UNIT 15 MAN-MACHINE SYSTEMS

Structure

15.1 Introduction

Objectives

15.2 Work Science – An Overview

15.3 Man-Machine System

15.4 Characteristics of Man-Machine System

15.5 Machine – As a Component of Man-Machine System

15.6 Man – As a Component of Man-Machine System

15.6.1 Functions of Man Element in Man-Machine System

15.6.2 Muscular Performance

15.6.3 Kinds of Muscular Activity

15.6.4 Nervous Control Movement

15.6.5 The Mechanism

15.7 Types of (Man-Machine) Systems

15.8 Man-Machine Relationships

15.9 Criteria for the Evaluation Man-Machine System

15.10 The Design Factors in Man-Machine System

15.11 Summary

15.12 Key Words

15.13 Answers to SAQs

15.1 INTRODUCTION

The recent researches in the field of industrial engineering are oriented to explore the various factors influencing the human efficiency while working on the machine. The objective is to obtain maximum output of a worker. It has been defined as the scientific study of the relationship between man, machine and the environment. The word environment includes the tools, the materials, method of work, working etc. All these are related to the nature of man himself, to his abilities and limitations. Today the industrial working has become very complex because of rapid technological development and increased demand of product. With the result the man has been subjected to heavy stresses (mental and physical) and as such he either fails to get best output out of himself or suffers operation break-down. These aspects have created the interest in industrial engineers to understand the relationship between man and machine and also with the environment.

Objectives

After studying this unit, you should be able to

- understand the application of work science,
- explain man-machine systems,
- define man-machine relationship, and
- suggest measures to reduce fatigue.

15.2 WORK SCIENCE – AN OVER VIEW

Work Science is the synonym of Ergonomics. The most important task to be done by Work Science is to explore the human capacities of all the industrial tasks concerned with all the factors of work and in the end it aimed at preventing the deterioration of efficiency, and economically too. No doubt the tasks require consumption of energy and physique; therefore, the outcome and costs of work depend on the efficiency. However, as discussed in Unit 14, of this Block 4, the human efficiency is considered to be revolving around two basic questions of work Science, viz. what technique is used and how the work is organised. Let us review these quickly as these are the fundamental concepts to describe a man-machine system.

Thus the work science can be studied under two heads :

(a) Techniques of Work, and

(b) Organisation of work.

Techniques of Work

These can be further divided into two major sections :

Biological Techniques

It deals with hygiene of work based on work psychology and work pedagogies (Science of Training and Instruction.)

Mechanical Technique

It deals with time and motion study.

Organisation of Work

It concerns with disposition of work and the valuation of work (It may be based on output of work and leading to work evaluation). It deals with how much a man may be asked to do and how much rest he should be allowed to take. Further, the work around the worker should be arranged in such a way that it can maximise the efficiency of operator.

Thus on reviewing the concept of Work Science, we can conclude that it is a combination of Methods Engineering, Ergonomics, Human Energy of Man-Machine systems.

15.3 MAN-MACHINE SYSTEM

Ergonomics through the man-machine system aims to perfection of the system or to improve the efficiency of human. According to Mr. C. T. Gould –"Ergonomics is also a branch of I. E. such as O. R., Work study, Organisation and Methods (O & M). It is a bridge between the social and human science on one side and engineer and manager on the other side."

According to Dr. Franklin V. Taylor – Ergonomics has twin goals :

(a) To increase the efficiency of human operator obtained through giving adequate attention to his comfort and to his needs as an organisation.

(b) To enhance the performance of the total man machine system.

All the researches in recent past in the field of industrial engineering, particularly, in the field of man-machine systems are oriented to investigate the factors influencing the human efficiency. The ultimate objective is to obtain maximum output of a worker with causing minimum or no fatigue. This area of study is mostly covered by the Man-Machine Systems under Ergonomics. In short, we can say that Ergonomics means the economics of work in man-machine system.

Man-Machine System has been defined "As the scientific study of the relationship between man and his working environment. The word environment includes the tools; materials; methods of work; organisation of his work. These are related to the nature of man himself to his abilities, capabilities and limitations."

This subject of study took its birth after Second World War. During this period, there was a tremendous development in the military equipment and hence became so complex in operation (high speed operation) that the men were subjected to such stresses. This led to two noteworthy consequences that they either failed to get the best output of equipment or suffered operational break down. Thence, it became essential to learn about the human performance, limitations or capacities.

