Total contribution from sales

= Rs. 2,95000 × 0·3143 = Rs. 97771·85

Profit = Contribution – Fixed cost = 97771·85 – 100000

Profit = Rs. –2228·15

∴ Loss = Rs. 2228·15

Therefore the company should adopt the 1st alternative because in this case company earn a profit of Rs. 19295. In the second alternative, there is a loss instead of profit.

9.21 Value Analysis

Value analysis, or value engineering is an organized system of techniques for identifying and removing unnecessary costs without compromising the quality and reliability of the design. The technique usually is applied to a spectrum of problems much broader than just materials selection, but he framework of value analysis methodology applies admirably to the problem of materials selection.

Value analysis asks the following questions :

How can a given function of a design system be performed at minimum cost ?

What is the value of the contribution that each feature of the design makes to the specific function that the part must fulfill ?

Value analysis usually is carried out by a team of engineers and managers possessing different backgrounds and view points, so that the problem gets looked at from many aspects. However, a value analysis needs the support and endorsement of top management if it to be most successful.

The value analysis approach seeks the development of answers to the following questions :

Can we do without the part ?

Does the part do more than is required ?

Does the part cost more than it is worth ?

Is there something that does the job better ?

Is there a less costly way to make the part ?

Can a standard item be used in place of the part ?

Can an outside supplier provide the part at less cost without affecting dependability ?

Value Engineering

The concept of value engineering was developed in 1940 and evolved into the 1980's. Value engineering is a *customer-oriented approach to the entire design process.* One key point of value engineering is that it is not sufficient to only find the cost, it is necessary to find the value of each feature, component, and assembly to be manufactured. Value is defined as

$$\text{Value} = \frac{\text{Worth of a feature, component or assembly}}{\text{cost of it}}$$

The worth of a feature of a component, for example, is determined by the functionality it provides to the customer. Thus, a refined definition for value is *function provided per rupee of cost.*

The value formula is used as a theme through the value engineering steps suggested below. These steps are focused on features of components. The method can also be applied to components and assemblies.

Step 1. To ensure that all the functions are known, for each feature of a component ask the question. What does it do ? If a feature provides more than one function, the fact must be noted.

Step 2. Identify the life cycle cost of this feature. This cost should include the manufacturing cost as well as any other downstream costs to the customer. If the feature provides multiple functions, the cost should be divided into cost per function to do this, consider an equivalent feature that provides only the function in question. Although it is not accurate because of the interdependence of functions, it gives an estimate.

Step 3. Identify the worth of the function to the customer. In an ideal world we would be able to ask customers how much each function was worth to them. However, if no formal method was used to develop the customers requirements and measures of importance, then the best that can be done is to ask, how important is this feature to the customer ?

Step 4. Compare worth to cost to identify features that have low relative value. If one feature costs more than the others and is worth more-provides important function to the product then its value may be as high as or higher than the others. On the other hand if its costs outweigh its worth, then it has low value and should be redesigned.

The round feature contributes to a number of important functions for very low cost and thus is considered to be of high value.

The concept of value is further discussed in Art. 13.11 & 13.12 & 13.14 on design for assembly. In that article features are added to ease assembly. Even though these features cut assembly time and thus cost, they often raise the manufacturing cost. Whether to use these features is best judged by considering their value.

9.22 Compatibility Analysis

Compatibility is a characteristic ascribed to a major or sub system that indicates it functions well in overall system. It may also be known as ability for two devices to communicate each other in a manner that both understand.

In designing a system it should be verified that various components fit and match well with each other. For example, in a pump and electric motor combination, the water horse power (produce of total head and discharge) of the pump should match the h.p. of the motor for attaining a high efficiency.

9.23 GLOSSARY

Annuity : Anannuity is a series of payments or deposits of the same size at equal interval of time.

Break-even analysis : The break-even point is the value for the factor at which the project is just marginally justified.

Compatibility analysis : It is a characteristic ascribed to a major or subsystem that indicates it functions well in overall system. It may also be known as ability for two devices to communicate each other in a manner that both understand.

Design tree : An approach for calculating the physical realisability of a design concept. It is a probability study.

Development test : This test is conducted to determine the variables of a new material/component/system and give a practical shape to a product.

