faces for 5 cm. dia. then time required

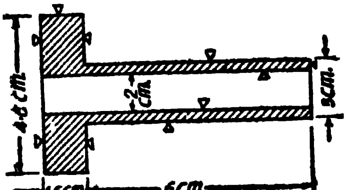


Fig. 6·14

$$T_1 = \frac{2{\cdot}5}{0{\cdot}2\times\frac{100\times 20}{\pi\times 5}}\times 2$$

$$= \mathbf{0{\cdot}20\ min.}$$

Step II. Now drilling a hole of 1·5 cm. dia. for a length of 7·5 cm., then time required

$$T_2 = \frac{7{\cdot}5}{0{\cdot}2\times\frac{100\times 20}{\pi\times 1{\cdot}5}} = \mathbf{0{\cdot}088\ min.}$$

Step III. Boring to enlarge the hole up to 2 cm. dia.

$$\text{Time, } T_3 = \frac{7{\cdot}5}{0{\cdot}2 \times \frac{100 \times 20}{\pi \times 1{\cdot}5}} = \mathbf{0{\cdot}088 \text{ min.}}$$

Step IV. *Turning.*

(*i*) Time required to reduce the dia. from 5 cm. to 4·6 cm. for 7·5 cm. length,

$$t_1 = \frac{7{\cdot}5}{0{\cdot}2 \times \frac{100 \times 20}{\pi \times 5}} = \mathbf{0{\cdot}30 \text{ min.}}$$

(*ii*) Time required for reducing the dia. from 4·6 cm. to 3 cm. in 3 cuts and for a length of 6 cm.

$$t_2 = \frac{6 \times 3}{0{\cdot}2 \times \frac{100 \times 20}{\pi \times 4{\cdot}6}} = \mathbf{0{\cdot}65 \text{ min.}}$$

$\therefore$ Total turning time $T_4 = t_1 + t_2 = 0{\cdot}30 + 0{\cdot}65 = 0{\cdot}95$ min.

$\therefore$ Total machining time $T = T_1 + T_2 + T_3 + T_4$

$= 0{\cdot}200 + 0{\cdot}088 + 0{\cdot}088 + 0{\cdot}95 = 1{\cdot}326$ **min. Ans.**

Example 29. A manufacturer desires to manufacture 100 bolts/day from mild steel bars of length 2 m. and dia. as 25 mm. Assume :

(*i*) Feed for turning = 0·2 cm./rev.

(*ii*) Cutting speed for turning = 20 m./min.

(*iii*) Cutting speed for threading = 10 m./min.

(*iv*) Depth of cut = maximum of 3 mm.

(*v*) Pitch for threads 2·5 mm.

(*vi*) No. of cuts required for threading = 6.

Calculate the machining time for 100 bolts, if the operator is paid at the rate of Rs. 1·25/hr. Estimate the labour charges, considering other allowances for fatigue etc. as 100%.

Solution.

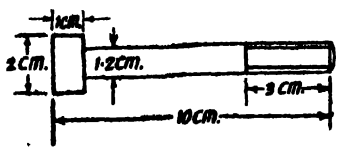


Fig. 6·15

Step I. *Turning*

(*i*) Reducing the dia. from 25 mm. to 20 mm. for a length of 10 cm.

Turning time

$$t_1 = \frac{\text{Length}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

$$= \frac{10}{0{\cdot}2 \times \frac{100 \times 20}{\pi \times 2{\cdot}5}} = \mathbf{0{\cdot}2 \text{ min.}}$$

(*ii*) Reducing the dia. from 20 mm. to 12 mm. in two cuts a length of 9 cm.

Time required in first cut to reduce the dia. from 20 mm. to 16 mm.

$$t_2 = \frac{9}{0{\cdot}2 \times \frac{100 \times 20}{\pi \times 2}} = \mathbf{0{\cdot}15\ min.}$$

And time required in second cut

$$t_3 = \frac{9}{0{\cdot}2 \times \frac{100 \times 20}{\pi \times 1{\cdot}6}} = \mathbf{0{\cdot}12\ min.}$$

∴ Total turning time

$$T_1 = t_1 + t_2 + t_3$$
$$= 0{\cdot}20 + 0{\cdot}15 + 0{\cdot}12 = \mathbf{0{\cdot}47\ min.}$$

Step II. *Threading.*

Threading time for one cut

$$= \frac{\text{Length}}{\text{Pitch} \times \text{r.p.m.}}$$
$$\frac{30}{2{\cdot}5 \times \frac{100 \times 10}{\pi \times 1{\cdot}2}} = \mathbf{0{\cdot}045\ min.}$$

∴ Total threading time for 6 cuts

$$= 0{\cdot}045 \times 6 = \mathbf{0{\cdot}27\ min.}$$

∴ Total machining time

$$= 0{\cdot}47 + 0{\cdot}27 = \mathbf{0{\cdot}74\ min.}$$

∴ Time required for 100 bolts

$$= 0{\cdot}74 \times 100 = \mathbf{74\ min.}$$ **Ans.**

∴ By considering allowances as 100%

Time taken by operator $= 74 \times 2$

$= 148$ min. $=$ **2·46 hrs.**

∴ Labour cost $= 2{\cdot}46 \times 1{\cdot}25$

$=$ **Rs. 3·08. Ans.**

Example 30. Estimate total cost of gun metal component as shown in Fig. 6·16. If material lost in machining is 20% of the weight of component, then find out the weight of gun metal required. Assume—density of gun metal as 8 gm./c.c., cost of gun-metal is Rs. 15/kg., machining charges are 10 paise per 10 sq. cm. of finished surface and total overhead charges are 10% of the material cost.

Solution.

Material Cost

Volume of the component

$$= \frac{\pi}{4}(3{\cdot}5)^2 \times 2 + \frac{\pi}{4}(3)^2 \times 3 - \frac{\pi}{4}(2)^2 \times 5$$

$$= \frac{\pi}{4}\left\{24{\cdot}5 + 27 - 20\right\}$$

24·5 cu. cm.

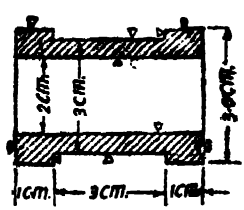


Fig. 6·16

$\therefore$ Wt. of the component

$$= 24{\cdot}5\times0{\cdot}008 = 0{\cdot}198 \text{ kg.}$$

$\therefore$ Wt. of the gun metal required, if scrap is 20%

$$= 0{\cdot}198\times1{\cdot}2 = 0{\cdot}2376 \text{ kg.}$$

$\therefore$ Cost of gun metal $= 0{\cdot}2376\times15 =$ **Rs. 3·56**

Labour Cost

Total surface area to be machined

= Outer surface area + face area + inner surface area

$$= \left(\pi\times3{\cdot}5\times2+\pi\times3\times3\right)+\left[2\times\frac{\pi}{4}\left\{(3{\cdot}5)^2-(2)^2\right\}+2\times\frac{\pi}{4}\left\{(3{\cdot}5)^2-(3)^2\right\}\right]+\left\{\pi\times2\times5\right\}$$

$$= \pi[7+9+\tfrac{1}{2}(8{\cdot}25+3{\cdot}25)+10]$$

$$= \pi\,(26+5{\cdot}75) = \mathbf{100\ sq.\ cm.}$$

$\therefore$ Labour cost = 100 paise = **Re. 1·00**

Overhead charges = 10% material cost

$$= 3{\cdot}56\times0{\cdot}10 = \text{Re. } 0{\cdot}36.$$

$\therefore$ Total cost = Material cost + Labour cost + Overhead charges

$$= 3{\cdot}56+1{\cdot}00+0{\cdot}36$$

$$= \text{Rs. } 4{\cdot}92. \quad \textbf{Ans.}$$

Example 31. Estimate the cost of 1000 pieces of spindle as shown in Fig. 6·17. Assume the following data :—

(*i*) Turning and facing cost = 2 paise/sq. cm. of surface area.

(*ii*) Threading cost = 5 paise/cm. length of thread.

(*iii*) Cost of milling a square plug = 4 paise/sq. cm. of surface area.

(*iv*) Material cost/piece = 20 paise.

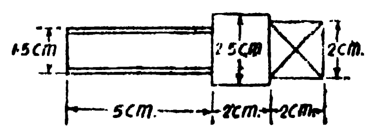


Fig. 6·17

Solution. (*i*) *Turning and facing charges* :

(*a*) Turning area of the portion where theading is done

$$A_1 = \pi\times1{\cdot}5\times5 = 7{\cdot}5\pi \text{ sq. cm.}$$

(*b*) Turning area of the collar,

$$A_2 = \pi\times2{\cdot}5\times2 = 5\pi \text{ sq. cm.}$$

(c) Total facing area,

$$A_3 = \frac{\pi}{4}(1.5)^2 + \frac{\pi}{4}\left\{(2.5)^2 - (1.5)^2\right\}$$

$$= \frac{\pi}{4}(2.5)^2 \quad 1.56\pi \text{ sq. cm.}$$

$\therefore$ Total turning and facing charges @ Re. 0·02/sq. cm.

$$C_1 = 0.02(A_1 + A_2 + A_3)$$
$$= 0.02\pi\,(7.5 + 5.0 + 1.56)$$
$$= 0.2812\,\pi$$
$$= \textbf{Re. 0.89.}$$

(ii) Threading charges for 5 cm. length @ Re. 0·05/cm.

$$C_2 = 5 \times 0.05 = \textbf{Re. 0.25}$$

(iii) *Milling charges* :

Total surface area of the plug for 5 surfaces

$$= 5(2 \times 2) = 20 \text{ sq. cm.}$$

$\therefore$ Milling charges @ Re. 0·04/sq. cm. area

$$C_3 = 20 \times 0.04$$
$$= \textbf{Re. 0.80.}$$

(iv) Material cost/piece,

$$C_4 = \textbf{Re. 0.20} \text{ (given)}$$

$\therefore$ Total cost of one spindle

$$= C_1 + C_2 + C_3 + C_4$$
$$= 0.89 + 0.25 + 0.80 + 0.20$$
$$= \text{Rs. } 2.14.$$

$\therefore$ Cost of 1000 spindles

$$= 2.14 \times 1000$$
$$= \textbf{Rs. 2140.} \quad \textbf{Ans.}$$

Example 32. Estimate the manufacturing cost of 100 pieces of a component shown in Fig. 6·18. These components are to be made from a 3·5 cm. mild steel stock. Assume the following data :

(i) Density of material = 8 gm./c.c.

(ii) Material cost = Rs. 2/kg.

(iii) Parting off and facing allowance/piece = 1 cm.

(iv) Cost of machining = 2 paise/cu cm. of material removed

(v) Overhead charges = 50% of labour cost.

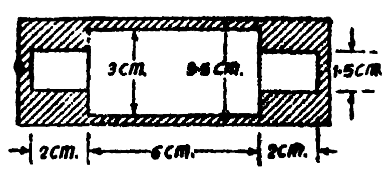


Fig. 6·18

Solution. Material Cost

Length of stock required/piece

$= 6+2+2+1$

$= 11$ cm. (considering 1 cm. as parting allowance)

$\therefore$ Volume of material required/piece

$$= \frac{\pi}{4}(3\cdot5)^2 \times 11 = 106 \text{ cm.}^3$$

$\therefore$ Wt. of material/piece $= 106 \times 0\cdot008$

$= \mathbf{0\cdot848}$ **kg.**

$\therefore$ Material cost/piece

$= 0\cdot848 \times 2 =$ **Rs. 1·70.**

Machining Cost :

Volume of material removed

= Volume of bar stock—volume of finished component

$$= 106 - \left\{\frac{\pi}{4}(1\cdot5)^2 \times 4 + \frac{\pi}{4}(3)^2 \times 6\right\}$$

$$= 106 - \frac{\pi}{4}(9+54) = 56\cdot6 \text{ cu. cm.}$$

$\therefore$ Machining cost @ Re. 0·02 cu. cm. of material removed

$= 56\cdot6 \times 0\cdot02 =$ **Rs. 1·13**

Overhead charges = 50% of labour cost

$= 0\cdot5 \times 1\cdot13 =$ **Re. 0·57.**

$\therefore$ Manufacturing cost/piece

= Material cost + Machining cost + Overhead charges

$= 1\cdot70 + 1\cdot13 + 0\cdot57$

= **Rs. 3·40**

$\therefore$ Cost of 100 pieces $= 3\cdot40 \times 100$

= **Rs. 340. Ans.**

Example 33. Find the time taken to prepare a job according to dimensions shown in Fig. 6·19 from a rod of 30 mm. diameter. Include the time for facing and parting off. Assume :

(*i*) Cutting speed = 20 metres/minute

(*ii*) Feed for facing and parting off

= 0·15 mm/rev.

(*iii*) Feed for turning

= 0·35 mm/rev.

(*iv*) Feed for drilling

= 0·06 mm/rev.

Depth of cut not to exceed 1·5 mm.

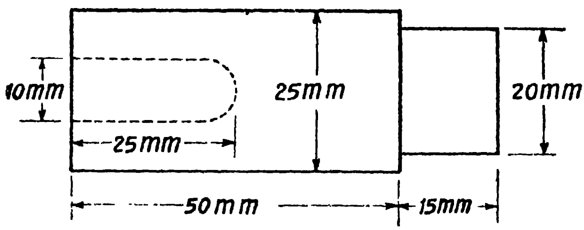


Fig. 6·19

Solution.

Step 1. *Turning.*

Reducing the diameter from 30 mm. to 25 mm. in two cuts, as the depth of cut is 1·5 mm. In first cut the diameter will be reduced to (30−2×1·5) = 27 mm. and in second cut the diameter will be reduced to (27−2×1) = 25 mm. This being the finishing cut, depth of cut can be taken as 1 mm.

$$N_1 = \frac{100\,S}{\pi D_1}$$

$$= \frac{100\times 20}{\pi\times\frac{30}{10}} = \frac{2000}{3\pi}\text{ r.p.m.}$$

$$T_1 = \frac{L}{\text{Feed}\times\text{r.p.m.}}$$

$$= \frac{50}{0{\cdot}35\times\frac{2000}{3\pi}} = 0{\cdot}673\text{ min.}$$

$$N_2 = \frac{100\,S}{\pi D_2}$$

$$= \frac{100\times 20}{\pi\times\frac{27}{10}} = \frac{2000}{2{\cdot}7\,\pi}$$

$$T_2 = \frac{L}{\text{Feed}\times\text{r.p.m.}}$$

$$= \frac{50\times 2{\cdot}7\,\pi}{0{\cdot}35\times 2000}$$

$$= 0{\cdot}6\text{ min.}$$

Step 2. *Facing.*

Facing of the face of 25 mm. dia.

$$T_3 = \frac{\text{Length to be faced}}{\text{Feed} \times \text{r.p m.}}$$

$$= \text{Length to be faced}$$

$$= \frac{25}{2} = 12{\cdot}5 \text{ mm.}$$

Feed for facing $= 0{\cdot}15$ mm./rev.

$$N_3 = \frac{100 \times S}{\pi \times D}$$

$$= \frac{100 \times 20}{\pi \times \frac{25}{10}} = \frac{2800}{11}$$

$$\therefore \quad T_3 = \frac{12{\cdot}5}{0{\cdot}15 \times \frac{2800}{11}} = 0{\cdot}327 \text{ min.}$$

Step 3. *Drilling.*

$$T_4 = \frac{\text{Length to be drilled}}{\text{Feed} \times \text{r p.m.}}$$

$$\text{r.p.m.} = \frac{100 \times 20}{\pi \times \text{dia. of drill}}$$

$$= \frac{100 \times 20}{\pi \times \frac{10}{10}}$$

$$= \frac{2000}{\pi}$$

$$\therefore \quad T_4 = \frac{25}{0{\cdot}06 \times \frac{2000}{\pi}} = 0{\cdot}717 \text{ min.}$$

Step 4. *Turning.*

To reduce the diameter, from 25 mm. to 20 mm. for a length of 15 mm. in 2 cuts.

$$T_5 = \frac{\text{Length of cut}}{\text{Feed} \times \text{r.p.m.}} \text{ reducing dia. to 22 mm.}$$

Here $\quad \text{r.p m.} = \dfrac{100 \times 20}{\pi \times \frac{25}{10}} = \dfrac{800}{\pi}$

$$\therefore \quad T_5 = \frac{15 \times \pi}{0{\cdot}35 \times 800} = 0{\cdot}18 \text{ min.}$$

$$T_6 = \frac{15 \times 1}{0{\cdot}35 \times \frac{100 \times 20}{\pi \times 22}}, \text{ reducing dia. to 20 mm}$$

$$= 0{\cdot}157 \text{ min.}$$

Step 5. *Parting off* from 20 mm. diameter

$$T_7 = \frac{\text{Length to be part}}{\text{Feed} \times \text{r.p.m.}}$$

$$= \frac{\frac{20}{2}}{0.15 \times \frac{100 \times 20}{\pi \times \frac{20}{10}}}$$

$$= 0.227 \text{ min}.$$

Hence total Machining Time

$$= T_1 + T_2 + \ldots\ldots + T_7$$

$$= 0.67 + 0.6 + 0.327 + 0.717$$

$$+ 0.18 + 0.157 + 0.227$$

$$= 2.878 \text{ minutes.} \quad \textbf{Ans.}$$

Example 34. A nickel-chrome-steel rod of 5 cm. diameter is to be reduced to 3·8 cm. diameter for 30 cm. length from one of its end. A fairly good finish is required on the machined surface. Calculate the time of machining the job on a centre lathe. Assume your own data regarding speeds, number of cuts, tool material and coolant. *(A.M.I.E., Sec. B May 1964)*.

Solution.

(i) Speed may be assumed as 30 m/minute being nickel chrome-steel

(ii) Tool material—Tungsten carbide tool

(iii) Coolant—High sulphur base mineral oil.

(iv) No. of cuts. As the dia. is to be reduced from 5 cm. to 3·8 cm., assuming depth of cut as 2 mm.

$$\text{No. of cuts} = \frac{(5-3.8)10}{2 \times 2} = \frac{12}{4} = 3$$

(v) Feed $= 0.3$ mm/rev.

$= 0.03$ cm./rev.

$$T = \frac{\text{Length of cut.}}{\text{feed} \times \text{r.p.m.}}$$

$$\therefore \quad T_1 \text{ for 1st cut} = \frac{30}{0.03 \times \frac{100 \times 30}{\pi \times 5}}$$

$$= 5.69 \text{ min.}$$

$$T_2 \text{ for 2nd cut} = \frac{30}{0.03 \times \frac{100 \times 30}{\pi \times 4.6}}$$

$$= 5.23 \text{ min.}$$

$$T_3 \text{ for 3rd cut} = \frac{30}{0.03 \times \frac{100 \times 30}{\pi \times 4.2}}$$

$$= 4.78 \text{ min.}$$

$$\therefore \quad T = T_1 + T_2 + T_3$$

$$= \mathbf{15.70 \text{ minutes.}} \quad \textbf{Ans.}$$

MILLING OPERATIONS

In estimating the time for milling operations it is essential to take into account.

(*i*) The time taken to mill the surface. This depends on the length of the job or the work piece.

(*ii*) The approach length. This is the distance by which cutter has to be engaged before the full depth of cut is reached. Figs. 6·20 and 6·21 show approach length.

(*ii*) The over-run. This is the distance considered so that the cutter may clear the job or work piece. Fig. 6·20 and 6·21 show over-run.

(*iv*) The total number of cuts to complete the operations.