Extensive research programmes were undertaken in UK and other countries to explore such aspects of this field of work. Researches related to human performance were continued even after the war and finally a decision was taken to form a society which should bring industrial engineers, design engineers, anatomists, physiologists, psychologists, etc. together. This society was later known as "Ergonomics Society."

The studies reviewed by the ergonomic society, in general and the man-machine systems in particular significantly exhibited the technological development that could produce the effects on operatives. There were two important findings :

(a) Stresses to which the human body is unwillingly subjected over a long period may cause loss of efficiency or disability.

(b) Failure to match requirement of a task with the capabilities of the operator may cause reduced output.

The importance or ergonomics is attributed because of three reasons :

(a) We, the human beings have the fallacy that we know all about ourselves. But while we work, we lack or fail.

(b) We are rather conservative and unwilling to make changes, and the poor designs are even accepted.

(c) The false notion that human body is very adaptable and can take any amount of punishment.

In every sphere of the technology, there is involvement of human power and hence there can be innumerable situations in which the human characteristics may conflict with the characteristics of technical products and procedures. This relationship is not simple since there are problems in discovering the characteristics and tolerances, of man since human behaviour is very complicated. In simple words, the importance lies with the designing of man-machine system as a whole.

Sir Wilfred Le Gros Clask, in the address to the Ergonomic Research Society at its symposium on "Human Factors in Equipment Design" expressed, "A man and his machine may be regarded as functional unit and the aim of ergonomics is the perfection of this unit so as to promote accuracy, speed of operation and at the same time to ensure minimum fatigue and thereby maximum efficiency."

A man-machine system is defined as an operating combination of one or more men with one or more equipments interacting to bring about from given inputs some desired output with in constraints of a given environment.

A simple form of man-machine system can be a man with some common tools or device, e.g. a data entry operator with a personal computer system; driver and a car or an automobile; conveyor with the man unloading; a checkout counter of a grocery store and the cashier; manned aircraft; A guided missile system, etc.

Reviewing these simple systems, it is obvious that a system must have some purpose and the following components also necessary (Refer Figure 15.1).

(a) Input

(b) Processing and Decision Making

(c) Output

(d) Feedback device for corrective action.

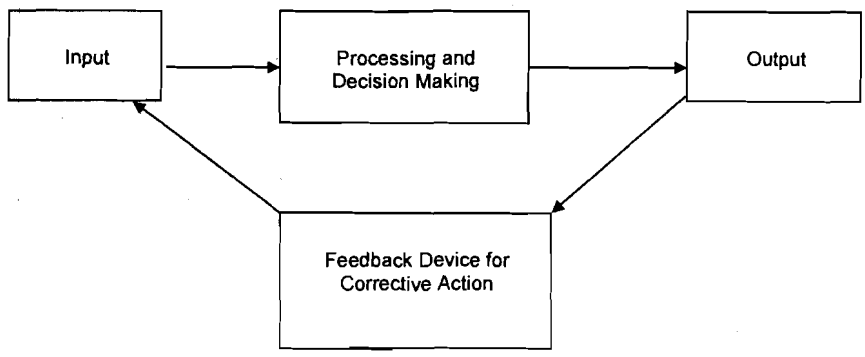

Figure 15.1 : A Simple Model of Man-Machine System

Figure 15.2 : A Man-Machine System with Computer Operator – Computer

Input of Information

It is the first and foremost feature and is very essential. The input information consists of various ingredients which are necessary to achieve the desired out-come. The input information may consist of physical objects or materials in the form of information and/or energy. For example, in a system of sawmill, the input is in the form of physical material, i.e. lumber where as the input at a data entry operator on a personal computer is information.

Information Processing and Decision

This subsystem covers the functions of sensing (information receiving), storage, processing and action. Sensing or receiving the information is a quite important sub-component. If there is no proper sensing i.e. receiving of the information, sometimes some information may enter from wrong direction from an outside System. For example a virus may be sent to a computer by a hacker. Hence this sub component (receiving information) becomes quite important. There are various types of sensing devices such as electronic device mechanical device, etc.