Linear programming : It deals with the maximising or minimising of an objective function subjected to some restrictions in those situations where the objective function and the constraints can be stated in terms of linear expressions.

Optimization : It is defined as the process of determining the conditions that gives the maximum or minimum value of a function.

Optimization theory : The specific methodology technique, and procedures used to decide on the one specific solution in a defined set of possible alternatives that will best satisfy a selected criterion.

Probabilistic design : Design methods involving with more versatile mathematical systems which takes into consideration both mean value and variance for the parameters.

Proof test : These tests indicate the degree of variability and also to identify the failure modes and weak links in the design.

Qualifying design concept : It signifies the validity of the design idea. The validity comes only after selecting the best solution, preparing a suitable model and testing it thoroughly to conclusively establish.

Sensitivity analysis : The analysis determine the factors most critical in economic decisions in order to check uncertainity. With the help of computers this analysis has become more practical.

Value analysis : This is an organized system of techniques for identifying and removing unnecessary costs without compromising the quality and reliability of the design. It is also known as *value engineering.*

MULTIPLE/OBJECTIVE TYPE QUESTIONS

(A) Fill in the blanks :

9.1 Probabilistic design methods involve with more versatile mathematical systems which takes into consideration both ________ value and ________.

9.2 Scale ________ test is one of the main type of test to qualify the design concept.

9.3 Development test conducted for qualifying the design concept are used to check the ________ of the design.

9.4 Present value (single payment) 'Economic Evaluation Formula' is given by ________.

9.5 Linear programming deals with the ________ or ________ if an objective function subjected to some restrictions (constraints) in those situations where the objective function and the associated restrictions can be stated in terms of linear expressions.

(b) Write down the expression of the probability of failure free operation for a time period equal to or greater than t.

take t = failure rate.

Ans. (a) Refer to Art. 15.7 (b) $P_s = R = e^{-t\lambda}$

15.5 What do you understand by the term designing for optimum reliability ?

15.6 Write down the exponential distribution for reliability work.

15.7 Explain the term 'Reliability allocation' with a suitable example.

15.8 What is Taguchi method ? Explain briefly. How does it find application in reliability and robust design ?

15.9 What are the seven points for achieving quality in Taguchi method ?

15.10 Discuss briefly the tools for Robust design.

16

Ergonomics Considerations in Design

16.1 Introduction

Technological changes in a production system often produce changes in the work design which may well-produce effects on the operator that were not expected. Unfortunately, only rarely do these chance effects increase the output of the system. Failure to match the demands of the job with the capacity of the operator is much more likely to reduce output. Stress on some physiological or biomechanical system may go even farther and produce temporary operator breakdown. This kind of poor design may go unrecognized and reduce system outputs for long periods, because the human operator has such adaptive capabilities. The fact that a man can do a certain job does not indicate by any means that the job was properly designed. Man's short-term adaptability and positive motivation for the present situation may mask fundamental design defects to which other persons may not be able to adopt or which they may not be able to tolerate.

If the industrial engineer is to design work for maximum productivity, he must learn the principle of *ergonomics* and how they can be applied.

16.2 Ergonomics

The word 'Ergonomics' is derived from the Greek word 'ergon' and 'nomos' and means the *laws of work*. Today, it is generally called the science of fitting the job to the worker, and concerns the field of the human operator and his working environment. It can therefore be seen that it covers a very wide field, and may be applied at the initial design stage of product design.

The areas of study covered under 'ergonomics' are Anatomy, Physiology and Psychology on one hand and Physics, Mathematics and Design on the other. This is illustrated in Fig. 16.1.