(*v*) The sum of approach length and over-run is called Added Table Travel.

Operations performed on the milling machines are mainly cutting and facing. The time taken for performing these operations can be obtained by using the same formula, *i.e.*

$$\text{Time required/cut} = \frac{\text{Length of cut}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

where, length of cut = Length of job + Added table travel

Feed/rev. = Feed/tooth × No. of teeths on cutter

$$\text{R.P.M.} = \frac{100S}{\pi D}$$

where D = Dia. of the cutter.

$$\text{Total time} = \frac{\text{Length of cut}}{\text{Feed/Min.}} \times \text{No. of cuts or Index}$$

(*a*) **Cutting Operation :**

Adjacent Fig. 6·20 shows how the cutter is adjusted to cut a depth d of the job and also shows the approach length and over-travel or over-run.

$$\text{Approach length } AB = \sqrt{OA^2 - OB^2}$$

$$= \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - d\right)^2}$$

$$= \sqrt{Dd - d^2} \qquad ...(i)$$

In these operations over-travel is generally taken as 5 mm.

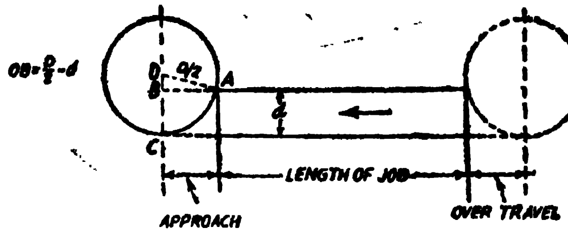


Fig. 6·20

(*b*) **Facing Operation** :

(*i*) If the cutter dia. *D* is less than the width of the job '*w*' then several cuts are required to face the width *w*. Fig. 6·21 shows the first and last position of the facing cutter.

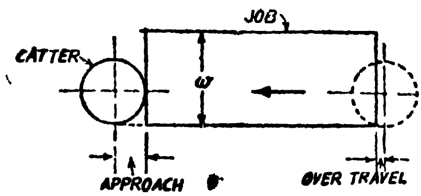


Fig. 6·21

In this case approach is generally taken as 0·5 *D* and over-travel as 7 mm.

(*ii*) If the cutter dia. *D* is bigger than the width of the job *w*, facing is done only in one cut.

Fig. 6·22 shows how the facing is done when the cutter dia. is greater than the width of the job. In this case over-travel is

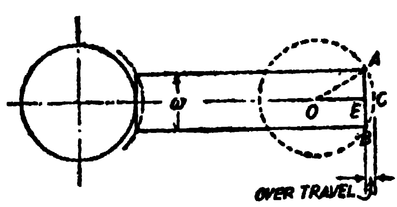


Fig. 6·22

$$EC = OC - OE$$

$$= \frac{D}{2} - \sqrt{OA^2 - AE^2}$$

$$= \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2}\right)^2}$$

$$\text{Over-travel} = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right)$$

Example 35. Estimate the time required to prepare a square prism on a milling machine from a round block 90 mm. length, 40 mm. in diameter, feed 25 mm./minute and set up and indexing time is 15 minutes.

Solution.

Here, length of cut = 90 mm.

Feed = 25 mm/min.

Let added table travel

= 10 mm.

$$\therefore \quad T_1 = \frac{90+10}{25} \times 4,$$

where 4 is the sides of square prism *i.e.* No. of Indexing

$$\therefore \quad T_1 = 16 \text{ minute}$$

Here set up and indexing time,

$$T_2 = 15 \text{ min.}$$

$\therefore$ Total time of milling, T

$$= T_1 + T_2$$
$$= 16 + 15$$
$$= 31 \text{ minute.}$$ **Ans.**

Example 36. Estimate the milling time to cut 60 teeth on a Gear blank 60 mm thick, feed 35 mm/minute and take overall set up time as 10 minutes.

Solution.

$$T = \frac{\text{Length of cut}}{\text{Feed/minute}} \times \text{No. of Index} + \text{set up time.}$$

Here, Set up time = 10 minutes

Length of cut = 60 mm.

Let table travel = 10 mm.

No. of Index = No. of teeth

= 60.

Feed/minute = 35 mm.

$$\therefore \quad T = \frac{60+10}{35} \times 60 + 10$$

$$= 130 \text{ minutes.}$$ **Ans.**

Example 37. A slot is to be made on a milling machine with the help of a cutter, revolving at 120 r.p.m. Find the time required to prepare the slot in two cuts, if it is 2 cm. deep and 10 cm. long with a cutter of 8 cm. dia. Assume the feed as 0·5 cm./rev.

Solution.

$$\text{Time taken/cut} = \frac{\text{Total table travel}}{\text{Feed/rev.} \times \text{r.p.m.}}$$

where,

Total table travel = Length of job + Added table travel

but added table travel = Approach + Over-travel

$= \sqrt{Dd-d^2}+0{\cdot}5$

where d = 1 cm. for one cut

$= \sqrt{8\times1-1}+0{\cdot}5$

= **3·14 cm.**

∴ Total table travel = 10 + 3·14

= **13·14 cm.**

∴ Time taken/cut $= \dfrac{13{\cdot}14}{0{\cdot}05\times120} = 2{\cdot}19$ min.

∴ Total time taken in two cuts

= 2·19 × 2 = **4·38 min. Ans.**

Example 38. A 20 × 5 cm. C.I. surface is to be faced on a milling machine with a cutter having a dia. of 10 cm. and 16 teeths. If the cutting speed and feed are 50 m/min. and 5 cm./min. respectively, determine the milling time, r.p.m. of the cutter and feed per tooth.

Solution. As the dia. of the cutter is larger than the width of the surface, hence only one pass is sufficient.

Added table travel $= \dfrac{1}{2}\left(D-\sqrt{D^2-w^2}\right)$

$= \dfrac{1}{2}\left(10-\sqrt{10^2-5^2}\right)$

= **0·675 cm.**

∴ Total table travel

= 20 + 0·675 = 20·675 cm.

As time taken $= \dfrac{\text{Total table travel}}{\text{Feed/rev.}\times\text{r.p.m.}}$ min.

$= \dfrac{\text{Total table travel}}{\text{Feed/min.}}$

∴ Milling time $= \dfrac{20{\cdot}675}{5}$

= **4·135 min. Ans.**

As r.p.m. $= \dfrac{100S}{\pi D}$

$= \dfrac{100\times50}{\pi\times10} =$ **159. Ans.**

As Feed/min. = 5 cm.

∴ Feed/rev. $= \dfrac{\text{Feed/min.}}{\text{r.p.m.}} = \dfrac{5}{159}$.

But $\text{Feed/tooth} = \dfrac{\text{Feed/rev.}}{\text{No. of teeth}} = \dfrac{5}{159 \times 16}$

$= 0{\cdot}002$ cm./tooth. **Ans.**

GRINDING OPERATIONS

It is a process of metal removal by abrasion. Following are the important methods of grinding :

(*a*) Surface Grinding.

(*b*) Cylindrical Grinding.

(*a*) **Surface Grinding.** This process is useful for removing small amount of material from flat surfaces. The time required for surface grinding is calculated by using the formula used in milling. When grinding is done as shown in Fig. 6·23 (*a*), time is calculated as for cutting operations on milling machine ; and when grinding is done as shown in Fig. 6·23 (*b*), time is calculated as for facing operations on milling machine.

Fig. 6·23

(*b*) **Cylindrical Grinding.** As the name suggests, the process is used for grinding the internal and external surfaces of the cylindrical jobs which have previously been turned on the lathe, to get accurate size and smooth finish.

Time required for cylindrical grinding/cut

$$= \frac{\text{Length of cut}}{\text{Feed/rev.} \times \text{r p.m.}}$$

where Length of cut = Length of job + Over-travel

$= L + 0{\cdot}5$ cm.

and Feed/rev. $= \dfrac{w}{2}$ (for rough cut)

$= \dfrac{w}{4}$ (for finishing cut)

where w = width of grinding wheel.

Example 38. Find the time required for doing rough grinding of a 15 cm. long steel shaft to reduce its dia. from 4 cm. to 3·8 cm., with the grinding wheel of 2 cm. face width. Assume cutting speed as 15 m/min. and depth of cut as 0·25 mm.

Solution. Total stock to be removed

$$\frac{4-3{\cdot}8}{2} = 0{\cdot}1 \text{ cm.}$$

But, Depth of one cut is 0·25 mm.

∴ No. of cuts required

$$\frac{0{\cdot}1\times 10}{0{\cdot}25} \quad 4 \text{ cuts}$$

As $\qquad \text{Time/cut} = \frac{\text{Length of cut}}{\text{Feed/rev.} \times \text{r.p.m.}}$

where

Length of cut = 15+0·5 = 15·5 cm. (assuming 0·5 cm. over-travel)

$$\text{Feed/rev.} = \frac{W}{2} \text{ (for roughing)}$$

$$= \frac{2}{2} = 1 \text{ cm.}$$

and $\qquad \text{r.p.m.} = \frac{100S}{\pi D} = \frac{100\times 15}{\pi\times 4} = \mathbf{120.}$

∴ Time required/cut $\quad \frac{15{\cdot}5}{1\times 120} \quad 0{\cdot}13$ min.

∴ Total time required for 4 cuts

$$= 0{\cdot}13\times 4 = 0{\cdot}52 \textbf{ min.} \quad \textbf{Ans.}$$

Example 40. Top of a C.I. table of size 30 cm. × 80 cm. is to be grounded by a wheel having 2 cm. face width. If the feed is ¼th of the width of the wheel and table moves 8 m. in one minute find out the time required for grinding in two cuts.

Solution. Time required/stroke

$$= \frac{\text{Length of table}}{\text{Speed of table}}$$

$$\frac{80}{8\times 100} = \frac{1}{10} \text{ min.}$$

As $\qquad \text{Feed} = \text{Width of wheel}$

$$\frac{2}{4} = 0{\cdot}5 \text{ cm.}$$

∴ No. of strokes $\quad \frac{\text{Width of table}}{\text{Feed}}$

$$\frac{30}{0{\cdot}5} = 60$$

As, Time required/cut

$$= \text{Time/Stroke} \times \text{No. of strokes}$$

$$= \frac{1}{10} \times 60 = 6 \text{ min.}$$

∴ Time required for 2 cuts

$$= 12 \text{ min.} \quad \textbf{Ans.}$$

SHAPING AND PLANING

These operations are carried out on reciprocating machines. On these machines cutting is done in one stroke and the second is the idle stroke which is also known as return stroke.

To reduce, the total time, the time required for idle stroke is reduced by increasing the speed of idle stroke.

Shaping operation. If a shaper has a length of stroke as S cm. and it has N cutting strokes per min., then its effective speed,

$$E = \frac{S}{100} \times N \text{ m/min.}$$

For example, a shaper makes 30 cutting strokes per minute each 20 cm. long. Then effective speed (E) will be

$$= \frac{20}{100} \times 30 = 6 \text{ m/min.}$$

Speed of the ram during cutting stroke is known as cutting speed, this speed is maximum at the middle of the stroke and minimum at the beginning and at the end of the stroke. Therefore, for calculation purposes an average cutting speed C is considered.

Mostly cutting time is $\frac{3}{5}$th of the total time. Therefore, the effective speed is $\frac{3}{5}$th of the cutting speed C.

Hence, $$E = \frac{3}{5} C$$

but, $$E = \frac{NS}{100}$$

∴ $$\frac{NS}{100} = \frac{3}{5} C$$

∴ $$N = \frac{100}{S} \times \frac{3}{5} C = \frac{60\,C}{S} \text{ strokes/min.}$$

In the above formulae, S is generally taken as $(L+5)$ cm., where L is the length of the job.

If F is the feed/stroke in cm. then, area swept by the tool/stroke

$$= F \times (L+5)$$

∴ Area swept/min. $$= F \times (L+5) \times N$$

$$= F \times (L+5) \times \frac{60C}{S}$$

$$F \times (L+5) \times \frac{60C}{(L+5)}$$

$$60\,CF \qquad \text{...(2)}$$

If the width of the job is B cm. then the width for calculations is taken as $(B+2{\cdot}5)$ cm.

Therefore, time required for shaping $= \dfrac{\text{Total area to be swept}}{\text{Area swept/min.}}$

$$\therefore \qquad T = \frac{(L+5)(B+2{\cdot}5)}{60\,CF} \text{ min.}$$

Planing operations. The effective speed of the planing machine is generally ¾th of the cutting speed. For time calculation, stroke length is taken as $(L+25)$ cm., while width is taken as $(B+5)$ cm.

Similar to that in shaping,

Time required in planing $\dfrac{(L+25)(B+5)}{K}$ min.

where, K is the area swept/min.

As in case of planing operations, $E = \dfrac{3}{4}C$

$$\frac{N \times S}{100} = \frac{3}{4}C$$

$$\therefore \qquad N = \frac{75\,C}{S} \qquad \ldots(1)$$

$$\therefore \quad \text{Area swept/min.} = N \times F \times S$$

$$\text{or} \qquad K = \frac{75C}{S} \times F \times S$$

$$\text{or} \qquad K = 75C\,F \qquad \ldots(2)$$

$$\text{Time taken} = \frac{(L+25)(B+5)}{75CF} \text{ min.}$$

Example 41. A.C.I. rectangular block of 10 cm. × 3 cm. is required to be shaped to reduce the thickness from 1·5 cm. to 1·3 cm. in one cut. Determine the time required for shaping, if cutting speed is 20 m/min and feed is 0·2 mm/stroke and the cutting time ratio is ⅗.

Solution. $S = L+5 = 10+5 =$ **15 cm.**

Width $= (B+2{\cdot}5) = 3+2{\cdot}5 =$ **5·5 cm.**

$$\because \qquad \frac{NS}{100} \quad \frac{3}{5}C$$

$$\therefore \qquad N = \frac{100}{S} \times \frac{3}{5}C \quad 60\,\frac{C}{S}$$

$$= 60 \times \frac{20}{15} = \textbf{80 r.p.m.}$$

Swept area/min. $= N \times F \times S$

$$= 80 \times \frac{0{\cdot}2}{10} \times 15$$

$$= \textbf{24 cm}^2\textbf{/min.}$$

As time required for shaping $= \frac{\text{Total area swept}}{\text{Area swept/min.}}$

$$\therefore \quad T = \frac{15 \times 5.5}{24}$$

$$= 3.44 \text{ min. } \textbf{Ans.}$$

Example 42. Find out the time required for shaping a block of 30 cm. × 15 cm. size in two cuts. Assume feed as 0·6 mm/stroke and cutting speed as 15 m/min.

Solution. As we know that,

$$\text{Time required/cut} = \frac{(L+5)(B+2.5)}{60\,CF}$$

here, $L = 30$ cm.

$B = 15$ cm.

$C = 15$ m/min.

and $F = 0.06$ cm./stroke

$$\therefore \quad T = \frac{(30+5)\times(15+2.5)}{60\times 15\times 0.06}$$

$$= \frac{35\times 17.5}{3.6\times 15} = 11.3 \text{ min./cut}$$

∴ Time required for 2 cut = **22·6 min. Ans.**

Example 43. A machine bed is to be planed in two cuts on a planing machine. If it takes 10 seconds in forward stroke and 4 seconds in return stroke, find out the time required to plane the bed of width 60 cm. Assume the feed as 2 mm./stroke.

Solution. Width to be moved by the tool

= Width of job + Tool clearance

= 60+5 = 65 cm.

$$\text{No. of forward strokes} = \frac{(B+5)}{\text{Feed/stroke}} = \frac{65}{0.2} = 325 \text{ strokes.}$$

As total time required for one complete stroke

= 10+4 = 14 sec.

$$\therefore \quad \text{Total time required/cut} = 325 \times \frac{14}{60} = 75.86 \text{ min.}$$

∴ Time required for 2 cuts = 2×75·86

= **151·72 min.**

= **2 hr. and 32 min.** (nearly) **Ans.**

Expmple 44. Estimate the machining time for finishing a surface of 1 m×20 cm. size on a planing machine. If the cutting speed is 10 m/min. and feed is 10 mm./stroke.

Solution. As we know that,

$$T = \frac{(L+25)(B+5)}{75\,CF}$$

where

$$L = 100 \text{ cm.}$$
$$B = 20 \text{ cm.}$$
$$C = 10 \text{ m/min.}$$
$$F = 0{\cdot}1 \text{ cm./stroke}$$

$$\therefore \quad T = \frac{(100+25)(20+5)}{75 \times 10 \times 0{\cdot}10}$$

$$= \frac{125 \times 25}{75} = 41{\cdot}66 \text{ min. Ans.}$$

UNSOLVED PROBLEMS

1. Calculate the machining time of a nickel steel gudgeon pin, if stroke dia. is 2 cm, pin. dia. is 1·8 cm. and length 6 cm. Assume cutting speed 300 r.p m. and feed as 0·20 mm/rev.

[**Ans.** 60 sec.]

2. Calculate the time required to bore a bronze bush whose internal dia. is 50 mm. and length 65 mm. The speed of machine is 176 r.p.m. and assume feed as 0·3 mm./rev. [**Ans.** 1 23 min.]

3. A 25 cm. dia. bar is revolving at 65 r.p.m. How much time it will take to machine a 45° by 3 125 mm. chamfer as shown in Fig. 6·24 if feed is 0·3 mm. [**Ans.** 0·162 min.]

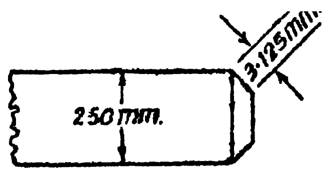
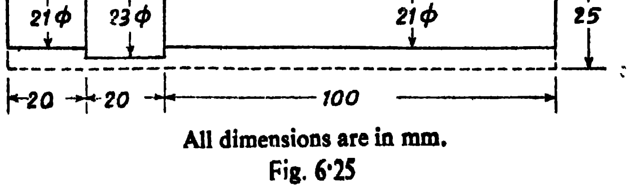


Fig. 6·24

4. Calculate the machining time of a centrifugal Pump shaft shown in Fig. 6·25. The bar shock dia. is 25 mm. and finished dimensions are shown in sketch and all are in mm.

Assume cutting speed as 350 r.p.m. for a depth of cut 2·0 mm. and feed/rev. as 0·20 mm. [**Ans.** 6·71 min.]



All dimensions are in mm.

Fig. 6·25

5. A mild speed bar is turned on a lathe, the cut being taken 0·6 cm. deep and feed/rev. as 0·15 cm. Assume cutting speed 2·5m./min., find the time required to reduce the bar from 25 cm. to 20 cm. dia. Length is taken as 40 cm. [**Ans.** 38·3 min.]

6. It is required to turn a steel rod 30 cm. long from 10 cm. to 8 cm. dia. on a lathe. Take cutting speed as 30 m./min. feed 2 mm./rev. find the time and number of cuts required.

[Ans. 5·8 min., 4 cuts]

7. Calculate the total time taken to turn a 15 cm. long, 2·5 cm. dia. mild steel rod to a dia. of 2·3 cm. in a single cut. Take cutting speed as 30 m/min., feed 0·1 mm/rev. and the mounting time in a self-centring 3-jaw chuck as 45 sec.

Neglect time taken for setting up tools etc. [Ans. 4·68 min.]

8. As a machine-shop estimator, you are required to estimate the time taken in machining a job on a particular machine. Describe the various components of time which should be considered.