Other subcomponent of this subsystem is the storage of information. Storage of information is synonymous with memory of learnt material. Information can be stored in many ways as on manually maintained record, punch cards, magnetic tapes, floppy, compact diskettes, etc. Most of the information is stored in coded or symbolic form, and the nature of the coding system can have bearing on the efficiency of storage or other processing devices.

Information processing means, the sensed information along with stored information undergo various types of operation. The identity and nature of such information in the case of human mental processes are not yet clearly understood and hence considered as a "BLACK BOX". But the information processing by

machines must be programmed either by simple or complex method (computers). The result of information processing services is the basis of decision regarding subsequent action. In man-machine system, a decision is a determination with respect to a succeeding act.

Action function means the operations as result of subsequent decisions. These actions can be classified into two broad categories :

(a) Physical control action or process equipments, movements, alterations, etc.

(b) Communication action in the form of signals, records, etc.

Output

Output is the result of a system after processing. It may bring a change in product; or a communication is transmitted; a service is rendered.

Feedback Device

It is not necessary that all man-machine systems should have a feedback device. It is necessary only in the case of closed loop systems. It is essentially needed for corrective action.

SAQ 1

(a) Explain the man-machine systems with suitable examples.

(b) State the objectives of man-machine system.

(c) Explain the features of man-machine system.

(d) Discuss the history and background of man-machine system.

(e) How do you use the man-machine system as tool to improvement of productivity?

Activity 1

Fit the following works as a model of man-machine system. Describe its features.

(a) Driver – Bike : .....

.....

(b) An operator – Lathe Machine : .....

.....

(c) Police – Gun : .....

.....

15.4 CHARACTERISTICS OF MAN-MACHINE SYSTEM

The man-machine system, to that matter any system should have the following three characteristics :

(a) System must have some purpose,

(b) System must have system components, and

(c) System should be designed to do some functions that suit the human beings.

The function is indicator of the purpose of the system. Therefore, all the data related to purpose should be made available to the system designer. For example, in the case of data entry operator and a personal computer system, the desired performance characteristics, the type of computer, the stresses or load taken up by the computer, the capabilities of its software, sitting and environmental conditions under which both have to work, etc. should be known.

A system consists of number of components or sub-systems and each sub-system can be considered as a system which may have all the requisites of a system. In order to analyse any system, the various sub-systems should be considered as independent systems. Output of a sub-system may become input to another sub-system.

15.5 MACHINE – AS A COMPONENT OF MAN-MACHINE SYSTEM

Machine receives instructions from the man and it carries them out and usually indicates its progress to the man by a display of information. Therefore as many ergonomic measures as possible should be introduced at the design stage of a building, appliance or machine, or when equipment is being installed. A machine user should incorporate ergonomic standards in the clauses of his contract with the machine manufacturer. It must cover safety colours, warning signals and controls that have already been standardised by International Organisation for Standardisation (ISO) and the International Electro-technical Commission, in particular display panels and dials. It is, therefore, obvious that machine is totally dependent on the understandability and reliability of the operator. Thus, the information to be displayed must be clearly understood and perceived by the operator for which universally acceptable, standard and good display instruments must be attached to the machine.

The function usually best to allocate to a machine,

(a) For computing, differentiation, integration,

(b) When Response is required at great speed,

(c) Short-term information storage (memory), and

(d) For simple yes/no decision.

However, the man may introduce in the system delays, disturbance and noise because of own limited capabilities. If the limitation data and capability – data of men are properly known, then the efficiency of work can be easily optimised considering man as an element of system.

15.6 MAN – AS A COMPONENT OF MAN-MACHINE SYSTEM

Man plays a vital role in the success of man-machine system. The sequence of events generated from the receipt of the external stimulus to the completion of a response is very complicated one. It involves the transduction of the external or internal stimuli, the

perception of the signals and their meaning, the making of judgment (mental process), the placing of information into temporary or permanent storage (memory) and recall as and when necessary, finally leading to a decision making.

When a man is acting as a controller in a man-machine system, a large number of human qualities play an important role, some of which make him outstandingly useful while others put limitations on his performance. All these qualities should be considered in relation to functions which are well done by man or not so well done by a machine. The most exciting and useful quality of the man component is his flexibility and hence the adaptability. Unlike a machine, which is designed for a specific purpose, a person can change his role rapidly and frequently, moreover he has a multiplicity of channels which he can select as and when required.