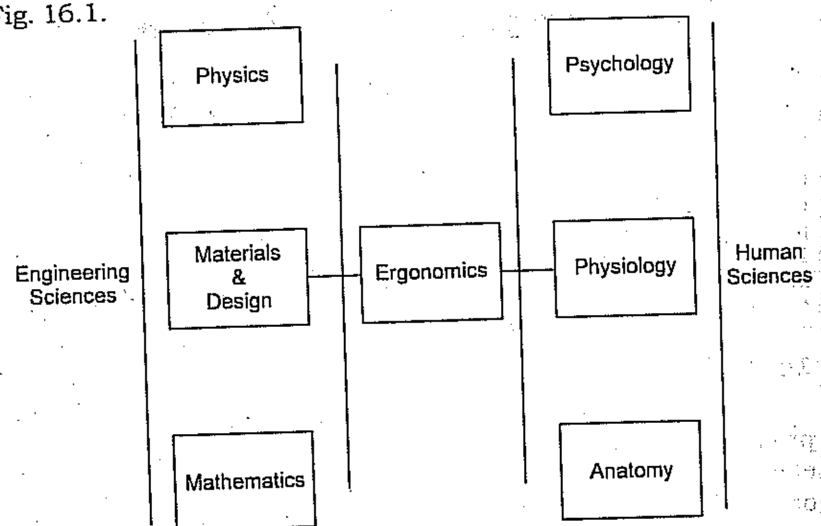

Fig. 16.1 Ergonomics linking the engineering and human sciences

16.3 Ergonomics—Definition and Scope

Ergonomics may be defined as a science which deals with the systematic study of the relationship and interaction between man, machine and working environment.

Here by 'environment' we mean not only the ambient environment in which a man works, such as, temperature, humidity, noise level etc., but also his method of work and relationship within the group.

The subject, therefore, relates to :

(1) himself :

(*a*) his ability,

(*b*) capacities and

(*c*) limitation; and

(2) his relationship with :

(*a*) his fellow workers,

(*b*) his superiors,

(*c*) management and

(*d*) his family.

Considerable part of ergonomics, therefore, deals with human behaviour encompassing (covering) a number of human parameters, known commonly as human factors. Such factors are liable to affect the ultimate output of a production unit, which is regarded as an integrated system of men and machines, within the envelope of environment. Design of a productive unit, be it a machine or a process plant, and its arrangement and layout pertaining to a specific flow line, require to be suited to the typical characteristics of human factors and synchronised adequately to effect harmonious output from the integrated production system.

This has resulted in a broad-based study and researches in the areas of bio-mechanics; bio-rhythm; system analysis and other related fields.

Objective of Ergonomics is to ensure that human needs for safe and efficient working are met at workplace.

16.4 Man-Machine System

Fig. 16.2 shows a typical 'Man-Machine System'. The information exchange between man and machine could be in the form of the following closed loop :

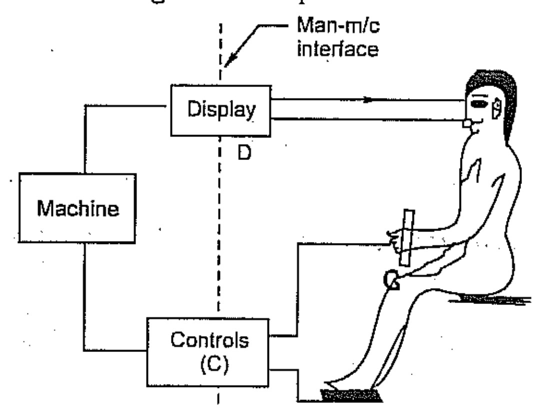

Fig. 16.2 A typical man-machine system

(i) Man observes the display (dial).

(ii) Man processes information on, say, speed. Takes a decision to increase speed.

(iii) Operates control C, to increase throttle.

(iv) The vehicle speeds up and the display indicates increase in speed to the satisfaction of the driver.

Most of the 'Man-Machine Systems' have such closed loop.

16.5 Purpose of Ergonomic Study

An ergonomic study has the purpose of verifying following aspects :

(i) Man as occupant of space should have comfortable posture and space at the workplace according to anthropometry (human dimensions).

(ii) Man as the applicator of force upon the control should have a properly designed control in a comfortable position with a mechanical advantage.

(iii) Man should be able to see the display with ease.

(iv) There should be proper relationship between control and display, termed as 'stereotype'.

For example, a clockwise turn of hand wheel should displace the display/controlled member to right.

An intensive ergonomic study should varify a proper 'fit' between man and the machine and a proper relationship between control and display. This will

(a) reduce fatigue,

(b) reduce errors,

(c) chances of accidents,

(d) reduce training periods,

(e) reduce response times, and

(f) increase output.

16.6 Application of Ergonomic to Product Design

(a) Instruments and controls. This group includes the design of the instruments which the operator must look at or listen to (called the *Display*), and the parts of the machine or equipment on which he exerts muscular force so as to change the state of the process or operation (called the *control*).