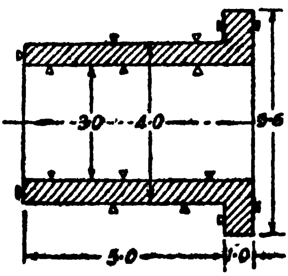
9. The comparative tooling up time and turning time for a component when made on an ordinary lathe and automatic lathe respectively are as follows :

Machine	*Turning Time*	*Tooling up time*
Automatic Lathe	100 sec.	4 min.
Ordinary Lathe	25 sec.	20 min.

Determine the minimum number of pieces of components for which automatic machine will be more economical instead of ordinary machine. [Ans. 13]

10. Estimate the machining time to face the end of a work piece of 30 mm. steel rod, if the cutting speed is 30 m/min. and cross feed as 0·2 mm./rev. [Ans. 0·236 min.]

11. A brass bush is to be prepared on a lathe from a 6 cm. dia stock and 60 cm. length. The finished dimensions are shown in Fig. 6·26. Determine machining time per bush, if cutting speed is 15 m /min. and feed as 0·2 mm./rev. Assume setting time as 7·48 min./piece. [Ans. 37 min.



All dimensions in cm.

Fig. 6·26

12. A casting is to be threaded with a single point tool on a lathe The threaded dia. is 15 cm. and length of thread 1·875 cm. There are two threads/cm. length. Assume spindle speed 15 r.p.m. and number of cuts 4 to complete threading, estimate the total time.

[Ans. 60 sec.]

13. Estimate the threading time on a lathe to cut square thread with the following assumptions :

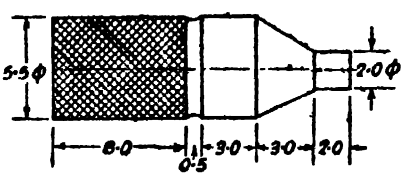
Length of thread = 15 cm., Dia. of thread = 4·375 cm.
No. of thread = 4/cm., Depth of thread = 0·164 cm.
Cutting speed = 25 m./min., Depth of cut = 0·125mm/pass.

[Ans. 4·34 min.]

14. Estimate the time required to rough bore to second bore and to finish bore a C.I. cylinder of 20 cm. dia. and 25 cm. length. Assuming the following data :

(a) Rough bore, 40 r.p.m., 0·3 cm. feed
(b) Second bore, 50 r.p.m. 0·1 cm. feed
(c) Finish bore, 25 r.p.m., 0·6 cm. feed. [Ans. 8·74 min.]

15. A 6 cm. rod of aluminium is be machined on a lathe, the finished size is shown in Fig. 6·27. The length of rod is 17·5 cm. Determine the total machining time and material cost, if material is purchased at the rate of Rs. 12 per kg. Assuming cutting speed 30 m./min. and feed 0·2 mm./rev.



All dimensions in cm.

Fig. 6·27

16. Estimate the manufacturing cost of the component shown in Fig. 6·28. Assume 15% of the material is lost in machining, machining cost 2 paise per sq. cm. and the cost of material as Rs. 1·50 per kg. Density of mild steel 8 gm/c.c.

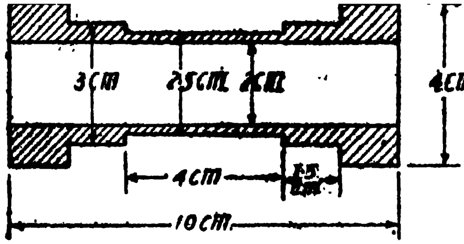


Fig. 6·28

17. Estimate the time for tapping a hole with 2·54 cm. dia. tap to a length of 2·54 cm. in mild steel plate, if for return stroke speed is 1·5 times the cutting stroke speed, which is 8 m./min.

[Ans. 12 sec.]

18. A Drilling machine spindle is revolving at 375 r.p.m. and is used to drill 20 mm. dia. hole in a metal plate. Calculate the cutting speed.

Also find out the depth drilled per minute, if speed is 0·3125 min./rev. [Ans. 23·8 m./min. 11·2 cm.]

19. Calculate the time required to drill two holes 1 cm. dia. and 3 holes of 1·5 cm. dia. through 2 cm. thick steel plate. Take cutting speed as 20 m./min. and feed as 1·2 mm./rev. for 1 cm. dia. drill and 1·3 mm./rev. for 1·5 cm. dia. drill. [Ans. 13 sec.]

20. (a) Estimate the time in drilling a 10 mm. hole on 50 mm. thick steel plate, if cutting speed is 17 m./min. and feed 0·30 mm./rev.

(b) If the above hole is enlarged to 20 mm dia. Calculate the drilling time, if the cutting speed is taken as 25 m. per min., and feed 0·35 mm./rev. [Ans. 22·2 sec., 26 sec.]

21. Calculate the cutting speed in m./min. in tapping a hole to suit 2·5 cm. dia. bolt, if it takes one minute to tap the hole through a length of 5 cm. Assume return speed is twice the cutting speed. [Ans. 2·215 m./min.]

22. A 3 cm. deep slab is to be formed with a milling cutter 8 cm. dia. Calculate the total table travel to complete the cut, if length of slot is 20 cm. [Ans. 24·373 cm.]

23. A milling cutter of 20 cm. dia. and having 18 teeth is given a feed of 0·1 mm./tooth. Calculate the feed/rev. and feed/min., assuming the cutter speed to be 80 m./min.

(*B.T.E., Rajasthan Nov. 1969*)
[Ans. 0·18 cm.; 22·9 cm.]

24. A milling cutter having 45 cm. dia. and 48 teeth is used to face steel casting of 1·5 m. length. Estimate the facing time, if the cutter is running at a speed of 64 r.p.m. with a feed of 0·025 cm./tooth. Assume one cut is sufficient. [Ans. 1·96 min.]

25. Calculate the time required to rough grind a 20 cm. long shaft of bronze from 5 cm., dia. to 4·8 cm. dia. using a grinding wheel of 5·5 cm. width. Assume cutting speed 22 m./min. and depth of cut as 0·25 mm. [Ans. 12·2 sec.]

26. Estimate the grinding time to finish a shaft from 38·5 mm. to 38 mm. dia. Length of shaft as 300 mm. Assume the following data :

Width of Grinding wheel	= 5
Depth of cut in roughing operation	= 0·0785 mm.
Depth of cut in finishing operation	= 0·05 mm.
Feed for roughing operation	= 3·25 cm.
Feed for finishing operation	= 3·25 cm.
Cutting speed	= 12 m./min.

Assume 0·1 mm. on dia. to be finish ground and remaining rough ground. [Ans. 20 sec.]

27. It is required to plane a job on a shaping machine. Length of job 40 cm. and width 15 cm. Find out the time required for shaping the size 40 cm. × 15 cm. Take cutting speed as 10 m./min. and feed 1 mm. [Ans. 13·125 min.]

28. A planer performs 30 strokes/min. and each stroke is 120 cm. long. If the return ratio is 4 : 1 what is the average cutting speed ?

If the forward cutting stroke of a planer is 15 m./min. and the return stroke is 4 times as fast. What should be the average cuttin speed ? [Ans. 48 m./min. ; 20 m./min.]

29. On a planing machine, the time taken on cutting stroke for job 3 m. long is 15 sec. and the time taken on the return stroke is 5 sec. Calculate the time it will take to plane a surface 3 m. long and 1 5 m. wide, if feed is 6 mm./cutting stroke. [Ans. 83·3]

30. Calculate the planing time required for a C.I. plate 12·5 cm. long and 50 cm. wide, assuming the following data :

Cutting speed	= 12 m./min.
Return speed	= 30 m./min.
Total No. of cuts	= 2

First roughing cut is with a depth of 3·125 mm. and feed 0·1 mm./rev.

Second finishing cut is with a depth of 0·125 mm. and feed 0·025 mm. [Ans. 15 min.]

7

ESTIMATION IN SHEET METAL SHOP

Introduction. Fabrication of components from sheets and plates is done in Sheet Metal Shop. For working in sheet metal shop, an engineer must have a good knowledge regarding plane geometry and mensuration ; development of surfaces etc.

Sheet metal process is generally used for preparing bodies of buses, cars, aeroplanes, boilers, shells, chimneys, pipes, boxes, toys and Furniture making etc.

For preparing a product, first development of the product is marked on the sheet and then sheet is cut along those marked lines.

When large number of products of same size are manufactured than a template is made and is used for marking on the sheet.

OPERATIONS IN SHEET METAL SHOP

Following are the important operations and processes carried out in Sheet Metal Shop.

(*i*) **Breaking out.** In this processes, folds or ribbs in sheets, if any, are removed either with the help of beating the sheets by mallet or by passing the sheet through rollers.

(*ii*) **Bending.** Bending is carried out for making cylindrical shapes from sheets. The length of sheet required for bending can be calculated as follows :

$$\text{Length for bending} = 2\pi r \times \frac{\theta^\circ}{360^\circ}$$

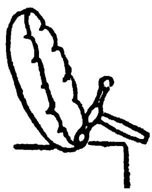
where, r = radius of bend

θ° = angle subtended by bend through centre.

(*iii*) **Turning up.** This process is done for making sharp bends to sheets for seeming, hemming etc.

(*iv*) **Hollowing.** It is the process of beating the metal for giving it concave shape. This process is done over a hollow staket. Fig. 7·1.

Allowance for hollowing = $\frac{1}{2}$ $(\text{Base})^2+(\text{Height})^2$



HOLLOWING

Fig. 7·1

(*v*) **Raising.** It is the process of beating the metal over a spherical head. This process gives a convex shape to the sheet metal. This process should be done on the sheets, having more than 20 gauge.

Allowance for raising = $\frac{1}{2}$ $(\text{Base})^2+(\text{Height})^2$.

(*vi*) **Planishing.** This is the process, which gives the final finish to the hollow or raised surfaces by removing miner bends. This is carried out by beating the sheet with the help of planishing hammer. Planishing hammer is a short hammer and has high polish.

(*vii*) **Edge stiffening.** For edge stiffening following are the important ways :

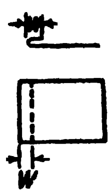
(*a*) **Wiring.** In this process, a wire is inserted at the edge of sheet metal articles. This wire adds in the stiffness of edges. Generally, wires used for the Black. Tin plated and G.I. sheets are of mild steel, copper and G.I. respectively.

Allowance for wiring $=2{\cdot}5\times$ dia. of wire $+4\times$ thickness of sheet.

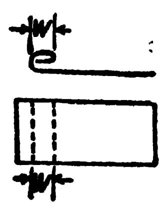
(*b*) **False Wiring.** This process is done as that in Wiring process but in the end wire is taken out so its appearance is just like that as it has been wired and therefore known as False Wiring. In this process strength will be weaker as compared to wiring process.

Allowance $= 2{\cdot}5\times$ dia. of wire $+4\times$ thickness of sheet.

(*c*) **Hemming.** In this process, edges of sheet is folded when folding is done once as shown in Fig. 7·2, it is called single hemming.



SINGLE HEMMING
Fig. 7·2



Double Hemming.
Fig. 7·3

The allowance for it is 4—5 times the sheet thickness. When folding is done twice at the edges to give larger strength, as shown in Fig. 7·3, it is known as double hemming. Allowance for it is 10 times the sheet thickness.

(*d*) **Flanging.** In this process, edge of the sheet is folded, at an angle of 90°, to give the shape of flange, as shown in Fig. 7 4.

SHEET METAL JOINTS

Sheet metal joints are known as seam joints. Various joints in sheet metal are :

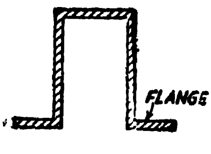


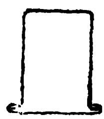
Fig. 7·4

(*i*) **Lap Joint.** It is the simplest type of joints. In this, one edge overlaps the other and than these are either welded, rivetted or soldered.

(*ii*) **Single Seam Joint.** This joint is used to join a bottom to a vertical body as shown in Fig. 7·5. For it, allowance is taken as 5 times sheet thickness.

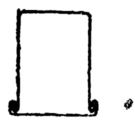
(*iii*) **Double Seam Joint.** It is similar to single seam joint. The only difference is that the formed edge at bottom is bent upwards against the body to give more strength as shown in Fig. 7·6.

Allowance is generally taken as 8 × sheet thickness.



SINGLE SEAM

Fig. 7·5



DOUBLE SEAM

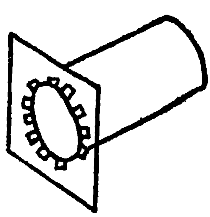
Fig. 7·6

(*iv*) **Grooved joint.** In this folded joints are locked together as shown in Fig. 7·7. This is used where, tension on the sheet is much.

Allowance = 10 × sheet thickness.

GROOVED JOINT

Fig. 7·7



DOVETAIL JOINT

Fig. 7·8

(*v*) **Single Plate Butt Joint.** In this a cover plate of width nearly 10 times the sheet thickness is jointed.

(*vi*) **Dovetail Joint.** In this type of joint, a portion of sheet of length 12 to 20 times, the thickness of the sheet and width 4-5 times the thickness of the sheet is cut to form dovetails as shown in Fig. 7·8.

It is used to join flat plates with cylindrical shapes.

(*vii*) **Rivetted Joint.** The readers very well be knowing about the rivetted joints. Therefore, here some of the important formulae required in estimation are only given.

(*a*) Diameter of rivet, $D = 1\,92\sqrt{t}$ mm., where t is thickness of sheet in mm.

(*b*) Minimum distance between first rivet centre and sheet edge

$$= 1{\cdot}5\,D$$

(*c*) Pitch (p) $= 3D$. (The distance between centres of adjoining rivets in the same row.

The following table gives an approximated value of D for different values of t.

t in mm.	25	22	20	18	16	14	12	11	10	9	8
D in mm.	27	25	24	24	22	22	20	20	20	18	18

Blank Lay-Outs

For preparing an article lay-out is required to done on the sheet metal as first step. For this purpose an outline of the object is either scratched on the sheet of metal directly or first drawn on a paper and later transferred to the sheet. Sheet is cut in accordance of lay-out and then different other operations like, forming, assenmbly etc. are performed on it to give the required shape of the article. At the time of lay-out allowances must be kept for different operations like, raising, wiring, jointing, hemming etc.

When articles to be produced are in lot, then strips are cut from long rolls of sheet. Width of each strip should be slightly more then the blank, so that

(*i*) material can be handled easily and safely by the operators, specially when working on the machines ;

(*ii*) clean blanks can be cut. The amount by which the strips must be wider than the blank depends on ;

(*i*) process to be performed ;

(*ii*) how they are to be handled, *i e.* manually or by machine ;

(*iii*) thickness of the sheet ;

(*iv*) accuracy desired. Generally the strip is kept 0·3 cm. to 0·5 cm. wider than the blank, and the distance between two consecutive blanks (known as bridge) is kept as 0·15 cm.

Estimation of Time

Before proceeding to actual operation, strip is to be picked up, entered in the dies and process is started, these preparation items generally require 15 sec for small strips to 30 sec. for heavy strips. This preparation time of 15 sec. to 30 sec. is equally divided among the blanks in each strip.

Actual operations are generally performed on presses, either having automatic feeding arrangement or manual feeding. In automatic feeding all the strokes of the ram are utilised for blanking while in hand feeding nearly 40% of the strokes are generally missed.

After blanking operation is over 10 to 15 sec. per strip are required for collecting the blanks and disposing the bridges. 10 to 15% of the total time, calculated as above, is generally added, for fatigue and personal needs etc., to get estimated time.

Estimation for inserting, piercing and ejecting etc.

After the blanks are prepared, each of the blank is to be inserted in the press to get the desired shape. For inserting (also known as loading) a blank estimated time, which is generally taken, is—

2 sec. to 5 sec. for small components.

6 sec. to 8 sec. for medium components

(of size say between 25 cm × 25 cm to 50 cm × 50 cm.)

8 sec. to 10 sec. for large size components.

To pierce a hole in a component generally 2 sec. are taken. Ejection or removal of the component after operation is over generally takes 10 sec. if it is done manually and takes 2 sec. if it is done on automatic machine.

Capacity for Power Presses

For capacity calculated purposes power presses can be divided into two categories,

(*i*) the shaft of which is driven (by gearing or by beld) for one end ;

(*ii*) the shaft of which is driven from both the ends. For calculation of capacity of these presses following emperical relations are generally used :

(*i*) When shaft is driven from one end—

Maximum pressure available, in tonnes $= 0{\cdot}5\ D^2$

where, D is the crank pin dia in cm.

(*ii*) When shaft is driven from both ends—

Maximum pressure available, in tonnes $= 0{\cdot}75\ D^2$

As,

Shearing force required

$= \text{Area to be sheared} \times \text{Shearing stress.}$

Hence, while procuring power press its crank pin dia. must be decided and which can be calculated by knowing the maximum shearing force required and using the above relations and putting the proper shearing stress of the material required to be used. Shearing stresses for the some of the metals are given hereunder :

Aluminium = 0·72 tonnes/cm² ;
Mild Steel = 3·1 tonnes/cm² ;
Alloy steel = 5·7 tonnes/cm² ;
Tin = 0·3 tonnes/cm².

Solved Problems

Example 1. We are required to make B.P. sheet containers with open top of size 0·25 m² are height 0·5 m. The size of B. P. sheet available is 2·3 m × 1 m. Find out how many maximum containers can be made out of it.

Solution. Size of sheet available

= 2·3 m.×1 m.

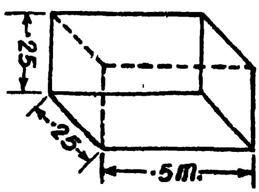


Fig. 7·9

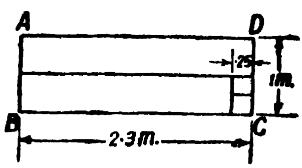


Fig. 7·10

Let the sheet available is *ABCD*. To get 0·5 m. height of one side for container, we cut the sheet into two equal parts of width 0·5 m. each.

∴ Two containers, vertical sides require 2 m. length and rest 0·3 m.×0·5 m. will be used to prepare base for these two containers leaving some scrap.

Therefore, containers prepared from 2·3 m.×1 m. will be 2×2 = 4. **Ans.**

Example 2. A container open on one side of size 0·5×0·5 ×1 m. height is to be made from plates of 6 mm. thickness. Take density of plate metal 8 gm./c.c. and joints are to be welded.

Estimate the cost of containers from the following data :

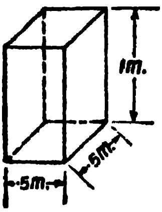
Cost of plate Re. 1·00/kg.
Sheet metal scrap = 5% of material.
Cost of labour = 10% of material cost.
Cost of welding material = Rs. 2 per m. of weld.

Solution

Material Cost. Sheet required

$= 4 \times 1 \times 0{\cdot}5 + 0{\cdot}5 \times 0{\cdot}5 = 2{\cdot}25 \text{ m}^2$

Scrap is 5% of material



$= 2{\cdot}25 \times \frac{5}{100}$

$= 0{\cdot}1125 \text{ m.}^2$

$\therefore$ Actual sheet needed for container

$= 2{\cdot}25 + 0{\cdot}1125$

Fig. 7·11

$= 2{\cdot}36 \text{ m.}^2$, nearly

$\therefore$ Volume of sheet $= 2{\cdot}36 \times$ Thickness of sheet

$= 2{\cdot}36 \times 0{\cdot}006 \text{ m.}^3$

$\therefore$ Wt. of sheet $= 2{\cdot}36 \times 0{\cdot}006 \times 8 \times \frac{10^6}{10^3}$ kg.