15.6.1 Functions of Man Element in Man-Machine System

Unless it is highly complex, Functions usually are done by a man better than a machine. The main functions of man a component of man-machine system can be observed under five sub-headings as follows :

As a Sensing Device

Man can act as a sensing device to minimal stimuli from a wide range of sources and link up these signals together to project a complete picture of an event. In carrying out this sensing, the man may respond to very dim lights or quiet sounds and can relate these changes which are of infinite variety so as to arrive at a view of their meaning. In this context, a term which is used to describe the means by which data (signals) is conveyed to the central mechanism (efficiency of central mechanism) is used known as reaction time. In simple words it is the time taken to respond to a signal.

As an Amplifier, Flexibility, Switching Device

After receiving the signal, he may take-some action. The action would be in reference to what he has perceived. In doing so he works as an amplifier. In carrying, out this work, the man behaves in a. very flexible manner. Further, the man can act as the switch also and use this information to any other relevant activity as and when required.

Long Term Storage

The wonder of the God's creation is that the brain of human being has memory of great capacity. The units that we use for measuring memory capacity such as Megabyte (MB), Gigabyte (GB), Terabyte (TB) or Petabyte (PB) are not at all sufficient to define the capacity of human brain. In addition to the memory space, the memory duration is also very long. It can store the information for years and decades also.

Perception of Depth and Pattern, Interpolation, Extrapolation, Translation

The man can perceive a signal in three dimensions and can also interpolate and extrapolate. After receiving two pieces of data, as it happens in the case of industrial measuring instruments, the man can interpolate satisfactorily between these two limits of data and similarly he can extrapolate also. Man can do prediction also on the basis of a signal data. Even if the data is spurious or erroneous, the man can detect this and correct this in most situations. Suppose, a sign-board at a road side was broken into pieces and a illiterate passerby joined these kept them which read as 'SLOW BREAKER GO SPEED AHEAD'. A car driver who notices this can understand the defect and correct and then interpolate to read correctly as 'GO SLOW SPEED BREAKER AHEAD'. This Signal would automatically cause the driver to decrease the speed and his judgement is fairly good.

Making Judgment and Predictions

Another magnificent function of man element in man-machine system is that human brain can do the judgments and predictions efficiently and effectively. In the entire system this phase is very important and vital for getting correct desired output. However, most times the judgment is made by the man element only in this

system and hence the efficiency of the system is highly dependent on the man element of the system.

15.6.2 Muscular Performance

Muscles influence man's working efficiency. About 45% of the body weight is constituted by Muscles. The most interesting characteristic of muscle tissue is its ability to contract to the extent of its half of the length. Each muscle – fibre contract with a certain force. The maximum muscular-force in man amounts to about 4 kg/cm^2 (cross section of the muscle). The maximum force is exerted at the beginning of the contraction, when the muscle length is still that of its relaxed state. As the muscle shortens, the force declines. These facts are important, in the practical physiology of work.

The muscular contraction force depends on the number of actively contracting muscle fibres. Fibre contraction is stimulated by incoming nervous impulses. Consequently the amount of muscular work is determined by the number of nervous impulses and hence by the number of excited motor neurons in the brain. The speed of a muscular contraction depends upon the amount of force exerted within a fixed time. The speed of movement is thus regulated by the number of fibres actively contracting during that time.

The mechanical energy due to muscular contraction is created from the chemical energy reserves in muscle. The glucose in muscles becomes the most important source of energy of muscular work. The presence of oxygen is necessary for the regeneration of glucose and of high energy phosphate compounds and thus oxygen becomes the second most important substance in the energies of the muscular system. Glucose and oxygen are stored only in limited amount in the muscle and the continuous supply of glucose and oxygen to the muscular system is maintained by the blood. So the supply of blood to the working muscle can limit muscular performance.

15.6.3 Kinds of Muscular Activity

There are two kinds of muscular activities :

(a) Dynamic muscular work (Rhythmic work), and

(b) Static muscular work (Postural work).

Dynamic Muscular Work

In dynamic work, expansion (tension) and contraction (relaxation) of a muscle follow one after the other rhythmically. Thus work be measured as a product of shortening of the muscle and the force used (work = height of rising X weight). During dynamic muscular work, a muscle operates like a motor pump for the circulation of the blood. Contraction causes an expulsion of blood and subsequent relaxation allows a renewed flow of blood into the muscle. Thus the blood circulation increases and a muscle receives the blood about fifteen to twenty five times during dynamic work. So the muscle receives plenty of sugar and oxygen and the waste products are readily removed. Because of this is the reason the dynamic work on a suitable rhythm can be executed for a long time without fatigue.