(b) Working environment. This group includes conditions of noise, heating and lighting under which the work is to be carried out.

(c) Ergonomics applied to instrument design. An instrument is a provider of information and the information should be displayed to the operator in the simplest manner. For example, a car temperature gauge need only display *N* for normal temperature, as against a fully calibrated scale which requires the motorist to know what is the normal working temperature for the engine. Display may be grouped into three types depending upon the type of information to be obtained. Digital indicators show the required information directly as a number. A kilometer in a car is an example where the number of kilometers covered can be read directly of the meter as a number.

The advantage here is that the precise reading in the desired accuracy can be read directly from the meter, however, for a quick approximate reading at a glance, the analogue version give the best results.

The two types may be combined when a rate indication is required. For example (which might possibly be returned to zero as required) speed in addition to a cumulative quantity.

(d) Multi-instrument display. In the case of a display having many instruments, a logical order pattern of dials and pointers should be presented to the user. The pointers should all be set so that they are in the same position for the 'Normal' reading of each instrument.

The classical example of this principle is provided in the ergonomic design of the instrument display in the cockpit of a modern air liner.

(e) Ergonomics applied to machines and controls. Levers, knobs, hand wheels etc., should be positioned so that the operator can manipulate them with the least change in body position and with the greatest mechanical advantage. The operator should not need to leave his normal working position (which may be sitting or standing) in order to reach a machine control. The controls should be placed comfortably close and in front such that the operator does not need to bend and twist to reach them. The ideal positions may be impossible to attain in the design of a machine because of difference in height and other anatomical dimensions. However, a machine for general use should be designed to suit the average human being and statistics are available to help to do this. This function of a control should be considered when it is positioned. If fine delicate adjustment is required then it should be located near the fingers. If heavy force is required then the legs through the medium of the feet can exert a large force. Foot operated controls relieve the hands for other tasks.

16.7 Human Factors of Design

Human factors engineering is recognised as a specialised discipline. We have often experienced that human error is chiefly responsible to a large number of equipment failures. Hence it becomes most essential to pay greater attention to human factors and human reliability during the design, manufacturing and operation phases of engineering systems.

A system always revolve around humans. The overall reliability of all engineering systems is a function of human reliability. If we observe the human factor principles during system design, it will immensely improve the reliability of human aspect. Another way of increasing human reliability is by careful selection and imparting training of concerned personnel.

16.8 Human Performance Effectiveness with Stress (Anxiety)

Stress or anxiety throws a direct impact on human performance. Fig. 16.3 shows a graph between human effectiveness and stress or anxiety.

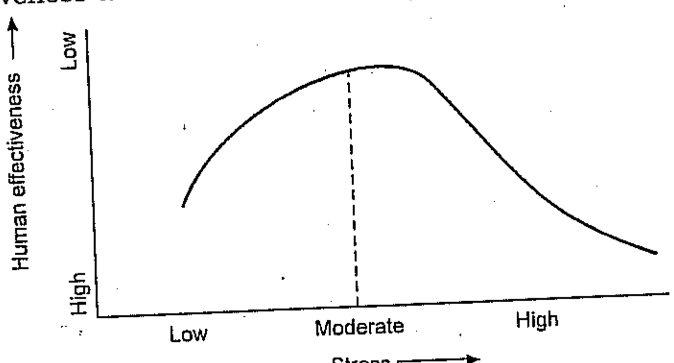

Fig. 16.3 A graph human effectiveness and stress

From graph, it is clear that at high stress, the human effectiveness is low and consequently there is high probability of committing human error. Again from the graph we note that at no or low stress the effectiveness is also very low. For this reason the task involving low stress are dull and unchallenging resulting in boredom. On the other hand, we notice that the maximum effectiveness will be seen at moderate stress. If the stress is very high due to worry, fear or security or any other psychological stress then the human effectiveness or performance will decline.

Reasons of stress **:** Reasons of stress in humans are given as under :

(*i*) Work overload (job requirements excess capacity) or work underload (due to lack of any intellectual input, or lack of opportunity to use individual's expertise and skills or job or repetitive nature).

(*ii*) Occupational change.

(*iii*) Occupational frustration.