$= 113$ kg.

Hence, cost of sheet @ Re. 1 per kg.

$= 113 \times 1 =$ Rs. 113·00.

Welding Material Cost. This cost is Rs. 2 per metre of weld.

Therefore cost $= 2 \times$ Length of weld

$= 2(1 \times 4 + 0{\cdot}5 \times 4) =$ Rs. 12·00.

$\therefore$ Total material cost = Sheet cost + Welding material cost

= Rs. 133 + Rs. 12 = Rs. 125·00.

Labour Cost. It is 10% of material cost.

$\therefore$ Labour cost $= 125 \times 0{\cdot}1$

= Rs. 12·50

$\therefore$ Total cost of container = Total material cost + Labour cost.

= Rs. 125 + Rs. 12·5

= **Rs. 137·50. Ans.**

Example 3. Cylindrical drums of size 1·5 m. high and 1 m. mean diameter are to be fabricated from sheet of 5 mm. thickness by grooved seam joint and both the covers should be jointed with single seam joint. Calculate the material cost, if sheet is available @ Rs. 15 per m.^{2}

Solution.

(*a*) **Height.** Height of cylindrical drum

= 1·5 m.

This height is to be jointed by single seam joint on both sides (Taking allowance for joint as $5 \times$ thickness of sheet)

∴ Excess height required on both sides

$= 5 \times 0{\cdot}005 \times 2 = 0{\cdot}05$ m.

∴ Heigth of sheet required

$= 1{\cdot}5 + 0{\cdot}05 = 1{\cdot}55$ m.

(*b*) **Length.** Length of sheet for 1 m. dia. $= \pi d$

$= 1 \times 3{\cdot}14 = 3{\cdot}14$ m.

As this will have a groove joint, therefore, as excess amount on each side (Taking 10 × thickness of sheet)

∴ Excess length required

$= 10 \times 0{\cdot}005 = 0{\cdot}05$ m.

∴ Total allowance in length on both sides

$= 2 \times 0{\cdot}05 = 0{\cdot}1$ m.

∴ Total length $= 3{\cdot}14 + 0{\cdot}1 = 3{\cdot}24$ m.

∴ Area of steel required

$= 3{\cdot}24 \times 1{\cdot}55 = 5{\cdot}03$ m.^{2}

Therefore cost of sheet metal $= 15 \times 5{\cdot}03$.

= **Rs. 75·45. Ans.**

Example 4. 1000 pieces of a part shown below are to be manufactured from a sheet of 300 cm. × 100 cm. × 2 mm. Estimate the number of such sheets required, assuming no wastage.

Solution. Width of part when it is straight will be equal to

$$10 + 10 + \frac{1}{2}\pi\left(\frac{20 + 20{\cdot}4}{2}\right) \text{ cm.}$$

$= 51{\cdot}71$ cm.

∴ Area of sheet required for one piece

$= 51{\cdot}71 \times 100$
$= 5171$ cm.^{2}

∴ Area of sheets required for 1000 sheets $= 5171 \times 1000$ cm^2

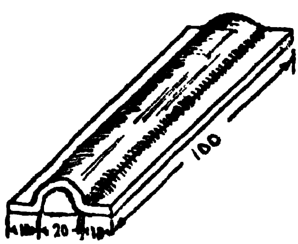


Fig. 7·12

∴ No. of sheets required

$$= \frac{5171 \times 1000}{304 \times 100}$$

$= 172{\cdot}4$ sheets.

Say **173 sheets. Ans.**

Example 5. A steel pipe 10 m. long and 0·6 m. diameter is to be fabricated from M.S. plate of 1·0 cm. thickness. Estimate cost if

(*a*) M.S. plates of size 2 m. × 1 m. are available at the rate of Rs. 70.

(*b*) Cost of rolling 10% of material cost.

(c) Cost of riveting 20% of material cost.

(d) Overhead charges 10% of material cost.

(a) **Material Cost.**

Circumference of pipe = πd

$= 3{\cdot}14 \times 0{\cdot}6 = 1{\cdot}884$ m.

Sheet size is 2 m. × 1 m.

From this sheet, we can prepare a ring of 1 m. height and 0·6 m. diameter taking 5·8 cm. $\left(\frac{2-1{\cdot}884}{2}\text{ m.}\right)$ as overlap using lap joint.

As we are required to prepare a pipe, which should be of uniform diameter, therefore different rings cannot be jointed by lap ioint. Therefore, butt joint with single cover plate is adopted.

As we have decided that the length of one ring can be 1 m., hence 10 such rings will give a full length pipe and one additional plate will be required to fabricate cover plates.

∴ Total number of plates of size 2 m. × 1 m. required

$= 10+1 = 11.$

∴ Total material cost of plates

$= 11 \times 70$

= **Rs. 770. Ans.**

(b) **Cost of Rolling.** It is 10% of material cost.

∴ Rolling cost $= \dfrac{770 \times 10}{100}$

= **Rs. 77·00. Ans.**

(c) **Cost of Riveting.** It is 20% of material cost.

∴ Cost of riveting = $770 \times 0{\cdot}20$

= **Rs. 154·00. Ans.**

(d) **Overhead Charges.** These are 10% of material cost

$= 770 \times 0{\cdot}10 =$ Rs. 77·00

∴ Total cost $= 770+77+154+77$

= **Rs. 1078.**

∴ Cost of fabrication of pipe will be **Rs. 1078. Ans.**

Example 6. The dimentions of steel tray made out of two m.s sheets 24 gauge and size 3 m. × 1 m. are shown in Fig. 7·13. Calculate the total no of trays which can be formed by these two sheets and also the cost of each tray, if:

(a) 3 m. × 1 m. sheet is available at Rs. 25·00 each.

(b) Labour cost is Re. 0·30 per tray and

(c) Overheads are 12% of material cost.

Solution. Following sketch shows the sheet required for one tray before folding the sides.

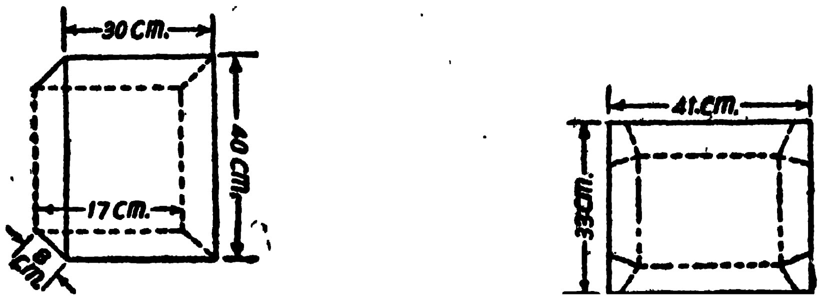


Fig. 7·13

From Fig. 7·13 (*b*) for one tray size of sheet required is 41 cm. ×33 cm.

As one sheet has 1 m., width, while width of one tray is 33 cm.

∴ From width of sheet, 3 widths of trays can be cut and each part will give

$$\frac{300}{41} \quad 7 \text{ trays/length}$$

No. of trays which can be made from one sheet

$$= 7 \times 3 = 21$$

∴ Total no. of trays which can be made from 2 sheets

$$= 21 \times 2 = 42$$

∴ Material cost/try $= \frac{25 \times 2}{42} = 1·20$

∴ Labour cost/tray = Re. 0·30

∴ Overheads/tray = 1·20×·12 = Re. 0·144

∴ Total cost/tray = 1·20+0·30+0·14 = Rs. 1·64

∴ Total cost of one tray will be **Rs. 1·64. Ans.**

Example 7. Estimate the cost of metal sheet for preparing a funnel of foollowing size. Assume the wastage of metal as 10% and cost of the sheet as Rs. 10/m².

Solution. For preparing the funnel, upper and lower parts are prepared separately and then joined together. Area of sheet required, for upper part can be calculated assuming it to be as frustum of cone with 8 cm. and 4 cm. diameters using the relation:

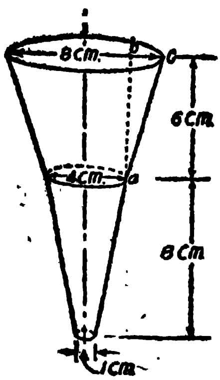


Fig. 7·14

Surface area for a frustum of cone
= ½ slant height × sum of circumferences

where, Slant height

$$ac = \sqrt{ab^2+bc^2}$$

$$= \sqrt{6^2+\left(\frac{8-4}{2}\right)} \qquad \sqrt{40}$$

$$= 6{\cdot}32 \text{ cm.}$$

and sum of circumferences $= \pi\times 8+\pi\times 4 = 12\,\pi$

∴ Surface area of upper part

$$= \tfrac{1}{2}\times 6{\cdot}32\times 12\pi$$

$$= 119 \text{ cm.}^2$$

Similarly surface area for lower part can also be calculated, taking two diameters for frustum of cone as 4 cm. and 1 cm.

∴ Surface area = ½ slant height × sum of circumferences

$$= \frac{1}{2}\left\{\sqrt{8^2+\left(\frac{4-1}{2}\right)^2}\right\}\times(\pi\times 4+\pi\times 1)$$

$$= \tfrac{1}{2}\times\sqrt{66{\cdot}25}\times 5\pi$$

$$= 64 \text{ cm}^2.$$

∴ Total surface area = 119+65 = 183 cm.²

∴ Area of the sheet required, taking 10% wastage

$$= 183\times 1{\cdot}1 = 201{\cdot}3 \text{ cm.}^2$$

$$= 0{\cdot}02013 \text{ m.}^2$$

∴ Cost of sheet @ Rs. 10/m.²

$$= 10\times 0{\cdot}02013 = 0{\cdot}201$$

= **Rs 0·20. Ans.**

Example 8. A conical body of base 10 cm. dia. of attitude 20 cm. is to be covered by a sheet. Find the area of the surface to be covered.

Solution. First, we find the slant height, thus slant height

$$= \sqrt{\left(\frac{10}{2}\right)^2+(20)^2} = \sqrt{425}$$

20·62 cm.

and Circumference of base $= \pi d = \pi\times 10$

31·42 cm,

But, surface area of the cone

$= \frac{1}{2}$ slant height × circumference of the base

$= \frac{1}{2} \times 20{\cdot}62 \times 31{\cdot}42$

$=$ **324 sq. cm. Ans.**

∴ 324 sq. cm. of sheet is required.

Example 9. Will it be possible to cut a rectangular blank of 50 cm. × 60 cm. from a mild steel plate of 0·3 cm. thickness by using a press, being driven by gears at both ends and having a 15 cm. dia. pin.

Solution.

Pressure required to cut the rectangular blank

= Area to be sheared × shearing stress.

= (total periphery × thickness) × shearing stress.

$= \{2(50+60) \times 0{\cdot}3\} \times 3{\cdot}1$

$= 220 \times 3 \times 3{\cdot}1$

= 204·6 Tonnes

While, the maximum pressure which this press can give

$= 0{\cdot}75D^2$

$= 0{\cdot}75(15)^2$

= 168·75 tonnes

Hence it would not be possible to cut the blank of this size from this press.

Example 10. For making a steel component, 1 cm. thick t is required to be bent through 90°. If the inner radius is 8 cm ulate the length of the metal in the curved portion.

Solution.

As, length of metal in bend portion

$$= 2\pi r \times \frac{\theta}{360}$$

where,

r = Mean Radius

and generally Mean Radius

= Inner radius + 0·5 thickness of sheet

∴ $r = 8 + 0{\cdot}5 \times 1$

$= 8{\cdot}5$ cm.

and, $\theta = 90°$.

Hence, length of bend portion

$$= 2\pi \times 8{\cdot}5 \times \frac{90}{360}$$

= **13·34 cm. Ans.**

Example 11. Explain the procedure you will follow for laying out a rectangular box open at the top.

Solution. Sequence of operations for laying out a rectangular box (also the same for square box) is given hereunder. Fig. 7·15 shows the layout on the sheet of metal :

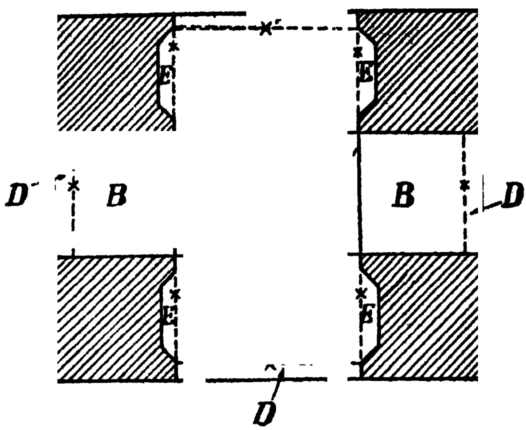


Fig. 7·15

1. First of all outline of the base is drawn, as shown at '*A*'.
2. Then, two sides (shown by '*c*') and ends (shown by '*B*') are drawn as shown in the above Fig.
3. Lines for preparing hems are drawn as shown by '*D*'.
4. Lines for preparing seams are drawn as shown by *E*.
5. Area to be removed is marked by hatchings.
6. The portions to be bent are indicated by '*X*'.

In this way blank layout is completed.

Example 12. A press making 60 strokes per min. is used for making 30 blanks of 10 cm. × 12 cm. size from each strip. Calculate the time required for blanking each strip if only 60% of the strokes are utilised. If holes are also pierced on this press. Find out the total time for blanking and piercing for 200 components.

Solution. (A).

Time Estimation for blanking.

(*i*) Time for inserting one strip = 15 sec.

(*ii*) If 60% are the effective strokes,

then, effective strokes/min.

$$= 60 \times 0{\cdot}6 = 36 \text{ strokes/min.}$$

∴ Time required for 30 blanks

$$= \frac{1}{36} \times 30 \text{ min.}$$

$$= 50 \text{ sec.}$$

(*iii*) Time required for removal of component = 10 sec.

∴ Total time required = 15+50+10= 75 sec.

Personal and fatigue time (15%)

$$= 75 \times \frac{15}{100}$$

$$= 11{\cdot}25 \text{ sec.}$$

∴ Total time required for blanking one strip (30 blanks)

$$= 75 + 11{\cdot}25 = \mathbf{86{\cdot}25 \text{ sec.}}$$

∴ Time required for blanking 200 blanks

$$= 86{\cdot}25 \times \frac{200}{30}$$

= **575 sec. Ans.**

(B) Estimation for piercing holes.

(*i*) Time required for loading one blank		= 2 sec.
(*ii*) „ „ „ piercing „ „		= 2 sec.
(*iii*) „ „ „ ejecting „ „ (assuming that it is done manually)		= 10 sec.
	Total	14 sec.

Personal and fatigue time (15%)

$$= 14 \times \frac{15}{100}$$

$$= 2{\cdot}1 \text{ sec.}$$

∴ Total time required for piercing one hole

$$= 16{\cdot}1 \text{ sec.}$$

∴ Time required for piercing 200 blanks

$$= 3220 \text{ sec.}$$

Hence time required for blanking and piercing 200 pieces

$$= 575 + 3220 = 3795 \text{ sec.}$$

= **63 min. 15 sec. Ans.**

Example 13. A 2 m × 5 m. sheet is available for cutting the 10 cm. × 15 cm. blanks. Show which of the following ways will give more number of blanks.

(*i*) When blanks are along the length of the sheet.

(*ii*) When blanks are across the length of the sheet.

Solution.

Case I. Blanks are along the length of the sheet.

(*a*) While doing the blanking by this way a strip of 10 cm. + 2×0·15 = 10·3 cm. will be cut from the sheet

Hence No. of strips

$$= \frac{200}{10{\cdot}3} \simeq 19.$$

(b) From each strip blanks of length 15 cm. will be cut. But in between two blanks a bridge of 0·15 cm. must be provided. Hence effective length of each blank = 15·15 cm.

∴ No of blanks/strip

$$= \frac{500}{15 \cdot 15} \simeq 33.$$

Hence, total No. of blanks from the sheet

$$= 33 \times 19$$

$$= \textbf{627 blanks.}$$

Case II. *Blanks are across the length of sheet.*

Width of strip in this case

$$= 15 + 2 \times 0 \cdot 15 = 15 \cdot 3 \text{ cm.}$$

No. of strips $\frac{200}{15 \cdot 3} \simeq 13.$

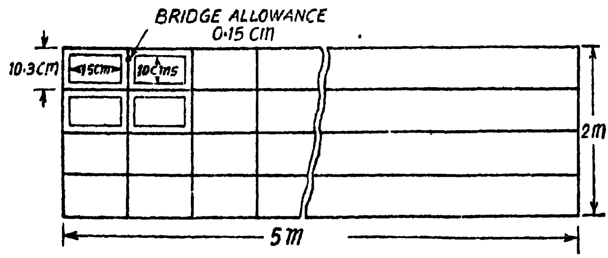


Fig. 7·16

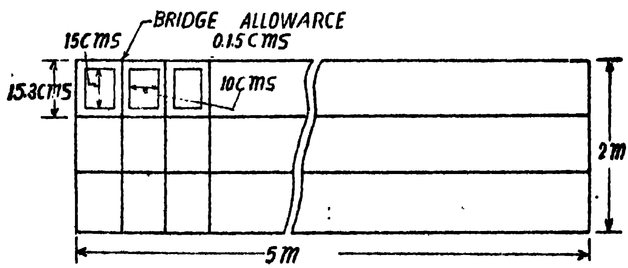


Fig. 7·17

Effective length of each blank = 10·15 cm.

∴ No. of blanks/strip

$$= \frac{500}{10 \cdot 15} \simeq 49$$

Hence, total No. of blanks

$$= 13 \times 49 = \textbf{6}\text{?}\textbf{3 blanks.}$$

Thus the second case will give more No. of blanks and will be more economical.

8

ESTIMATION IN FORGING SHOP

Forging. It is the process, in which metal is heated at sufficiently high temperature to bring it to the plastic state. During this plastic state desired shape is given by applying sufficient force either by hand or by machine.

The shop in which forging is done is known as "Forging shop".

Types of Forging :

(*a*) Hand Forging

(*b*, Machine Forging.

(*a*) **Hand Forging.** When forging is done by hand, the process is known as hand forging. In case of heavy jobs, smith is assisted by a hammerman. Important hand forging operations are drawing down, upsetting, bending, punching, swaging and shearing etc.

(*b*) **Machine Forging.** The processes, in which forging is done by machines are known as "Machine Forging." Machine forging is useful for heavy and complicated jobs requiring large forces.

Machine forging can be classified as :

(*i*) *Smith Forging.* In this process metal is heated in suitable forges and than shaping of the metal is carried out by power or steam hammers and hand tools. In this method, accuracy, depends upon the experience and skill of the smith.

With this method, similar pieces cannot be obtained and also require too much time.

This method is useful for large and simple types of products.

(*ii*) *Drop Forging.* It is a process of hammering the metal during plastic state in impression dies. Die is used in two parts, one die is allowed to drop on the other. The hot metal in the plastic state is thus squeezed between the two dies and thus forms the desired shape of the forged product. Steam or power hammer can be used, instead of allowing the upper die to drop on the lower die from certain height. This process takes less time.

This is generally used, where large number of identical shapes of good quality forgings are to be produced.

(*iii*) *Press Forgings.* Very heavy forgings are given proper shape by the presses. These presses can either be hydrolically operated or mechanically operated. Press forging method employes squeezing of plastic metal or metal in plastic condition and gives the required shape in the dies. Pressure is applied continuously and gradually. By applying gradual pressure, excessive vibrations can be avoided, which may otherwise disturb the machine alignment by rapid blows of hammer.