The best example goes with the Heart muscles that work dynamically all through life without 'fatigue'.

Cranking of wheel is another classic example of dynamic work. Therefore, it is recommended that the work can be efficiently carried out if it is carried out on a rhythmic scale.

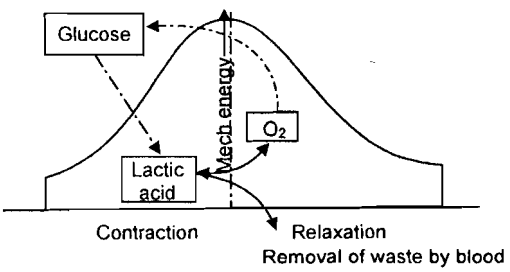

Figure 15.3 : Dynamic Muscular Work : Relaxation Removal of Waste by Blood

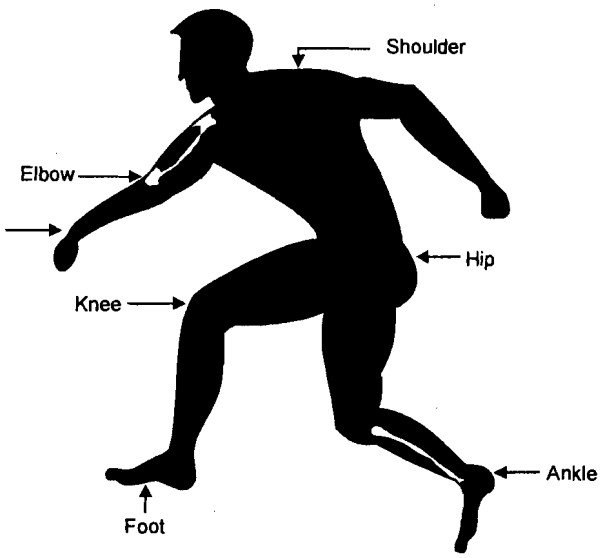

Figure 15.4 : Muscular Movements while Working

Static Work

Holding of a weight with an extended arm can considered as static work where the muscle remains in a state of contraction for sometime, and thus does not extend its length. Hence, no visible work is achieved and it cannot be defined as force multiplied by weight. During standing in a fixed posture, the muscles of legs, hips, back and neck, etc. are in continuously in the state of contraction, so the blood vessels are compressed by the rise of pressure within the muscles and this reduces the blood supply. Thus a muscle which executes a long static contraction receives neither sugar nor oxygen from the blood. As a result it has to consume its reserves. Moreover, the waste products are not carried off but accumulate which in turn produce acute muscular pain and fatigue. It also follows that static muscular stress. Hence this type of work postures should be avoided or at least reduced to a minimum (Figure 15.5).

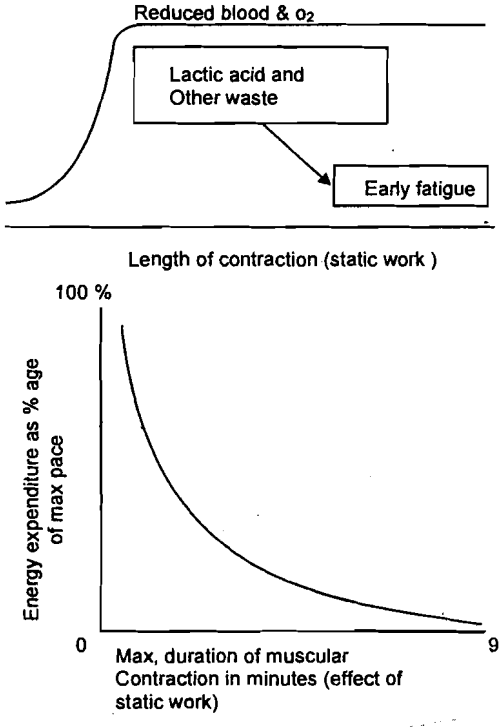

Figure15.5 : Reduced Blood and Oxygen Supply and Maximum Duration of Muscular Contraction in Minutes (Effect of Static Work)

15.6.4 Nervous Control Movement

Every muscle of human body is connected to the brain and so the nervous system is the controlling system upon the activities of organs of the body. When nerve cells are stimulated, they transmit impulses along the nerve fibres to the concerned organs. The neural impulses are of electrochemical in nature and so produce a very small potential difference (few micro volts) which passes at a speed of 10-100 ms^{-1} along the fibre. The nerves are only able to conduct impulses and not a constant stream of direct current. The number of impulses carried out by nerve fibre is regulated by the original potassium-sodium equilibrium.