(*iv*) Factors, such as high noise, poor lighting etc.

16.9 Human Errors

It has been observed that most of the equipment failures take place mainly due to human failures or errors. Hence we see that the overall reliability of a system is adversely effected as humans have some probability of performing their tasks incorrectly.

The main reasons of human error are given below :

(*i*) Inadequate training or skill

(*ii*) Tendency to do a thing in diverse ways

(*iii*) Poor equipment design

(*iv*) Improper tools

(*v*) Inadequate lighting

(*vi*) High noise

(*vii*) Dusty and warm environment

(*viii*) Inadequate work layout

(*ix*) Crowded work space

(*x*) Poor motivation

(xi) Poor understanding of operation and maintenance procedures

(xii) Complex task

(xii) Poor management

(xiv) Lack of communication.

16.10 Methods for Preventing Human Errors

Human errors should be prevented maximum possible in order to get maximum possible output from him.

Methods for preventing human errors are the following :

(i) Man-machine system analysis method

(ii) Error cause removal program.

(i) *Man-machine system analysis method.* Under this method, the following steps are to be followed :

(a) Define the function and goals of the system in unambiguous terms.

(b) Improve the environment of operator.

(c) Impart proper training.

(d) Poor motivation.

(e) Evaluate the skills of job and type of experience called for.

(f) Clearly state the tasks and job to be performed.

(g) Determine estimate for occurrence of each potential error.

(h) Determine estimate for the likelihood of each potential error remaining undetected and uncorrected.

(i) Determine estimate for the consequence of each undetected potential error.

(j) Make recommendations for change in the system.

(k) Re-valuate the system after change.

(ii) *Error cause removal program.* The basis of this method is for preventive measures. It leads to job satisfaction as the workers involvement is required in this method. The error and error—likely situations and accidents prone situation reports are submitted by workers. Based on such reports, the remedial or prevention measures are immediately taken up.

16.11 Work Conditions and its Effect on Productiv

The condition of place of work plays a vital role in the production process. The workers in a factor will not be able to give their best if the conditions under which they perform their task is not up to the mark. In an unsatisfactory condition, the over-all production will come down heavily thus resulting into closure of the industrial unit. We summarise below the conditions necessary to be fulfilled for higher production.

(i) Lighting (ii) Ventilation and heating

(iii) Noise (iv) House keeping

(v) Colour (vi) Workplace

(vii) Amenities.

(i) *Lighting.* Workers in a factory can work better and with reasonable speed will certainly contribute in higher production. An adequate standard of general illumination should be provided which will increase the efficiency of a worker resulting in higher output.

(ii) *Ventilation and heating.* A worker who spends 8 hours daily with his machines is required to pay due attention toward his health and comfort. Adequate ventilation will increase productivity because of favourable conditions created inside the workshop. Care must be taken to provide exhaust fans at those places where natural ventilation is not sufficient.

Excessively high or excessively low temperature at the place of work will hamper the working capacity of worker. This aspect should receive the utmost attention of the management.

(iii) *Noise.* Noise at the place of work will contribute towards the fatigue and irritation to the worker and his efficiency will be low. Noise should be reduced to minimum by providing adequate lining the walls and ceilings of the rooms with suitable material.

(iv) *Housekeeping.* This term when used in the context to factory signify the cleanliness, tidiness and general state of arrangement at the workpiece. Remove accumulation of dirt daily from all workrooms passages and staircases. Tidiness in a factory is most essential as it will lead to higher production and serve as a means of reducing accidents.

(v) *Colour.* Always use light colours in a factory. Such colours provide the feeling of coolness and contribute toward general tidiness of the factory premises. The colouring of certain machine controls differently helps the worker in the task of controlling with ease.

(vi) Workplace. A worker can work efficiently and smoothly if the sufficient working space is provided to him. Space provided should be such so as to allow the worker to sit and relax whenever he feels tired from his hard work.

(vii) Amenities. The facilities provided to a worker to achieve satisfactory working conditions are :

(*a*) Provisions of lockers for safety of personal belongings

(*b*) Provision of canteen, tea and safe drinking water

(*c*) Rest room

(*d*) Clean and tidy toilet and room near the workplace

(*e*) Adequate first aid and fire precautions.