FORGING OPERATIONS

The shape of material by forging can be transformed with the aid of the following operations.

(1) **Drawing Down.** It is also known as "Drawing Out". This operation is performed to increase the length of the work piece in forging by decreasing the cross-sectional area.

This process can be performed by hammering the hot work piece lengthwise to reduce cross-section.

(2) **Up Setting.** This is the reverse of Drawing Down operation. In this operation, the cross-section of the work piece is increased at the expense of length.

This process can be performed by hammering one end of hot work piece while other end is supported against the anvil.

(3) **Bending.** Bending is done by holding the work piece between two fixtures and desired bend can be given by striking the work piece with the help of hammer. This operation can also be carried out on the anvil beak.

(4) **Punching and Drifting.** Punching operation is performed by a tool called punch, for producing holes in the work piece, when it is in the hot state and drifting is an operation carried on by a special tool known as drift to enlarge the hole.

ESTIMATION PROCEDURE

Estimation procedure varies from shop to shop and person to person but for a general procedure, following factors may be considered.

(*i*) **Estimation of Net Weight.** For estimation of net weight of the forged component, following procedure is adopted

(*a*) Break up the job drawing into suitable geometrical sections, whose volumes can easily be calculated by using mensuration.

(*b*) Next, find the volume of each section, neglecting rounded corners and taking suitable assumptions.

(*c*) Now, find total volume of material required by substracting the volume of the hollow spaces.

(*d*) Lastly, calculate the weight of the component by multiplying the total volume with its density.

ESTIMATION OF LOSSES

Certain amount of material is lost during different forging operations. The exact estimation of losses is very difficult but by practical experience, the losses can be calculated by the weight of material lost during forging as accurate as possible and these are :

(*i*) **Tong Loss.** While performing forging operations, some length of stock is required for holding the job in Tong. This length, is an extra length which is removed after completion of the job. For estimation purposes, the weight of this extra length is also considered and is known as Tong loss. This loss may be taken as 2—3 cm. of the stock length.

(*ii*) **Scale Loss.** The outer surface of the hot metal is generally oxidised and when hammering is done, the oxidised film is broken and falls down in the form of scale. It reduces the dimensions of the job and, therefore, this loss must be considered for estimation purposses. Generally, it is taken as 6% of the net weight.

(*iii*) **Flash Loss**. It is the surplus metal, which comes out between the two meeting surfaces of the dies. This surplus material will be all around the periphery of the dies. For getting finished product, this surplus metal is required to be trimmed off.

This loss may be calculated by assuming it to be 20 mm. wide and 3 mm. thick all around the periphery of the dies.

Thus, volume of flash loss $=$ periphery $\times 20 \times 3$ cu. mm. nearly.

(*iv*) **Shear Loss.** The required sizes of work pieces for forging operations are obtained from long bars by sawing or shearing. In sawing operation, some material is always lost. Sometimes, if the lost piece of bar is not to the required length, it is rejected. This loss of material is taken as 5% of the net weight.

(*v*) **Sprue Loss.** The portion of metal between the length held in the tong and the material in the die is called sprue. This is also a metal loss and can be taken as 7% of the net weight.

Thus, we can see that nearly 15—20% of the net weight of metal is lost during forging. Therefore, in estimation their consideration is very essential and total weight will be net weight of job plus the sum of the weight of different losses occurred during forging. Thus, this gives the amount of weight of material required for forging.

ESTIMATION OF TIME

Estimation of time required in forging is very difficult and only by practical experience it can be ascertained, which is also not satisfactory, since it varies from worker to worker depending on their skill. However, time required can be divided into following two categories.

(i) Heating the job upto the required temperature.

(ii) Performing the operations to get the required shape. Following tables give the idea of approximate time required.

First table gives the approximate time required for heating the jobs of different weights and different materials.

Second table gives the approximate time required for performing forging operations of different volumes of job.

These timings are with normal working on Anvil and Hammer.

First Table

Job	*Time required for heating the Job*			
	M S. or W.I.	*Medium C. steel*	*High C. steel*	*Tool or H.S. steel*
Upto 100 gm.	50 sec.	Upto 1 min.	Upto 1 min.	Upto 1·5 min.
100 to 200 gm.	90 sec.	1 to 1·6 min.	1 to 2 min.	1·5 to 2·5 min.
200 to 400 gm.	2·5 min.	1·5 to 3 min.	2 to 3 min.	2 to 3·5 min.
400 to 800 gm.	3 to 3·5 min	3 to 4 min.	3 to 4 min.	3 to 4·5 min.

Second Table

Job Vol. in cu.cm	*Time required for performing operations*			
	M.S. or W.I.	*Medium C. steel*	*High C. steel*	*H.S. steel*
upto 2	upto 20 sec.	upto 25 sec.	upto 30 sec.	upto 32 sec.
2—4	20—30 sec.	25—35 sec.	35—40 sec.	35—40 sec.
4—8	40—50 sec.	35—50 sec.	45—60 sec.	35—50 sec.
8—16	1—1·5 min.	1—2 Min.	1—2·5 min.	1—2·5 min.
16—32	3—6 min.	3·5—6 Min.	4—7 min.	3—7 min.

Solved Problems

1. Determine the length of a circular rod of 12 mm. diameter required for the U-shaped component shown in Fig. 8·1 below.

Solution. Length of rod required = Length AB + Length CD + Mean length of arc BC

$70+70+\pi\times$ Mean radius

$140+\pi(2{\cdot}5+0{\cdot}6)$

$=140+3{\cdot}1\,\pi$

$=149{\cdot}63$ cm.

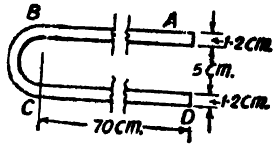


Fig. 8·1

Therefore, length of circular rod required is **149·63 cm. Ans.**

2. We are required to prepare a hexagonal bolt of 15 cm. dia. and 25 cm. length from a bar stock of 1·8 cm. dia. Calculate the length of the bar stock required and also give the sequence of operations for forging the above bolt.

Solution. (*A*) First, calculate length of bar stock.

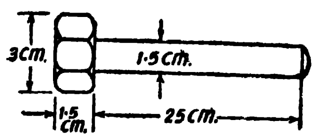


Fig. 8 2

Area of hexagonal head

$=\frac{3\sqrt{3}}{2}a^2$, where a = 1

gth of each side

$=\frac{3\sqrt{3}}{2}\times\left(\frac{3}{2}\right)^2$

$=5{\cdot}85$ sq. cm.

$\therefore$ Volume of hexagonal head $=$ Area $\times 1{\cdot}5$

$=5{\cdot}85\times1{\cdot}5=8{\cdot}775\text{ cm}^3.$

Volume of bolt shank $=\frac{\pi}{4}(1{\cdot}5)^2\times25$

$=44{\cdot}15\text{ cm.}^3$

$\therefore$ Total volume of bolt $=44{\cdot}15+8{\cdot}77=52{\cdot}92\text{ cm.}^3$

In forging this bolt only "scale loss" will occur, assuming it to be 5% of the total volume.

Hence, volume of bar stock required

$=52{\cdot}92\times1{\cdot}05=55{\cdot}5\text{ cm}^3.$

Therefore, length of bar stock $=\frac{\text{Volume}}{\text{Area of bar}}$

$\frac{55{\cdot}5}{\frac{\pi}{4}(1\ 8)^2}$

$=$ **22 cm. nearly. Ans.**

(*B*) Sequence of operations.

(1) Estimate the length of bar stock required.

(2) Cut the required length of bar.

(3) Heat one end of bar to make head.

(4) Upsetting of this heated portion is done by keeping it vertically on anvil and hammering by sledge hammer.

(5) Spread its head to the required size, for this purpose bolt spreader may be used.

(6) Make this head round.

(7) Make head hexagonal by using hexagonal swage in anvil.

(8) Reduce the diameter of shank on anvil face.

(9) Make the shank to be straight.

(10) Length of bolt may be checked, if it is greater than the required length, extra length may be cut off, after heating the end.

Thus, above are the required sequence of operations in forging a bolt.

3. Estimate the size of stock and weight of material required to forge 40 mild steel bolts as shown in Fig. 8·3.

The bar stock diameter is 2·5 cm.

Solution. In this example, we have to forge head only and rest part may be kept as it is. Therefore, volume of head = Area of haxagon × Length of head.

$\therefore$ Volume $= \frac{3\sqrt{3}}{2} \times a^2 \times (2)$, where a = length of each side of hexagon and equal to dia. of bolt.

$= \frac{3\sqrt{3}}{2} (2{\cdot}5)^2 \times 2$

$= 32{\cdot}5 \text{ cm.}^3$

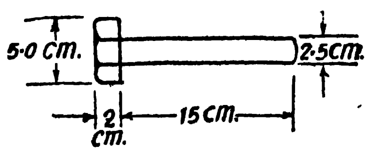


Fig. 8·3

$\therefore$ Length of bar stock required for making head.

$= \frac{\text{Volume}}{\text{Area of bar}}$

$\frac{32{\cdot}5}{\frac{\pi}{4}(2{\cdot}5)^2} = 6{\cdot}63$ cm.

Therefore, length required for making one bolt $= 6{\cdot}63 + 15$

$= 21{\cdot}63$ cm.

$\therefore$ Length required for 40 pieces $= 40 \times 21{\cdot}63 = 865{\cdot}2$ cm.

Now, during forging operation of bolt head, there will be two types of loss. (*i*) scale loss, assuming it as 5%.

Then scale loss $= \frac{865{\cdot}2 \times 5}{100} = 43{\cdot}2$ cm.

(*ii*) Shear loss, assuming it as 0·2 cm./bolt.

Then, shear loss $= 0{\cdot}2 \times 40 = 8{\cdot}0$ cm.

Hence, actual bar stock required for 40 pieces of bolt

$= 865{\cdot}2 + 43{\cdot}2 + 8{\cdot}0 = 916{\cdot}4$ cm. **Ans.**

4. Determine the length of 10 mm. dia. rod required to forget a ring of 50 mm. inner dia.

Solution. To calculate the length of rod, mean circumference is calculated.

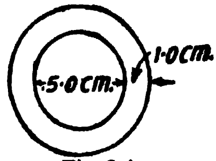


Fig. 8·4

$$\text{Mean dia.} = \text{Inner dia.} + 2 \times \text{rod dia}$$

$$= 5 + 2 \times \frac{1}{2} = 6 \text{ cm.}$$

$\therefore$ Mean circumference = $\pi \times$ mean dia. $\pi \times 6 = 18{\cdot}84$ cm.

Assuming, scale loss in forgoing = 5 %.

Then scale loss = $18{\cdot}84 \times \frac{}{100} \cdot 0{\cdot}942$ cm.

Hence total length of 1 cm. rod required $= 18{\cdot}84 + 0{\cdot}942$

$= 19{\cdot}782$ **cm.**

5. A square bar of 3 cm. diameter and 25 cm length is to be converted by hand forging into a bar of hexagonal section having each side equal to 1·5 cm. Calculate the length of hexagonal bar produced, consider scale loss to be 7% of total.

Solution. Volume of square bar = Area of cross-section × Length

$= 3 \times 3 \times 25 = 225$ cm.^{3}

As 7% of the material is lost in forgoing as scale loss, hence material available for producing hexagonal bar $= 225 \times \frac{93}{100}$

$= 209$ cm.^{3}

Now, this 209 cm^3 volume of material is given the shape of hexagonal bar.

As area of cross-section of hexagonal bar $3\sqrt{3}\ a^2$

where, a is the length of each side of hexagon

$\therefore$ Area $= \frac{3\sqrt{3}}{2}(1{\cdot}5)^2 = 5{\cdot}85$ cm.^{2}

$\therefore$ Length of hexagonal bar produced $= \frac{\text{Volume}}{\text{Area of cross-section}}$

$= \frac{209}{5{\cdot}85} = 35{\cdot}7$ **cm. Ans.**

6. Estimate the length and weight of 1 cm. dia. stock required to hand forge 200 rivets of dimensions given in Fig. 8·5. Assume density of material as 8 gm./c.c.

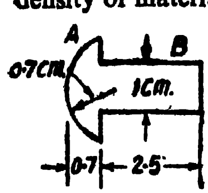


Fig. 8·5

Solution. In this example we have to calculate the length of stock required for 200 rivets and its weight.

Now in hand forging process, there will be two losses.

(*i*) Shear loss.
(*ii*) Scale loss.

From the figure, weigth of one forged rivet can be obtained by assuming the rivet in two parts A and B, where A is the segment of a sphere and B is the solid cylindrical portion.

Using the relation, Volume of segment

$$A = \frac{\pi}{6} h^2 (3D-2h)$$

$$\therefore \quad \text{Volume of } A = \frac{\pi}{6}(0{\cdot}7)^2[3\times1{\cdot}8-2\times0{\cdot}7]$$

$$= 1{\cdot}025 \text{ cm.}^3$$

$$\text{Volume of } B = \frac{\pi}{4}\times1^2\times2{\cdot}5 = 1{\cdot}963 \text{ cm.}^3$$

Hence, volume of each rivet = Volume of A+Volume of B

$$= 1{\cdot}025+1{\cdot}963 = 2{\cdot}988 \text{ cm.}^3$$

$\therefore$ Volume of 200 rivets $= 200\times2{\cdot}988 = 597{\cdot}6$ cm.^{3}

Assuming scale loss as 6%,

Scale loss $= 597{\cdot}6\times0{\cdot}06 = 35{\cdot}856$ cm.^{3}

Assuming shear loss as 5%,

Shear loss $= 597{\cdot}6\times0{\cdot}05 = 29{\cdot}88$ cm.^{3}

Hence, total volume of stock required

$$= 597{\cdot}6+35{\cdot}856+29{\cdot}88$$

$$= 663{\cdot}336 \text{ cm.}^3$$

$$\therefore \text{ Length of stock required} = \frac{\text{Volume}}{\text{Area of stock}}$$

$$\frac{663{\cdot}336}{\frac{\pi}{4}(1)} \text{ cm.}$$

$= 844$ cm. **Ans.**

Hence, weight of stock

$$= \frac{663{\cdot}336\times8}{1000} \text{kg.}$$

$= 5{\cdot}30$ kg. **Ans.**

7. It is required to make a key of dimensions given in Fig. 8·6 from a rod of 20 mm. dia. calculate the length of rod required in forging.

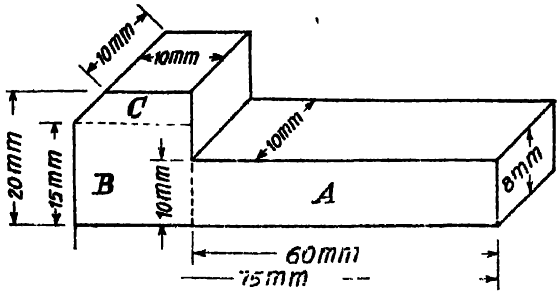


Fig. 8·6

Solution. Split up the drawing into simple parts *A*, *B* and *C*.

Volume of part $A = \left(\frac{10+8}{2}\right) \times 60 \times 10 = 5400$ cu. mm.

Volume of part $B = 15 \times 15 \times 10 = 2250$ cu. mm.

Volume of part $C = \left(\frac{10+15}{2}\right) \times 5 \times 10$

$= 625$ cu. mm.

$\therefore$ Volume of key $= 5400+2250+625$

$= 8275$ cu. mm.

In forging key, only scale loss will occur, assuming it to be 6% of the total volume.

$\therefore$ Scale loss $= \frac{8275 \times 6}{100} = 496·5$ cu. mm.

Hence, total volume of material required

$= 8275+496·5$

$= 8771·5$ cu. mm.

$\therefore$ Length of bar stock

$\frac{\text{Volume}}{\text{Area of bar}}$ mm.

$\frac{8771·5}{(20)^2}$ mm.

= 27·90 mm. Ans.

8. 1000 M.S. pins of 4 cm. diameter and 10 cm. length are to be drop forged from a bar stock of 5 cm. diameter. Calculate the material cost, if bar is available at Rs. 20·00 per metre length.

Assuming all the possible losses.

Solution. Volume of one pin.

$$\frac{\pi}{4} d^2 l$$

$$= \frac{\pi}{4}(4)^2 \times 10 = 125{\cdot}6 \text{ cm.}^3$$

(*i*) Scale loss is 5%

∴ Scale loss of one pin

$$= 125{\cdot}6 \times 0{\cdot}05 = 6{\cdot}28 \text{ cm.}^3$$

(*ii*) Shear loss, assuming 2 mm. length is lost per pin.

∴ Shear loss $= \frac{\pi}{4}(5)^2 \times 0{\cdot}2$ (As it will be from 5 cm. bar stock)

$$= 3{\cdot}925 \text{ cm.}^3$$

(*iii*) Flash loss = periphery of parting line of dies $\times 2 \times 0{\cdot}3$

∴ Flash loss $= 2 \times 0{\cdot}3\,(4+10+4+10) = 16{\cdot}80$ cm.^{3}

(*iv*) Tong loss, assuming 1 cm. length is required to be held in tong.

∴ Tong loss $= 1 \times \frac{\pi}{4}(5)^2 = 19{\cdot}625$ cm.^{3}

(*v*) Sprue, let it to be 5% of net volume.

∴ Sprue loss $= 125{\cdot}60 \times 0{\cdot}05 = 6{\cdot}280$ cm.^{3}

∴ Gross volume $= 125{\cdot}60 + 6{\cdot}28 + 3{\cdot}925 + 16{\cdot}80 + 19{\cdot}625 + 6{\cdot}280$

$$= 178{\cdot}51 \text{ cm.}^3$$

∴ Length of stock required $= \dfrac{178{\cdot}51}{\frac{\pi}{4}(5)^2} = 9$ cm. per piece

Therefore, length of stock required for 1000 pieces

$$= 9 \times 1000 \text{ cm.} = 90 \text{ metres.}$$

∴ Material cost = Rs. 20×90

= **Rs. 800 only. Ans.**

9. 200 pieces of a component, as shown in Fig. 8·7 are to be drop forged from a 4 cm. diameter stock bar. Calculate the cost of manufacture, if

(*i*) Material cost is Rs. 15·00/metre.

(*ii*) Forging charges Re. 0·01 per cm.^{2} of surface area to be forged.

(*iii*) On cost is 30% of material cost

Consider, all possible losses during operations.

Solution. Volume of component

$$= 5\times\frac{\pi}{4}(4)^2+4\times\frac{\pi}{4}(3)^2+2\times2\times2$$

$$= 99{\cdot}06 \text{ cm.}^3$$

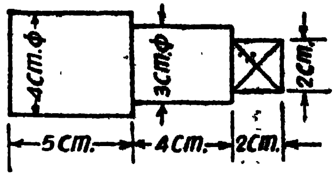


Fig. 8·7

Considering various losses in Drop forging :

(*i*) Scale loss, let it be 6% of the volume.
Then, scale loss $=0{\cdot}06\times99{\cdot}06=5{\cdot}98$ cm.^{3}

(*ii*) Shear loss, considering it as 2 mm. length in cutting one piece from long bar stock.

Shear loss/piece $= 0{\cdot}2\times\frac{\pi}{4}(4)^2 \quad 2{\cdot}512$ cm.

(*iii*) Flash loss, assuming width of surplus material as 2 cm. and thickness as 0·3 cm.