Each muscle is connected to brain by two types of nerves :

(a) Sensory, and

(b) Motor.

The microvolt potential difference (action potential) is transmitted to muscle fibre through motor in the form of number of Pulses which controls the muscle movement, its force and speed. The nervous impulses originate in spinal cord whereas a consequence of reflex activity, action potentials is stimulated in the motor nerves.

The sensory nerves start in muscle spindles which are stimulated by change in length and tension in the muscle and forward impulses through the sensory nerves into the spinal cord. Finally, these sensory impulses are perceived in the brain as sensations of position, tension and force. Thus they give information about the state of the muscular system which is essential for the delicate control of muscular movement. Similarly, sight, hearing, taste, etc. are connected by sensory nerves to the brain and the nervous impulses received by the brain are interpreted as visual, acoustic and other forms of perception.

15.6.5 The Mechanism

The nervous controls are complex mechanisms particularly, directing the movements of the body members according to the nature of the work perceived by the brain. For instance let us consider the visual mechanism. Chiefly on the strength of visual information, the nervous impulses travel from the retina (a part of eye) to the visual area of the brain, where the sum of the incoming pulses is perceived as a picture or figure or object. Suppose this object is to be grasped, then, from this visual area of the brain, impulses are transmitted to other muscle control centres connected with voluntary movement. This control center relays the signals to the fingers via hand to grasp. On the strength of the visual information the brain thus controls the further sequence of movements. When the object is grasped, new information reaches the brain from the pressure sensitive nerves of skin and the brain alters the grip pressure accordingly, and thus this process continues till the work is accomplished.

SAQ 2

(a) Explain the characteristics of man-machine systems.

(b) Explain the functions of machine element in man-machine system.

(c) Explain the functions of man element in man-machine system.

(d) Discuss Muscular performance and kinds of muscular activities.

15.7 TYPES OF (MAN-MACHINE) SYSTEMS

Though, each man-machine system has got different characteristics, but can be characterized in terms of major attributes. There are two major classifications of man-machine systems we often consider. These are :

(a) Based on the importance of feedback.

(b) Based on the type of processing.

(c) Based on the number of men and machines.

Based on the Importance of Feedback

Under this category we have two types of systems. They are :

(a) Open Loop Systems, and

(b) Closed Loop Systems

Open Loop Systems

An open loop system is one which activates but needs no further control, e.g. priming of a pump, a rocket firing system, i.e. after priming or firing, no control is applied for tracking (Refer Figure 15.6).

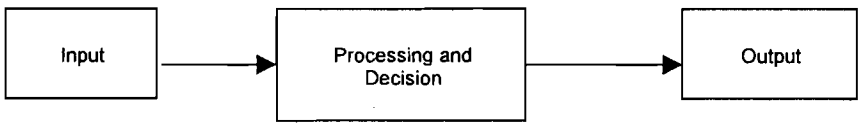

Figure 15.6 : An Open Loop System

Closed Loop Systems

A closed loop system is continuous which requires continuous control, e.g. driving a vehicle. In this system, the feedback is a necessary component by which the continuous control is possible (Refer Figure 15.7).

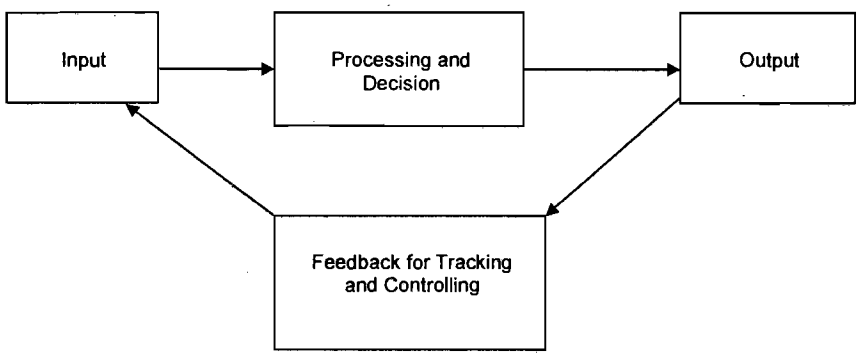

Figure 15.7 : A Closed Loop System

Based on the Type of Processing

There are three types of systems under this category :

(a) Manual Systems,

(b) Semi-automatic Systems, and

(c) Automatic Systems.