16.12 Fatigue Reduction Methods

While working for long hours a worker is affected by fatigue (tired). It can be reduced to the minimum by the methods given below :

(*i*) Prcvide frequent short test pauses than less frequent longer breaks. This will surely prevent fatigue to a great extent.

(*ii*) Improve better and improved environmental conditions.

(*iii*) Muscular fatigue can be reduced to minimum by ensuring that not more than about one fifth the maximum power of the muscle is utilised.

(*iv*) Another novel method of fatigue reduction is the introduction of more variety into the work and the work methodology.

Modern Ergonomics : Modern ergonomics contributes to the design and evaluation of work systems and products. These activities refer to integral part of the design and management of systems. Unlike in earlier times when an engineer used to design a whole machine or product. Now a days designing is a team effort.

Now, we give some solved problem to understand the utility and importance of ergonomic principles in an industry.

SOLVED PROBLEM

Problem 16.1. *Discuss some of the ergonomic factors that influence the design of workstation for making sub-assembly of three light components in large quantities.*

Solution. Ergonomic factors that affect design for workstations :

In general, certain principles of motion economy are followed in design of workstations.

(*A*) *Use of human body.* The two hands should begin as well as complete their motions at the same time. There should be minimum idle time. Motion of arms should be in opposite directions and symmetric. Hand motions should be confined to the lowest classification level.

(*B*) *Arrangement of workplace.* Tools, materials and controls should be located close in front of the operator. Gravity chutes should be used, if possible. Lighting should be good. A chair of suitable type and design should be provided.

(*C*) A jig or fixture should be used to permit both hands to be active.

Design of workplace for three light components A, B and C :

A plan view shows a suitable design for bins for three components *A*, *B* and *C* to be assembled.

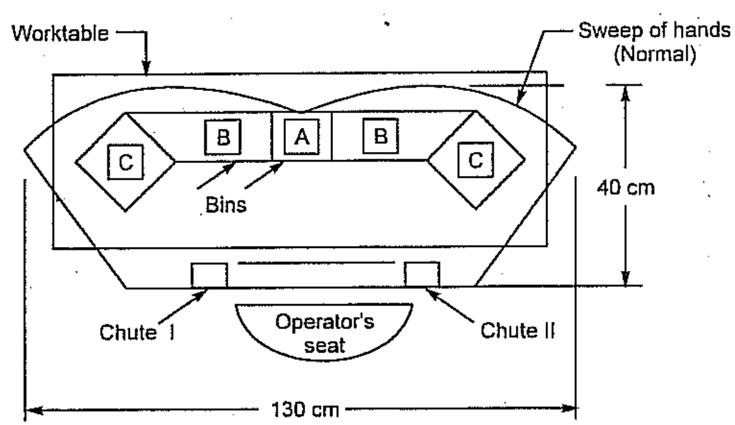

Fig. 16.4

The bins, chute and assembly board should be placed within the normal reach of a normal operator, from the point of view of Anthropometry (Body dimensions).

16.13 GLOSSARY

Ergonomics : It is generally called the science of fitting the job to the worker, and concerns the field of the human operator and his working environment.

Human errors : It has been observed that most of the equipment failures take place mainly due to human failures. Hence we see that the overall reliability of a system is adversely effected as humans.

Lighting : A Illumination source provided at work place. A good lighting makes workers to work better with reasonable speed will certainly contribute in higher production.

Man-machine system : The information exchange between man and machine.

Noise : Noise at the place of work will contribute towards the failure and irritation to the workers and his efficiency will be effected.

Working environment : This group includes conditions of noise, heating and lighting under which the work is to be carried out.

MULTIPLE/OBJECTIVE TYPE QUESTIONS

(A) Choose the most appropriate answer :

16.1 Ergonomic factors are included in the product design to have
- (*a*) Comfort to user
- (*b*) Comfort to manufacturer
- (*c*) Comfort to user and manufacturer
- (*d*) Comfort to tester.

16.2 Most of the man-machine systems have
- (*a*) Opened loop
- (*b*) Closed loop
- (*c*) Both (*a*) and (*b*)
- (*d*) None of the above

16.3 Reasons of stress in
- (*a*) Work over load
- (*b*) Poor motivation
- (*c*) Poor management
- (*d*) None of the above

(B) Fill in the blanks :

16.1 __________ is the technology of work design and is based on human biological sciences.