∴ Flash loss=periphery of parting line of dies $\times2\times0{\cdot}3$

$$= 2(2+5+0{\cdot}5+4+0{\cdot}5+2+1)\times0{\cdot}3$$
$$= 18 \text{ cm.}^3$$

(*iv*) Tong loss, taking 2 cm. extra length required for the use of tong.

∴ Tong loss $\quad 2\times\frac{\pi}{4}(4)^2 = 25{\cdot}12$ cm.^{3}

(*v*) Sprue loss, assuming it to be 5% of the volume.

∴ Sprue loss $= 0{\cdot}05\times99{\cdot}06 = 4{\cdot}98$ cm.^{3}

∴ Total volume of material required for each component

$$= 99{\cdot}06+5{\cdot}98+2{\cdot}51+18{\cdot}00+25{\cdot}12+4{\cdot}98$$
$$= 155{\cdot}65 \text{ cm.}^3$$

Hence, Volume required for 200 pieces

$$= 200\times155{\cdot}65$$
$$= 31130 \text{ cm.}^3$$

∴ Length of bar stock required

$$= \frac{31130}{\frac{\pi}{4}(4)^2} = 2478 \text{ cm.}$$

$$= 24{\cdot}78 \text{ metres}$$

∴ Material cost $= 24{\cdot}78\times15 =$ Rs. 371·70

Forging charges $=$ Rs. $0{\cdot}01\times$(surface area)

$$= \text{Rs. } 0{\cdot}01\times\left\{\frac{\pi}{4}(4)^2+\pi\times4\times5+\frac{\pi}{4}\left(4^2-3^2\right)\right.$$
$$\left.+\left(\frac{\pi}{4}\times3^2-2\times2\right)+\pi\times3\times4+4\times2\times2+2\times2\right\}$$

$= \text{Rs. } 0{\cdot}01(4\pi+20\pi+1{\cdot}75\pi+3+12\pi+16+4)$

$= \text{Rs. } 1{\cdot}48$

∴ Forging charges for 200 pieces

$= 200\times1{\cdot}48 = \text{Rs. } 296{\cdot}00$

Now on-cost is 30% of material cost.

∴ On-cost $= 0{\cdot}30\times371{\cdot}70 = \text{Rs. } 111{\cdot}51.$

Therefore, manufacturing cost

$= \text{Rs. } 371{\cdot}70+\text{Rs. } 296{\cdot}00+\text{Rs. } 111{\cdot}51$

$=$ **Rs. 779·21. Ans.**

Unsolved Examples

1. A bar stock of 3 cm. dia. and 2 m. long is to be converted into (*a*) Square bar 3 cm. side and (*b*) Octagonal bar 3 cm. side. Calculate the length of bar made in each case. Assume hand forging and neglect losses. [**Ans.** 1·57 m., 32·5 cm.]

2. A component shown in Fig. 8·8 is to be hand forged from a raw stock of 2·5 cm. dia. Estimate the weight of stock required, if density of material is 8 gm./c.c. Assume shear loss 2% and scale loss 5%. [**Ans.** 0·866 kg.]

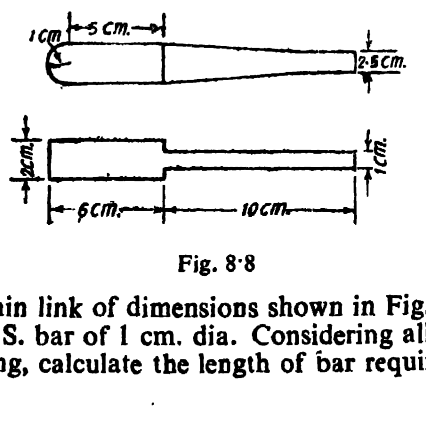


Fig. 8·8

3. A chain link of dimensions shown in Fig. 8 8 is to be hand forged from M.S. bar of 1 cm. dia. Considering all the possible losses during forging, calculate the length of bar required/piece.

[**Ans.** 1·09 cm.]

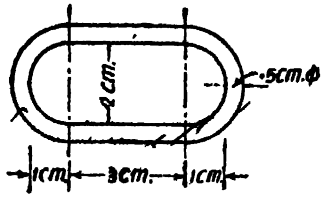


Fig. 8·9

4. U-shaped links are to be forged from a bar of 1 cm. dia. and 5 m. length. Considering all the possible losses, estimate the total number of links, which can be produced. [**Ans.** 28 links.]

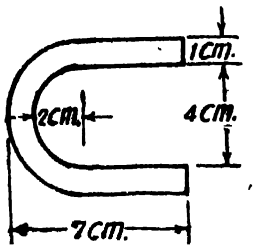


Fig. 8·10

5. Two workers complete 20 connecting rods, each weighing 3·5 kg. by forging per day. They are paid at the rate of Rs. 6·00 and Rs. 4 00 per day respectively. If the material cost is Rs. 1·25/kg. and 60% of the direct labour is required to compensate for the factory overheads, 30 % administrative overheads and 40% sales overheads, estimate the total cost of each rod. [**Ans.** Rs, 5·08]

6. 500 M.S. bolts shown in Fig. 8·11 are to be forged in an upsetting machine from 2 cm. dia. rod. What should be the length of each such bolt before upsetting ?

Also calculate, length of rod required for 500 such bolts, if 5% of the length goes to scrap. [**Ans.** 7·65 cm. ; 38·25 m]

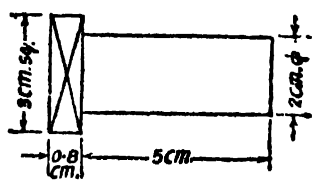


Fig. 8·11

7. 1000 shafts as shown in Fig. 8·11 are to be drop forged from the bar stock of 5 cm. in dia. Consider all losses and assuming that

(*i*) Material cost is Rs. 12 per metre.

(*ii*) Cost of forging is Re. 0·05/cm² surface area forged.

(*iii*) Overheads to be 50% of material cost.

(*iv*) Profit 20% of the total cost.

Estimate the selling price of forged shaft. [**Ans.** Rs. 4·20]

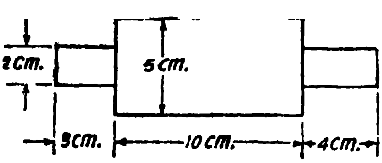


Fig. 8·12

9

ESTIMATION IN WELDING SHOP

Welding. It is the process of joining two or more metal pieces by heating them upto the desired temperature with or without the application of pressure and with or without the use of filler metal.

Detailed descriptions regarding various welding processes are beyond the scope of this book.

Types of Welding Joints. Before dealing with actual estimation work, different types of welded joints are given below :

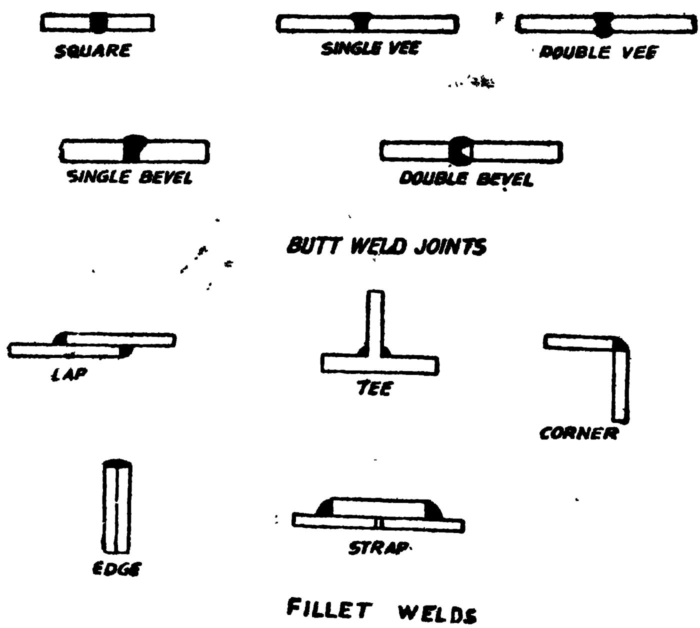


Fig 9·1

GAS WELDING

In case of gas welding following two welding techniques are adopted in practice.

(*i*) Leftward or Fore-hand welding.

(*ii*) Rightward or Back-hand welding.

(*i*) **Left-ward Welding.** In this type, welding is started from right hand side of the joint and proceeds towards the left hand side. This method is suitable for welding plates upto 3 mm. thickness without edge preparation and upto 5 mm. thickness with edge preparation.

(*ii*) **Rightward Welding.** In this type, welding is started from left hand side of the joint and proceeds towards the right hand side. This method is suitable for steel plates which are more than 5 mm. thickness. In plates upto 8 mm. thickness, edge preparation is not required and beyond 8 mm. thickness, plates should be bevelled to about 30°.

Gas welding can only be done on plates upto 25 mm. thickness.

Table 1 on next page is useful in estimating the welding cost in case of gas welding.

ESTIMATION OF WELDING COST

For estimating the welding cost, following costs, should be considered.

(*a*) **Preparation Cost.** It includes the cost of edge preparation, proper fit up and other elements before actual starting of welding.

(*b*) **Actual Welding Cost.** This includes two costs.

(*i*) Cost of material used in welding process like O_2. C_2H_2, filler rod, flux etc.

(*ii*) *Labour Cost.* It will be obtained from wage sheets.

(*iii*) *Welding Finishing Cost.* This includes, the expenditure made for finishing the welded joint after welding. Post welding treatment (such as heat treatment) cost can also be taken into account.

(*iv*) *Oncost.* All the other overheads on the equipment and other facilities connected with welding operations are considered in oncost heading.

GAS CUTTING

It is the cutting of material with the help of gas flame. It is generally done with the help of oxy-acetylene flame. It can be done either by hand or by machine.

Table 2 gives approximate data about the gas cutting operations.

ESTIMATION OF GAS CUTTING COST

Gas cutting cost may be estimated by considering the following steps :

(*i*) **Actual Cutting Cost.** This includes two costs :

(*a*) Cost of material used in cutting process like cost of oxygen, actytelene etc.

TABLE 1

Plate thickness in mm.	*Welding technique*	*Filler rod dia. in mm.*	*O_2 Consumption in cu m/hr.*	*Acetylene Consumption in cu m/hr.*	*Welding Time per metre in min.*	*Length of filler rod required/m. of welding in metre.*
1	Leftward	1·00	0 04	0·02	9 to 11	1·0
2	,,	2·0	0·10	0·04	10 to 12	1·5
3	,,	2·5	0·12	0·07	12 to 13	1·6
4	,,	3 0	0 15	0·10	13 to 15	2·6
5	,,	3 or 4	0·21	0 14	15 to 17	4·0 or 4·8
5	Rightward	2·5	0·3	0 20	16 to 18	3·3
6	,,	3·0	0·4	0·25	18 to 20	3·4
8	,,	4·0	0·5	0·30	20 to 28	3·6
10	,,	5·0	0·7	0·5	30 to 35	4·5
15	,,	6·0	1·0	0·6	45 to 50	6·8
20	,,	6·0	1·2	0·8	60 to 67	10·0
25	,,	6·0	1·6	0·9	85 to 100	16·0

ABLE

Plate thickness in mm.	Nozzle dia. in mm.	O_2 pressure kg./cm.^{2}		Consumption, m^3/hr.				Cutting speed m/hr.	
				O_2		C_2H_2			
		Hand	Machine	Head	Machine	Head	Machine	Hand	Machine
3	0·8 or 1	1·0—1·65	1·0—2·0	1·3—1·4	1·2—1·4	0·2—0·25	0·18—0·25	30—45	30—50
5	1	0·75—1·50	0·75—2·0	0·8—2·0	0·8—2·0	0·15—0·20	0·12—0·2	20—30	18—32
10	1 or 1·5	1·5—2·0	1·5—3·5	1·2—2·4	1·0—2·4	0·20—0·25	0·15—·250	15—30	15—30
15	1·5	1·7—2·5	1·5—3.5	3·4—4·5	3·5—4·5	0·33—0·45	0·33—0·42	18—27	18—30
25	1·5	3·1—2·8	2·0—2·8	3·6—5·0	3·6—5·0	0·36—0·47	0·36—0·47	15—28	18—30

(b) Labourcost·

(ii) **Finishing Cost.** This is the expenditure made on finishing and cleaning the cut parts.

(iii) **Oncosts.** These are all the other overhead charges made on equipment and other items which are connected with cutting processes.

ELECTRIC WELDING

Electric welding is very economical because it requires very less time than that required for gas welding. Following table gives the approximate data which helps in estimating the cost of electric welding.

TABLE 3

Plate thickness in mm.	*Electrode No.*	*Length of electrode reqd. m./m. of welding*	*Welding time in min./m.*	*Power consumption per m. length in kwh.*
3	10	0·50 to 0·60	6 to 7	1·2
5	8	0·70 to 0·80	10 to 12	2·0
10	6	1 00 to 1·20	20 to 25	3·0
15	6	1·75 to 2·00	35 to 40	3·7
20	4	2·00 to 2·50	40 to 45	4·8

ESTIMATION OF ARC WELDING COST

For estimating the cost of arc welding following costs are included.

(i) Material cost—It includes the cost of electrodes.

(ii) Labour cost.

(iii) Power charges.

(iv) Finishihg cost, including post welding treatment cost, if any.

(v) On-cost.

FACTORS AFFECTING WELDING COST

There is certain factors which affects largely on the welding costs. These factors are being discussed below :—

(i) Time required for handling and setting the job and equipment in correct position.

(*ii*) Time required for fixing the fixctures.

(*iii*) Rest and fatigue time allowance. These are generally taken as 5 to 10% of the total time for which an operator remains engaged.

(*iv*) Excessive welding—it increases the cost of welding.

(*v*) When excessive current is used, welding cost also increases.

Solved Problems

Example 1. Estimate the time required for making an open tank of size 40×40×40 cm. by gas welding. Size of the sheets used is 40×40×·3 cm. Welding is to be done on inner sides only. Assume fatigue allowance to be 5%.

Solution. Length of portion where welding is required to be done, which is clear from the above Fig. 8·2.

$=(AB+BC+CD+DA+AE+BF+CG+DH)$

$= 40\times 8 = 320$ cm. $=$ **3·2 m.**

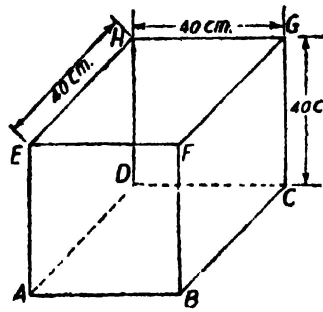


Fig. 8·2

As we are required to weld plates of 3 mm. thickness, which is less than 5 mm. thickness, hence we shall adopt leftward welding technique.

From table, welding speed is 12 min/m. of welding, for 3 mm. thick plates.

∴ Time required for making one tank

$= 12\times 3{\cdot}2$

$=$ **48·4 min.**

Considering fatigue allowance as 5% ;

Actual time taken by welder for welding one tank

$= 38{\cdot}4\times 1{\cdot}05$

$=$ **40·3 min. Ans**

Example 2. Estimate the material cost for welding 2 flat pieces of m.s. 15×6×1 cm. size, to form an angle iron of 90° by gas welding. Neglect edge preparation cost and assume :—

(*a*) cost of O_2	Rs. 60/100 cu. m.
(*b*) cost of C_2H_2	Rs. 500/100 cu. m.
(*c*) density of filler metal	7 gm./c.c.
(*d*) cost of filler metal	Rs. 2/kg.

Solution. As the thickness of the plates to be welded is more than 5 mm., therefore rightward welding method is adopted.

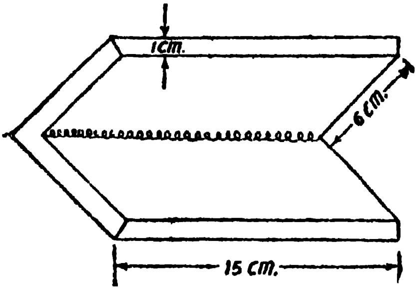


Fig. 8·3

From tables, for 10 mm thick plates.

O_2 consumption
= 0·7 cu. m./hr.

C_2H_2 consumption
= 0 5 cu. m./hr.

Filler rod dia. = 5 mm.
Length of filler rod required
= 4·5 m./m. of welding

Welding time
= 30 min./m. of welding.

∴ Time required to weld 15 cm. length

$$= \frac{15}{100} \times 30$$

= **4·5 min.**

(*i*) Amount of oxygen consumed @ 0·7 cu. m./hr.

$$= 0{\cdot}7 \times \frac{4{\cdot}5}{60} = 0{\cdot}053 \text{ cu. m.}$$

∴ Cost of oxygen @ Rs. 60/100 cu. m. $= 0\ 053 \times \frac{60}{100}$

= **Re. 0·0318**

(*ii*) Now, Amount of C_2H_2 consumed in 4·5 min.
@ 0·5 cu. m./hr,

$$= 0{\cdot}5 \times \frac{4{\cdot}5}{60} = 0{\cdot}0375 \text{ cu. m.}$$

Cost of C_2H_2 @ Rs. 500/100 cu. m.

$$0{\cdot}0375 \times \frac{500}{100}$$

= **Rs. 0·1875**

(*iii*) Length of filler rod required for 15 cm. job @ 4·5 m./m. of welding

$$= 0{\cdot}15 \times 4{\cdot}5 = {\cdot}675 \text{ m.}$$

But for 10 mm. thick plates, filler rod dia. = 5 mm.

∴ Weight of filler rod consumed

= Volume × density.

$$= \frac{\pi}{4} (0{\cdot}5)^2 \times 67{\cdot}5 \times 7 \text{ gm.} = 92{\cdot}8 \text{ gm.}$$

= **0·0928 kg.**

∴ Cost of filler rod @ Rs. 2/kg. $= 2 \times 0{\cdot}0928$

$= \textbf{Re. 0·1856}$

∴ Total material cost

$= 0{\cdot}0318 + 0{\cdot}1875 + 0{\cdot}1856$

$= \textbf{Re. 0·4049}$ =41 paise (say)

Example 3. Calculate (*a*) cost of cutting 'V' groove with gas, (*b*) welding cost for welding two 1 m long m.s. pieces of 8 mm. thickness. If cost of O_2 is Re 0.60 per cu. m. ; cost of C_2H_2 is Rs. 5·0 per m. ; cost of filler rod is Rs. 2 per kg. ; labour chages are Re 0·80 per hr. ; and 60° V-groove is prepared for welding.

Solution.

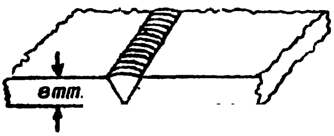


Fig. 8·4

(*a*) **Groove Cutting** :—

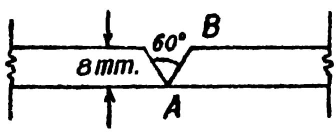


Fig. 8·5

$$\text{Length of cut } AB = \frac{8}{\sin 60} = \frac{8 \times 2}{\sqrt{3}} = 9 \text{ mm. (say)}$$

From tables, cutting speed = 20 m./hr.

Oxygen consumption = 2 cu. m./hr.

Acetylene consumtion = 0·2 cu. m./hr.

Therefore, time required to cut one piece of 1 m. length

$$= \frac{1}{20} \text{ hr.} = 3 \text{ min.}$$

∴ Time required to cut both pieces each of 1 m.

$= 2 \times 3 = 6$ min.

(*i*) Amount of oxygen required $= 6 \times \frac{2}{60}$ cu. m. $= 0{\cdot}2$ cu. m.

∴ Cost of oxygen @ Re. 0·60/cu. m.

$= 0{\cdot}2 \times 0{\cdot}60$

$= \textbf{Re. 0·12.}$

(*ii*) Amout of acetylene required $= 6 \times \frac{0{\cdot}2}{60}$ cu. m.

$= 0{\cdot}02$ cu. m.

$\therefore$ Cost of acetylene @ Rs. 5·0/cu. m. $= 0{\cdot}02 \times 5{\cdot}0$
$=$ **Re. 0·10**

(*iii*) Labour cost of cutting @ Re. 0·80/hr. $= 0{\cdot}80 \times \frac{6}{60}$

$=$ **Re. 0·08**

$\therefore$ Total cutting cost $= 0{\cdot}12 + 0{\cdot}10 + 0{\cdot}08$
$=$ **Re. 0·30. Ans.**

(*b*) **Welding cost.** From tables, for 8 mm. thick plate (rightward welding).

Filler rod dia. $= 4$ mm.
Oxygen consumption $= 0{\cdot}5$ cu. m./hr.
Acetylene consumption $= 0{\cdot}3$ cu. m./hr.
Welding time/m. length $= 25$ min.
Length of filler rod used/m. of welding $= 3{\cdot}6$ m.
As length of portion to be welded is 1 m.
$\therefore$ Time required for welding $= 25 \times 1 = 25$ min.

(*i*) Oxygen consumed $= 0{\cdot}5 \times \frac{25}{60} = 0{\cdot}209$ cu. m.

$\therefore$ Cost of oxygen @ Re. 0·60/cu. m.
$= 0{\cdot}209 \times 0{\cdot}60 =$ Re. 0·125

(*ii*) Acetylene consumed

$= 0{\cdot}3 \times \frac{25}{60}$

$=$ Re. 0·125 cu. m.

$\therefore$ Cost of acetylene @ Rs. 5·0/cu. m.
$= 0{\cdot}125 \times 5$
$=$ **Re. 0·625.**

(*iii*) Length of filler rod used for 1 m. welding $= 3{\cdot}6$ m.

$\therefore$ Wt. of filler rod $= \frac{\pi}{4}(0{\cdot}4)^2 \times 360 \times 7$ gm.

$= 0{\cdot}3168$ kg.

$\therefore$ Cost of filler rod @ Rs. 2/kg.
$= 2 \times 0{\cdot}3168$
$=$ **Re. 0·6336.**

(*iv*) **Labour charges of welding @ 0·80/hr. for 25 min.**

$= \frac{25}{60} \times 0{\cdot}80$

$=$ **Re. 0·33.**

∴ Total cost of welding

$= 0{\cdot}125+0{\cdot}625+0{\cdot}633+0{\cdot}333$

= Rs. 1·716

= **Rs. 1·72. Ans.**

Hence,

(*a*) Cost of cutting = Rs. 0·30
(*b*) Cost of welding = Rs. 1·72 } **Ans.**

Example 4. Find the welding material cost for making a rectangular frame for a gate of 2 m. × 1 m. from angle iron of size 30 mm. × 30 mm. × 5 mm. Assume the following data :

(*a*) Oxygen consumption = 0·4 cu. m/hr. which is available @ Re. 0·60/cu. m.

(*b*) Acetylene consumption = 0·4 cu. m./hr. which is available @ Rs. 5 0/cu. m.

(*c*) Welding speed = 4 m./hr.

(*d*) Lenth of filler rod of dia. 2·5 mm. = 3·4 m/m. of welding

(*e*) Filler rod material cost = Rs. 3/kg.

(*f*) Welding is to be done on both the sides.

Solution. Portion to be welded in the frame is shown in Fig. 8·6.

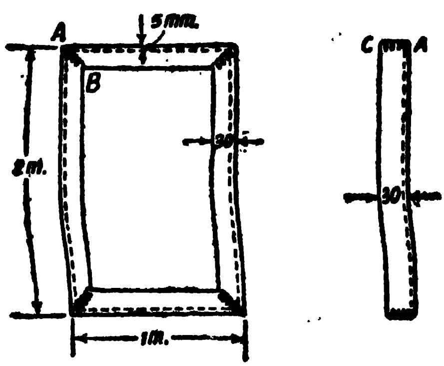


Fig. 8·6

Let us consider that first of all welding is done only on one corner, where welding is done on portions *AB* and *AC*.

where, Length $AB = \dfrac{30}{\sin 45} = 30\sqrt{2}$

= 42 4 mm.

and Length AC = 30 mm.

∴ Length of welding on one corner on one side

= 42·4+30 = 72 4 mm.

= **7·24 cm.**

∴ Length of welding on all the 4 corners and on both sides

$= 7{\cdot}24 \times 8$

$=$ **57·92 cm.**

$= 0{\cdot}58$ m. (say)

As welding speed $= 4$ m/hr.

∴ Time required for welding

$$0{\cdot}58 \text{ m.} = \frac{60}{4} \times 0{\cdot}58$$

$=$ **8·7 min.**

(*i*) Oxygen consumption @ 0·4 cu. m./hr.

$$= \frac{8{\cdot}7}{60} \times 0{\cdot}4 = 0{\cdot}058 \text{ cu. m.}$$

∴ Cost of oxygen @ Re. 0·60/cu. m. $= 0{\cdot}058 \times 0{\cdot}60$

$=$ **Re. 0·0348.**

(*ii*) Acetylene consumption @ 0·4 cu. m./hr.

$= 0\ 058$ cu cm.

∴ Cost of acetylene @ Rs. 5·0/cu. m.

$= {\cdot}058 \times 5{\cdot}0 =$ **Re. 0·29.**

(*iii*) Length of filler rod required @ 3·4 cu. m./m. of welding.

$= 3{\cdot}4 \times 0{\cdot}58$

$=$ **1·972 m.**

∴ Weight of filler rod (assuming the density as 7 gm./c.c.)

$$= \frac{\pi}{4}(0{\cdot}25)^2 \times 197{\cdot}2 \times 7 = 67 \text{ gm.}$$

$=$ **0·067 kg.**

∴ Cost of filler rod @ Rs. 3/kg. $= 0{\cdot}067 \times 3$

$=$ **Re. 0·201.**

∴ Total welding material cost

$= 0{\cdot}03448 + 0{\cdot}2900 + 0\ 2010$

$=$ Re. 0·5258

$=$ **Re. 0·53 (say). Ans.**

Example. 5 Two 1 m. long m.s. plates of 10 mm. thickness are to be welded by a lap joint with the help of a 6 mm. electrode. Calculate cost of welding. Assume following data :

(*i*) Cureent used—250 ampere.

(*ii*) Voltage—30V.

(*iii*) Welding speed = 10 m./hr.

(*iv*) Electrode used = 0·4 kg./m. of welding.

(*v*) Labour charges = Re. 1 00/hr.

(*vi*) Power charges = Re. 0·20/kWh.

(*vii*) Cost of electrode = Rs. 5·00/kg.

(*viii*) Efficiency of machine 60%.

Solution.

(*a*) **Cost of Electrode.** Metal of electrode required for 1 m. length of welding = 0·4 kg.

∴ Cost of electrode @ Rs. 5·00/kg. = 5 × 0·4

= **Rs. 2·00.**

(*b*) **Lobour Cost.** Time required for welding 1 m. length

$= \frac{1}{10}$ hr.

∴ Labour cost @ Re. 1·00/hr.

$= \frac{1}{10} \times 1 =$ **Re. 0·10**

(*c*) **Power Charges.** As, power consumed

$$= \frac{V \times I}{\text{Efficiency of the machine}}$$

$$= \frac{250 \times 30}{0\cdot6} \text{ watt} = 12\cdot5 \text{ kW}$$

∴ Energy cunsumed for welding 1 m. length

$$= 12\cdot5 \times \frac{1}{10} = 1\cdot25 \text{ kWh}$$

∴ Power charges @ Re. 0·20/kWh

= 1·25 × 0·20 = **Re. 0·25**

∴ Total welding cost = Cost of electrode + Labour charges + Power charges

= 2·00 + 0·10 + 0·25

= **Rs. 2·35. Ans.**

√**Example 6.** A cylindrical boiler drum 2½ m. × 1 m. dia. is to be made from 15 mm. thick m.s. plates. Both the ends are closed by welding circular plates to the drum. Cylindrical portion is welded along the longitudinal seam. Welding is done both on inner and outer sides. Calculate electric welding cost using the following data :

(*i*) Rate of welding = 2m./hr. on inner side and 2·5 m./hr. on outer side.

(*ii*) Length of electrode required = 1·5 m./m. of welding.

(*iii*) Cost of electrodes Re. 0·60/m.

(*iv*) Power consumption = 4 kWh/m. of weld.

(*v*) Power charges = 15 paise/kWh.

(*vi*) Labour charges = 80 paise/hr.

(*vii*) Other overhead charges = 200% of prime cost.

(*viii*) Discarded electrodes = 5%.

(*ix*) Fatigue and setting up time = 5% of welding time.

Solution. Total length of weld on outer side = Length of weld on inner side = Length for welding on circular plates + length for welding seam joint.

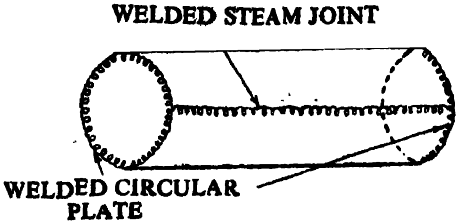


Fig. 8·7

$= 2(\pi \times 1) + 2{\cdot}5 = 8{\cdot}78$ m.

(*i*) **Labour Charges.** Time required for welding 8·78 m. is :

(*a*) On outer side $= \dfrac{8{\cdot}78}{2{\cdot}5}$ hrs.

$= 3{\cdot}51$ **hrs.**

(*b*) On inner side $= \dfrac{8{\cdot}78}{2{\cdot}0}$ hrs.

$= 4{\cdot}39$ **hrs.**

∴ Total time required

$= 3{\cdot}51 + 4{\cdot}39 = 7{\cdot}90$ hrs.

∴ Labour charges @ 80 paise/hr.

$= 7{\cdot}9 \times 0{\cdot}8 =$ **Rs. 6·32.**

But considering fatigue and setting up time,

Actual labour charges

$= 6{\cdot}32 \times 1{\cdot}05 =$ **Rs. 6·64.**

(*ii*) **Cost of Electrodes.** Length of electrode required @ 1·5 m./m. of welding $= 1{\cdot}5 \times (2 \times 8{\cdot}78) = 26{\cdot}34$ **m.**

Considering 5% discarded electrodes,

Electrodes consumed $= 26{\cdot}34 \times 1{\cdot}05$

$= 27{\cdot}66$ **m.**

∴ Cost of electrode @ Re. 0·60/m.

$= 27{\cdot}66 \times 6 =$ **Rs. 16·60.**

(*ii*) **Cost of Power.** Power consumption for 17·56 m. of welding

$= 4 \times 17{\cdot}56 = 70{\cdot}24$ kWh.

∴ Cost of power @ 15 paise/kWh.

$= 70{\cdot}24 \times 0{\cdot}15 =$ **Rs. 10·54.**

Overheads. As, prime cost = Direct labour cost+Direct material cost

= 6·64+16·60 = Rs. 23·24

∴ Overhead = 200% of prime cost

= 2×23·24 = **Rs. 46·48.**

Total welding cost = 23·24+10·54+56·48

= **Rs. 80·26 Ans.**

Unsolved Problems

1. You are required to weld two flat plates 25 cm.×10 cm. ×0·625 cm. each to make a plate of 25 cm.×20 cm. Calculate the welding material cost, if no edge preparation is required. Assume rightward welding technique.

Cost of oxygen 75 paise/cu. m. ; of acetylene Rs. 7·50/cu. m. Cost of filler material = Rs. 2·00/kg. [**Ans.** Re. 0·65]

2. Calculate the material cost and labour cost for welding 3·5 cm.×3·5 cm.×0·6 cm. angle iron into an equilateral triangular frame of side 17·5 cm. each. If the rates for oxygen, acetylene and filler material are Re. 0·80/cu. m., Rs. 7·25/cu. m. and Rs. 2·00/kg. respectively. Worker is available at 80 paise/hr.

[**Ans.** 17 paise and 29 paise]

3. Two 50 cm. long m.s. plates of 1 cm. thickness are to be welded by a lap joint with the help of a 6 mm. electrode. Calculate the cost of welding if :

(*i*) Current used 250 amps.

(*ii*) Voltage = 30 V.

(*iii*) Welding speed = 10 m./hr.

(*iv*) Electrode used 0·4 kg./m. of welding.

(*v*) Labour charges Re. 1·00/hr.

(*vi*) Labour charges Re. 0·20/kWh.

(*vii*) Cost of electrode Rs. 5·00/kg.

(*viii*) Efficiency of machine = 60%. [**Ans.** Rs. 1·18]

9

PATTERN MAKING AND FOUNDRY SHOPS

Definition of Pattern. It is a model of the product to be casted. It may differ in dimensions by an amount equal to sum of that allowances considered, such as shrinkage allowance, draft allowance and machining allowance etc.

Pattern can be made from wood, metals, plaster of paris and plastics etc. For precision work, wax can also be used. Wood patterns are useful where castings required are in small number because wood is cheap, easily workable and light. For large number of products, metallic patterns are used because they are durable and are not affected by atmospheric conditions.

Pattern Allowances. Following are the important allowances which should be considered while making pattern :

(*i*) Contraction or shrinkage allowance,

(*ii*). Machining allowance.

(*iii*) Draft allowance.

Contraction allowance. Different metals contract during cooling at different rate. This amount is given for some important metals as under :

Cast Iron	=10 mm. per metre length.
Brass	=15 mm. per metre length.
Aluminium	=13 mm. per metre length.
Steel	=21 mm. per metre length.

(*ii*) **Machining Allowance.** Surfaces of casting, which are to be machined are made slightly larger than that of finished size by an amount known as machining or finishing allowance.

This allowance varies with the nature and quality of work.

(*iii*) **Draft Allowance.** This allowance is provided to facilitate the withdrawal of the pattern from the mould. For this purpose, a slight taper is provided in the pattern.

ESTIMATION OF PATTERN COST

Estimation of pattern cost can be divided into the following :

(*a*) Direct material cost.

(*b*) Direct labour cost.

(*c*) Overheads.

(*a*) **Direct Material Cost.** The material cost of a pattern is estimated after calculating the amount of material required for making it. For determining this cost, suitable allowances provided in making a pattern should also be estimated.

(*b*) **Labour Cost.** Calculation of labour cost is a very difficult problem. It can be estimated from any of the two methods.

(*i*) Estimator by his experience can judge the time needed in the manufacture of a particular pattern and then calculates labour cost.

(*ii*) Time taken by similar previous works are accounted for estimating labour cost.

(*c*) **Overheads.** Overheads consist all other charges which include the salaries of supervisors, indirect labour charges, depreciation of tools and machines etc. These are fixed as percentage of the total cost, which can be determined by previous experience.

ESTIMATION IN FOUNDRY SHOP

Definition of Foundry. It is a shop, in which metal is melted in a furnace and then poured into the moulds prepared from the patterns to get the casting of the required product.

Foundry Cost. This cost can be estimated by adding the following three costs :

(*i*) Material cost.

(*ii*) Labour cost.

(*iii*) Oncost.

Foundry shop involves various operations, such as, moulding, melting, pouring, casting and fettling etc.

Material cost in foundry is the sum of expenditure made on material required in all the above operations.

Labour cost is the cost of labour for performing all the above operations.

Oncost includes all other expenses, which are not considered in material and labour costs.

Following numerical examples will give the complete procedure for the estimation in pattern making and foundry shops.

Solved Problems

Example 1. A finished drawing of a C.I. flanged pipe is given below in Fig. 9·1. You are required to prepare a wooden pattern in the pattern making shop. Find the quantity of wood required for manufacturing the pattern.

Also estimate the cost of pattern, if :

(*a*) Wood is available at the rate of Rs. 800/m.^{3}

(*b*) Pattern maker is available at the rate of Rs. 8 per day and takes 6 hours in preparing the pattern.

(c) Overhead charges are 100% of material cost.

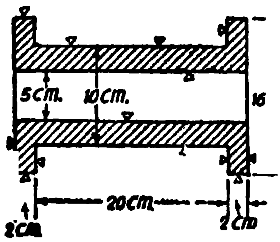


Fig. 9·1

For making the pattern, allowances for metal shrinkage (10 mm per metre length) and for machining (2 mm. on each side on casting) is added in the dimensions of the finished product.

Now considering these allowances, the dimensions of pattern with core prints will be as shown in Fig. 9·2.

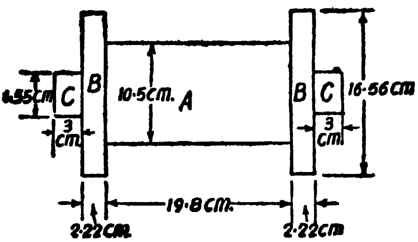


Fig. 9·2

For simplicity in calculations, Fig. 9·2 can be split up into parts *A*, *B* and *C*.

The amount of rough wood required for each part can be estimated by considering pattern finishing allowance 3 mm. on each surface to be finished. To make the pattern economical each part is prepared separately and then fixed together to get the complete pattern instead of preparing the whole pattern from one piece of wood.

Part A. The size of rough wood required would be :

Length	=19 8+0 3+0·3	=20·4 cm.
Width	=10·5+0·3+0·3	=11·1 cm.
Thickness	=10·5+0·3+0·3	=11·1 cm.
∴ Volume	=20·4×11·1×11·1	= 2513 cm.³

Part B. These are two in number.

The size of rough wood required would be :

Length	= 16·56+0·3+0·3	= 17·16 cm.
Width	= 16·56+0·3+0·3	= 17·16 cm.
Thickness	= 2·22+0 3+0·3	= 2·82 cm.
∴ Volume	= 2×17·16×17·16×2·82	= 1593 cm.³

Part C. There are 2 core prints which are made on the pattern for resting the core in the mould.

The size of rough wood required would be :

Length = 4·55+0·3+0·3 = 5·15 cm.

Width $= 4{\cdot}55+0{\cdot}3+0{\cdot}3 = 5{\cdot}15$ cm.

Thickness $= 3+0{\cdot}3+0{\cdot}3 = 3{\cdot}60$ cm.

$\therefore$ Volume $= 2\times 5{\cdot}15\times 5{\cdot}15\times 3{\cdot}60 = 191{\cdot}0$ cm^3.

$\therefore$ Total amount of wood required

$= 2513+1593+191{\cdot}0$

$=$ **4297 cm.^{3} Ans.**

Costing.

(*a*) Material cost Rs. 800/m.^{3}

$$\frac{4297}{10^6}\times 800 = \text{Rs. } 3{\cdot}44.$$

(*b*) Labour cost @ Rs. 8 per day

$$= \frac{6}{8}\times 8$$

$=$ Rs. 6·00.

($\because$ Worker completes pattern in 6 hours and it is assumed that normal working hours for workers are 8 hours per day.)

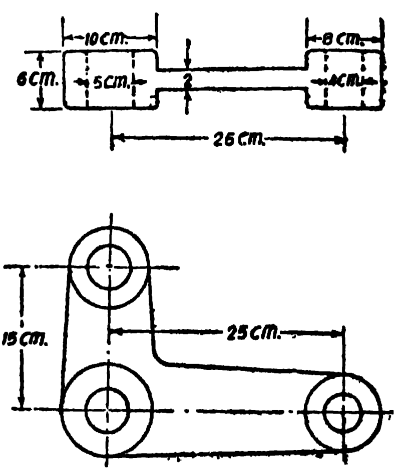
(*c*) Overheads, therefore 100% of material cost,

$=$ Rs. 3·44.