16.2 __________ is concerned with behaviour.

16.3 __________ physiology is concerned with the expenditure of energy.

16.4 Fatigue may be reduced by an __________ in environmental conditions.

16.5 Provide frequent short rest pauses to prevent __________.

(C) Match parts *X* and *Y* relating in terms of human factors.

X	*Y*
16.1 The probability of accomplishing a job successfully by humans at any required stage within a specified time limit.	(*a*) human performance
16.2 A measure of man's functions and actions under stated condition	(*b*) human performance reliability
16.3 The probability that a human will function all specified human functions subjected to stated condition.	(*c*) human reliability

ANSWERS

(A) Choose the most appropriate answer :

16.1 (*a*) 16.2 (*b*) 16.3 (*a*)

(B) Fill in the blanks :

16.1 ergonomics 16.2 psychology
16.3 work 16.4 improvement
16.5 fatigue

(C) Match parts *X* and *Y* relating in terms of human factors.

16.1 (*c*), 16.2 (*a*) 1.6.3 (*b*)

EXERCISES-16

16.1 (*a*) Discuss the purpose of ergonomic studies of a man machine system.
(*b*) State the areas of study covered under ergonomics.
(*c*) Define ergonomics. Explain its applications in the product design.

16.2 Discuss briefly and to the point 'human factors of design'.

16.3 Explain with the help of a suitable graph the human effectiveness and stress (anxiety). Explain the term reasons of stress.

16.4 What are human errors ? How these can be prevented ?

16.5 Write short notes on :
  (a) Work conditions and its effect on productivity
  (b) Fatigue reduction methods
  (c) Modern ergonomics
  (d) Amenities

16.6 Explain ergonomic factors in the design of
  (a) bicycle; (b) telephone

16.7 What are the human needs requiring considerations in a design problem.

16.8 Write short notes on the following terms :
  (a) Ergonomics
  (b) Man-machine system
  (c) Human errors
  (d) Preventing human errors

17

Communicating the Design

17.1 Introduction

Communication of design is an important task for the design team. Any design concept developed by the team is to be communicated to company executives, related clients and sometimes to experts also. The team or individual responsible for design development must be aware of various forms of communication in order to properly and correctly communicate his work. There are several methods for communicating the design. New a days e-mail has also facilitated for quick and fast communication. The design can be communicated to various concerned persons by following methods.

1. Oral presentations 2. Reports (oral and written)
3. Visual aids (transperencies and charts etc.)
4. Video films 5. Electronic mails

In preceding pages we present the above methods to readers. Let us first understand what communication is ?

17.2 What Communications is ?

Communication can be defined as an exchange and exact replication of thoughts, feelings, facts, beliefs and ideas between and among the individuals through common system of symbols to cause some actions or change in behaviour.

Communication can be simply described as the *flow of intelligence from one mind to another.* Communication occurs through a common system of symbols, signs, and behaviour that (*iii*) Watch and Metal cutting machine

(*iv*) None of the above

Fill in the blanks :

1.1. _________ system is a part of, and operates, within, several larger socio-economic-political systems, oriented towards a definite goal.

ANSWERS

1.1. (*ii*) 1.2. (*i*)

Fill in the blanks :

1.1. Production

EXERCISES-1

1.1 What is a 'system' ? How do you represent it ? Explain with a neat illustration.

1.2 How do you classify a system ? Explain by giving suitable examples.

1.3 Discuss 'System Concept of Production'. Explain it with a help of neat illustration.

1.4 Explain 'Production System' as an input-output model with the help of neat illustration.

1.5 Discuss 'Input-output' model. How will you use this model to analyse an automobile industry ?

[**Hint :** Refer to solved problem 1.1]

2

Classification and Selection of Manufacturing Process

2.1 Introduction

There are a number of ways to classify manufacturing. Broadly speaking, the functions are mass production, and job lot production. A part is said to be ***mass produced*** if it is produced continuously or intermittently at high volume for a considerable period of time. Some authorities say that over 100,000 parts per year must be produced to qualify as a *mass-produced part*, but this is a restrictive definition. In *mass production* industry, sales volume is well-established and production rates are independent of individual orders. Machines producing these parts are usually incapable of performing operations on other work. Unit costs must be kept to an absolute minimum. Easily recognized examples of mass-produced items are matches, bottle caps, pencils, automobiles, nuts, bolts, washers, light globes, and wire.