$\therefore$ Cost of pattern $=$ Rs. 3·44+Rs. 6·00+Rs. 3·44

$=$ **Rs. 12·88. Ans.**

Example 2. Find out the cost of wood required for making the pattern of a Bell crank lever. The finished drawing of C.I. Bell crank lever is given in Fig. 9·3. Wood is available @ Rs. 800/m.^{3}. Holes are to be bored on machines after casting.

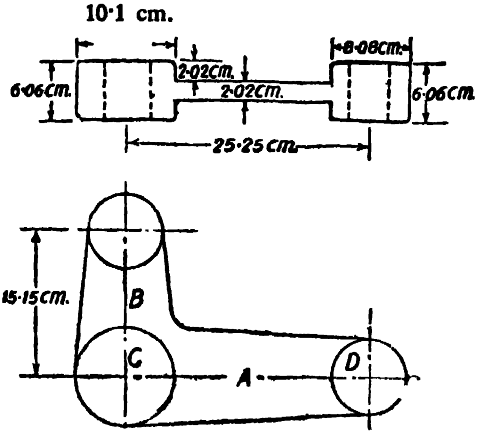


Finished Drawing

Fig. 9·3

Solution. To find out the amount of wood required for making the pattern, shrinkage and pattern finishing allowances would be necessary to consider :

After considering the shrinkage allowance 10 mm./metre length and finishing allowance 3 mm. on each side, the sketch of pattern is shown in Fig. 9·4.



Pattern of Bell Crank Lever
Fig. 9·4

For simplicity in calculations, the drawing is split up in four parts *A*, *B*, *C* and *D*.

Long Arm A. The size of rough wood required should be as follows :

Length $25{\cdot}25+\frac{10{\cdot}1}{2}+\frac{8\ 08}{2}+0\ 3+0{\cdot}3$

$= 34\ 94$ cm.

Width $=$ Dia. of C $(10{\cdot}1)+0{\cdot}3+0{\cdot}3 = 10{\cdot}7$ cm.

Thickness $= 2\ 02+0{\cdot}3+0{\cdot}3 = 2{\cdot}62$ cm.

∴ Volume of rough wood required for *A*

$= 34{\cdot}94\times 10\ 7\times 2{\cdot}62$

$= 980$ cm.^{3}

Small Arm B. The size of rough wood required for this arm would be as follows, considering that this pipe would be fixed with arm *A*.

Length $= 15\ 15+\frac{10{\cdot}1}{2}+\frac{8{\cdot}08}{2}+0{\cdot}3+0{\cdot}3$

$= 24{\cdot}84$ cm.

Width $=$ Dia. of $C(10{\cdot}1)+0{\cdot}3+0{\cdot}3 = 10{\cdot}7$ cm.

Thicknes $= 2{\cdot}02+0{\cdot}3+0{\cdot}3$

$= 2{\cdot}62$ cm.

∴ Volume of rough wood required for *B*

$= 24{\cdot}84\times 10{\cdot}7\times 2{\cdot}62 = 696$ cm.^{3}

Hub C. These are two in number and will be fixed on both the sides of arm.

The size of rough wood required for making the hub will be as follows :

Length	$= 10{\cdot}1+0{\cdot}3+0{\cdot}3$	$= 10{\cdot}7$ cm.
Width	$= 10{\cdot}1+0{\cdot}3+0{\cdot}3$	$= 10{\cdot}7$ cm.
Thickness	$= 2{\cdot}02+0{\cdot}3+0{\cdot}3$	$= 2{\cdot}62$ cm.

$\therefore$ Volume of rough would required for C, two hubs

$$= 2\times 10{\cdot}7\times 10{\cdot}7\times 2{\cdot}62$$
$$= 600 \text{ cm.}^3$$

Hub D. These are two in number and each will be fixed on both the sides of arm A and arm B as shown.

The size of rough wood required will be as follows :

Length	$= 8{\cdot}08+0{\cdot}3+0{\cdot}3 = 8{\cdot}68$ cm.
Width	$= 8{\cdot}08+0{\cdot}3+0{\cdot}3 = 8{\cdot}68$ cm.
Thickness	$= 2{\cdot}02+0{\cdot}3+0{\cdot}3 = 2{\cdot}62$ cm.
$\therefore$ Volume	$= 4\times 8{\cdot}68\times 8{\cdot}68\times 2{\cdot}62 = 789$ cm.^{3}

To make the pattern economical, each part is prepared separately from wood pieces and then fixed together to get complete pattern, instead of preparing the whole pattern from one piece of wood.

Now, total volume of wood required will be

$$= 980+696+600+789$$
$$= 3065 \text{ cm.}^3$$
$$= \frac{3065}{10^6} = 0{\cdot}003065 \text{ m.}^3$$

Rate of wood $=$ Rs. $800/\text{m.}^3$

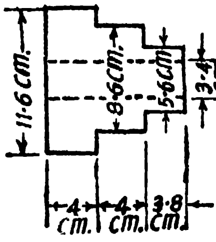
$\therefore$ Cost of wood $= 0{\cdot}003065\times 800$

$=$ **Rs. 2·45. Ans.**

Example 3. Find the cost of 2000 C.I. pulleys shown in Fig. 9·5. Its surfaces are to be machined after casting. The pattern is supplied by the customer itself. Following data can be used.

Cost of metal = Re. 0·75/kg.

Moulds prepared by each worker/day = 20.



Finishing Product
Fig. 9·5

Melting charges $= 20\%$ of metal cost.

Machining allowance on each side may be taken as 2 mm.

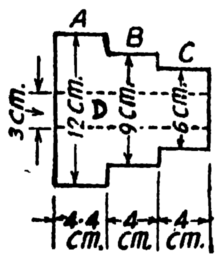
Wages of each moulder = Rs. 6/day.
Density of C.I. $= 7{\cdot}2$ gm./c.c.
Overhead charges $= 25\%$ of metal cost.

Solution. Size of the casting is shown in sketch Fig. 9·6 in which machining allowance has been added.

For easy calculations, split up the drawing into simple parts *A*, *B*, *C* and *D*.

Volume of step *A* $= \frac{\pi}{4}(12)^2 \times 4{\cdot}4$

$= 158{\cdot}4$ cm.^{3}



Casting
Fig. 9·6

Volume of step *B* $= \frac{\pi}{4}(9)^2 \times 4$

$= 81\pi$ cm.^{3}

Volume of step *C* $= \frac{\pi}{4}(6)^2 \times 4$

$= 36\pi$

Volume of hole *D* $= \frac{\pi}{4}(3)^2 \times 12{\cdot}4$

$= 27{\cdot}9\,\pi$

∴ Total volume of pulley

$= (158{\cdot}4+81+36-27{\cdot}9)\pi = 777$ cm^3.

∴ Weight of C.I. required

$= 777 \times 0{\cdot}0072$ kg. $=$ **5·6 kg.**

Costing. Cost for each piece is determined as under :

(*a*) Material cost $=$ Re. $0{\cdot}75 \times 5{\cdot}6 =$ Rs. 4·20

(*b*) Melting charges $= 0{\cdot}20 \times 4{\cdot}20 =$ Re. 0·84

(*c*) Moulding charges $= \frac{6}{20}$

$=$ Re. 0·30

$\frac{25}{100} \times 4{\cdot}2 =$ Rs. 1·05

∴ Total cost/casting $= 4{\cdot}20+0{\cdot}84+0{\cdot}30+1{\cdot}05$

$=$ **Rs. 6·39.**

∴ Cost of 2000 castings

$= 2000 \times 6{\cdot}39$

$=$ **Rs. 12,780. Ans.**

Example 4. 50 bevel gear blanks are to be casted as per finished drawing shown in Fig. 9·7. 2 mm. machining allowance in the pattern is allowed on each side. Estimate the selling price of one gear blank, using the following data :

Pattern is supplied by the customer.

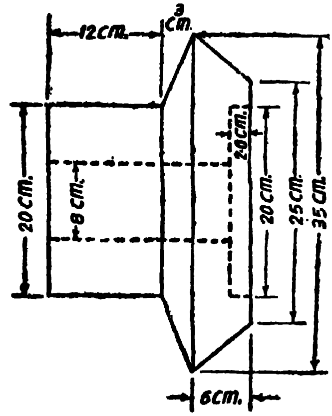
Cost of C.I. = Re. 0·80/kg.

Melting charges = 15% of the material cost

Administrative overheads
= 15% of the material cost

Profit = 10% of total cost

Moulding charges = Re 0·25 each mould.



Finished Gear Blank.

Fig. 9·7

Solution. Size of the casting will be larger than the finished gear blank by an amount equal to machining allowance. Casting will be of size shown in Fig. 9·8.

Split up the drawing into simple parts *A*, *B*, *C*, *D* and *E*.

Volume of *A*

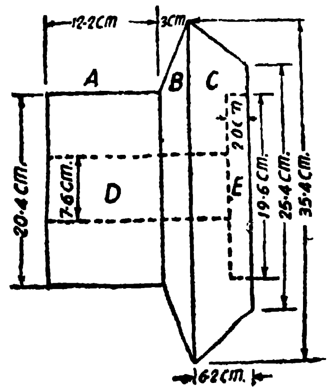
$$= \frac{\pi}{4}(20{\cdot}4)^2 \times 12{\cdot}2$$
$$= 2245\ \pi\ \text{cm.}^3$$

Volume of *B*

$$= \frac{h}{3}(a_1 + a_2 + \sqrt{a_1 a_2})$$

$$\left[\frac{\pi}{4}(35{\cdot}4)^2 + \frac{\pi}{4}(20{\cdot}4)^2 + \frac{\pi}{4}\sqrt{(35{\cdot}4)^2 \times (20{\cdot}4)^2}\right.$$

$$597{\cdot}7\ \pi\ \text{cm.}^3$$



Casting

Fig. 9 8

$$\text{Volume of } C = \frac{h}{3}(a_1+a_2+\sqrt{a_1a_2})$$

$$= \frac{6{\cdot}2}{3}\left\{\frac{\pi}{4}(35{\cdot}4)^2+\frac{\pi}{4}(25{\cdot}4)^2 + \frac{\pi}{4}\sqrt{(35{\cdot}4)^2\times(25{\cdot}4)^2}\right\}$$

$$= 1454{\cdot}4\ \pi \text{ cm.}^3$$

$$\text{Volume of } D = \frac{\pi}{4}(7{\cdot}6)^2\times 19{\cdot}4$$

$$= 280\ \pi \text{ cm.}^3$$

$$\text{Volume of } E = \frac{\pi}{4}(19{\cdot}6)^2\times 2 = 192\ \pi \text{ cm.}^3$$

∴ Total volume of casted gear blank

$$= A+B+C-D-E$$

$$= \pi(1245+597{\cdot}7+1454{\cdot}4-280-192)$$

$$= 8870 \text{ cm.}^3$$

Costing

Weight of casting = 0·0072×8870 = 64 kg.

(*a*) Cost of C.I. = 0 80×64 = Rs. 51·20

(*b*) Melting charges = 0·15×51·20 = Rs. 7·68

(*c*) Moulding charges = Re. 0·25

(*d*) Administration overheads

= 0·15×51·20 = Rs. 7·68

∴ Total cost = 51·20+7·68+7·68+0·25

= Rs. 66·81

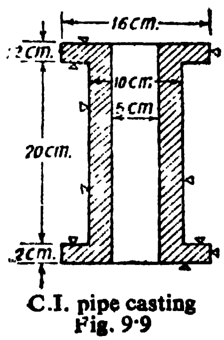
∴ Profit = 10% of total cost

= 0·10×66·81 = Rs. 6·68

∴ Selling price = 66·81+6·68

= **Rs. 73·49. Ans.**

Example 5. Estimate the total cost of 20 C.I. flanged pipe casting shown in Fig. 9·9, assuming the following data :



C.I. pipe casting
Fig. 9·9

(*i*) Cost of C.I. = 70 Paise/kg.

(*ii*) Cost of process scrap=25 Paise/kg.

(*iii*) Process scrap = 2% of net weight of casting

(*iv*) Moulding and pouring charges = Re. 1·00/piece

(v) Casting removal and cleaning = Re. 0·20/piece
(vi) Administrative overheads = 5% Factory cost
(vii) Selling overheads = 70% Administrative overheads

Solution. Volume of C.I. pipe

$$= \frac{\pi}{4}(16)^2\times4+\frac{\pi}{4}(10)^2\times20 - \frac{\pi}{4}(5)^2\times24$$

$$= 1902 \text{ cm.}^3$$

Wt. of C.I. pipe = 0 0072×1902 = 13 7 kg.

∴ Process scrap @ 2% net wt. of casting

$$= \frac{2}{100}\times13{\cdot}7 = 0{\cdot}274 \text{ kg.}$$

∴ Total C.I. required

= 13·7+0·274 = 13·974 kg.

∴ Cost of C.I. = 0·70×13·974
= Rs. 9·80 (nearly)

Amount recovered back by selling process scrap
= 0·274×0·25 = Re. 0 07

Costing/pipe

(a) Material cost = Rs. 9·80−0 07 = Rs. 9·73
(b) Moulding and pouring charges
= Re. 1·00
(c) Casting removal and cleaning = Re. 0·20
(d) Factory cost = 9·73+1·00+0·20 = Rs. 10·93
(e) Administrative overheads
= 0·50×10·93 = Rs. 5·47
(f) Selling overheads = 0 70×5·47 = Rs. 3·83
∴ Total cost = 10 93+5·47+3·83 = Rs. 20·23
∴ Total cost of 20 pipes
= 20×20·23 = **Rs. 404·60. Ans.**

Example 6. A manufacturer is willing to undertake the casting of 100 cast iron wheels shown in Fig. 9 10

Estimate the selling price of each wheel assuming the following :

(i) Cost of pattern = Rs. 10·00
(ii) Process Scrap = 10% of net weight
(iii) Scrap return value = Re. 0·25/kg.
(iv) Cost of C.I. = 70 Paise/kg.
(v) Administrative overheads
= Re. 1 00/piece

(*vi*) Selling overheads = 25% of production cost
(*vii*) Profit = 15% of total cost

Unit operation	*Time*	*Rate/hour*	*Shop overheads*
Moulding	10 minutes	Re. 0·50	Rs. 2·00/hr.
Pouring	5 minutes	Re. 0·20	Re. 1·00/hr.
Shot Blasting	4 minutes	Re. 0·45	Rs. 1·50/hr.
Fettling	4 minutes	Re. 0·60	Re. 1·00/hr.

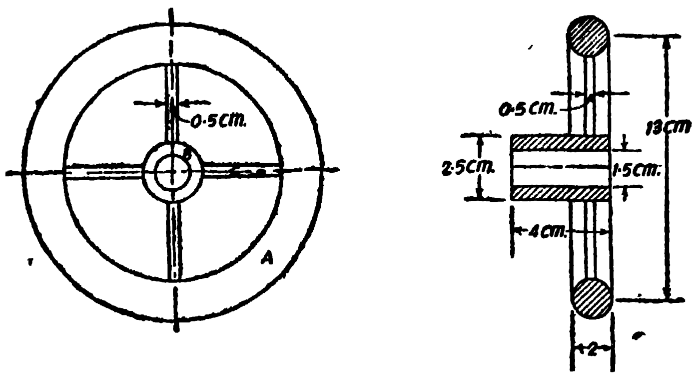


Fig. 9·10

Solution. Volume of rim,

$$A = \pi \times 13 \times \frac{\pi}{4}(2)^2 = 128{\cdot}3 \text{ cm.}^3$$

Volume of hole $B = \frac{\pi}{4}\left[(2{\cdot}5)^2-(1{\cdot}5)^2\right]\times 4$

$$\doteq 12{\cdot}56 \text{ cm.}^3$$

Length of one spoke, $C = \frac{13-2-2{\cdot}5}{2} = 4{\cdot}25$ cm.

∴ Volume of 4 spokes,

$$C = 4\times\frac{\pi}{4}(0{\cdot}5)^2\times 4{\cdot}25 = 3{\cdot}34 \text{ cm.}^3$$

∴ Total volume of casting

$$= 128{\cdot}30+12{\cdot}56+3{\cdot}34$$
$$= 144{\cdot}20 \text{ cm.}^3$$

∴ Weight of casting = $0·0072 \times 144·2 = 0·99$ kg.
Now, weight of scrap = $0·10 \times 0·99 = 0·099$ kg.
∴ Weight of C.I. required
= $0·99 + 0·099 = 1·089$ kg.

Costing

A

(*i*) Cost of C.I. = $0·70 \times 1·089$ kg. = Re. 0·76

(*ii*) Amount recovered from scarp
= $0·099 \times 0·25$
= Re. 0·03 (say)

(*iii*) ∴ Material cost = $0·76 - 0·03$ = Re. 0·73.

B

Pattern cost is Rs. 10·00 for 100 wheels
∴ Pattern cost/wheel = Re. 0·10

C

(*i*) Moulding charges = $0·50 \times \frac{10}{60}$ = Re. 0·08

(*ii*) Pouring charges = $0·20 \times \frac{5}{60}$ = Re. 0·02 (say)

(*iii*) Shot blasting charges = $0·45 \times \frac{4}{60}$ = Re. 0·03

(*iv*) Fettling charges = $0·60 \times \frac{5}{60}$ = Re. 0·05

D

(*i*) Moulding shop overheads
= $2·00 \times \frac{10}{60}$ = Re. 0·33

(*ii*) Pouring shop overheads
= $1·00 \times \frac{5}{60}$ = Re. 0·08

(*iii*) Shot blasting overheads
= $1·50 \times \frac{4}{60}$ = Re. 0·10

(*iv*) Fettling overheads = $1·00 \times \frac{5}{60}$ = Re. 0·08

(*v*) Administrative overheads
= Rs. 1·00

E

Production cost $= 0{\cdot}73+0{\cdot}10+(0{\cdot}08+0{\cdot}02+0{\cdot}03+0{\cdot}05)$
$+(0{\cdot}33+0{\cdot}08+0{\cdot}01+0{\cdot}08)+1{\cdot}00$
$=$ Rs. 2·60

Sales overheads $= 0{\cdot}25\times 2{\cdot}60 =$ Re. 0·65

$\therefore$ Total cost $= 2{\cdot}60+0{\cdot}65 =$ Rs. 3·25

Profit $= 0{\cdot}15\times 3{\cdot}25 =$ Rs. 0·49

$\therefore$ Selling price $= 3{\cdot}25+0{\cdot}49$
$=$ Rs. 3·74

$\therefore$ Selling price of each wheel will be **Rs. 3·74. Ans.**

Unsolved Problems

1. A finished drawing of an iron crank is shown in the Fig. 9·11.

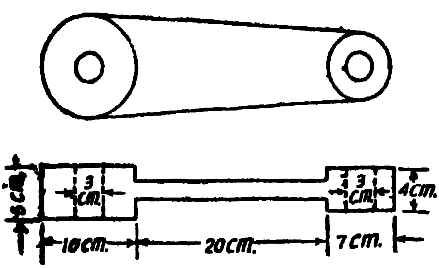


Fig. 9·11

Estimate the wt. of casting, if contraction allowance and machining allowance is considered.