Parts made in moderate production operations are produced in relatively large quantities, but the output may be more variable than for mass-produced parts and more dependent on sales orders. The machines will likely the multi-purpose ones, although this is not true in plants producing specialty items with less demand or sales than is the case with mass-produced parts. The number of parts may vary from 2500 to 100,000 per year depending on complexity. Examples of this type of industry are more descriptive : printing of books, aircraft compasses, and radio transmitters.

The ***Job lot*** industries are more flexible, and their production is usually limited to lots closely attuned to sales orders or expected sales. Production equipment is multi-purpose, and employees may be more highly skilled, performing various tasks depending on the part or assembly being made. Lot sizes, customarily varying from 10 to 500 parts per lot, are moved through the various processes from raw material to finished product. The company usually has three or more products and may produce them in any order and quantity depending on demand. In some cases the plant may not have its own product, and if so it then "contracts" work as a subcontractor or vendor. Product changes are rather frequent, and in some the percentage profit per item exceeds other types of manufacture. For example, the following products may be produced in job lot-type industries; airplanes, antique automobile replacement parts, oilfield valves, special electrical meters and artificial hands.

Mass, moderate, and job lot production require different equipment and systems. The specification of the equipment identifies what it is and what it can do. See Fig. 2.1, for example.

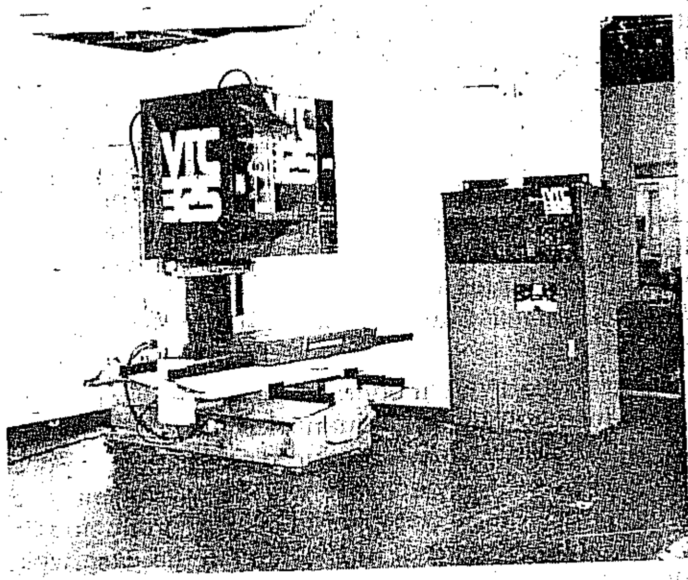

Fig. 2.1 Vertical turret numerical controlled machine tool

In this introductory chapter, we point out that Fig. 2.1 is a vertical turret numerical controlled machine tool. This machine is constructed of close-grain cast iron for its structural members; it has an adjustable carriage, hardened and ground steel wrap-around ways for rigidity, electric lead screw drive, and a 20-tool storage capacity. These specifications may seem meaningless to the reader at this point but elaboration is provided in later chapters. The role of this tool is in moderate to job lot production quantity ranges. It is not intended for high volume.

Job and station

A job is a group of related operations generally performed at one station.

A station is a position or location in a machine (or process) where specific operations are performed.

Operations

An operation is a distinct action performed to produce a desired result or effect.

Typical machine operations are loading and unloading.

Operations categorized by function are :

(i) *Material handling and transporting :* Change in position of the product.

(ii) *Processing :* Change in volume and quality, including assembly and disassembly.

(iii) *Packaging :* May be temporary a permanent for shipping.

(iv) *Inspection and testing :* Comparison to the standard or check process behaviour.

(v) *Storing :* Time lapses without further operations.

Treatment : Treatments operate continuously on the workpiece. They usually alter or modify the product in process without tool contact.

e.g. Heat treating, curing, galvanizing, plating etc.

Treatments usually do add value to the part.

2.2 Job production

As already mentioned, this is the manufacture of products to meet specific customer requirements of special