Manual Systems

It is one in which all actions are performed by a human being using non-powered devices.

Semi-Automatic Systems

In these systems certain functions are performed by a machine component under human control. It may have a feed back information component, but it is not always necessary. It is a relationship between some standards that provide a basis for the operator to make appropriate adjustments or corrections. The operator then makes the decision about the corrective actions to be taken. The corrective action is taken by the operator through certain control mechanism such as wheels, levers, switches, knobs, buttons, etc.

Automatic Systems

It is essentially a closed loop system and is designed in such a manner that it should perform all required operational functions. These systems must possess two characteristics.

(a) A built in mechanism for sensing the existing state of affair, i.e. the sensing function must be able to detect the error or difference between the desired output and the actual output.

(b) A self-correcting mechanism, i.e. the error should be minimised to have more accurate control in terms of desired output.

Based on the Number of Men and Machines

Man-Machine System or One to One Type Man-Machine System

One man and one machine exist in this type of system, e.g. a driver with a car, a data entry operator and a computer.

Men-Machine System or Many to One Type Man-Machine System

More number of people work on one machine in this type of system. For example : people work at construction of a bridge or building.

Man-Machines System One to Many Type Man-Machine System

One man will be controlling more than one machine. It becomes easily possible if some part or most part will be automated in such systems. For instance : A man beating on a Jazz, A cook or housewife cooking more than one dish simultaneously.

Men-Machines System Many to Many Type Man-Machine System

More men and machines are involved here. The assembly lines and mass production lines can be included under this category.

15.8 MAN-MACHINE RELATIONSHIPS

All the fields of man-machine systems deal with the relationship of men and machines. As discussed above, the relationship may be referred to as open loop or close loop.

We understood that, when there is no link from output to input (i.e. feedback), the system is said to be open loop, but when the output may have some influence on the input then the system is said to be close loop. In the backdrop of this let us now understand some relationships between the components (i.e. man and machine) of the man-machine system.

Suppose that a housewife wants to wash her clothes in a washing machine. Now pressing a start button on the washing machine, in response to the decision that the time has now come to start, the machine starts. This operation can be considered as an example of open loop system and the operator (i.e. housewife who is acting as the man component of the system) is working as a link of open loop.

In the case of operation of a driver on a car, the speed and direction will depend on the information coming through the eyes from the nature of the process. In this case rate of movement can be modified or adjusted according to the information coming. Here the man is working as a link of close loop system.

Most of the man-machine relationships are quite complex and multiple closed loop systems where man serves as integral link of the system. Most of the tasks are tracking tasks, i.e. man as controlling component. The tracking tasks are characterized by following conditions :

(a) The operator actuates the control system so as to maintain the alignment of the output signal with the input signal of the control system.

(b) An externally driven input signal defines an index of desired performance.

(c) The input signal is semi-based and independent of the operator's response, i.e. the task is paced (*A paced task, is one in which the input stimulus is not influenced by operator's response and defines the desired motor response of the operator*).

(d) The control system induces certain constraints that impose some transitional courses of action on the human operator *(The operator cannot move the control from one possible condition to another directly such as from left to right – without moving through all the intervening states of the control system).*

(e) The states of the input signal have the same transitional constraints as the control system (*The input signal must also change through the intervening states*).

Generalised illustration of a continuous closed loop man-machine system is referred to as tracking system.

An essential feature of such a model is the relationship between desired output and actual output, this error is, of course, being used. The essential feature of the task of the operator is that of sensing this error and taking corrective action.

This error is the consequence of a number of contributing factors relating both to desired output and to the man-machine system.

SAQ 3

(a) Explain the man-machine relationship.

(b) By what aspects the man-machine relationship can be described? Explain.

Activity 2

Identify the man-machine systems in your organization or the organization with which you are familiar, and write down here below. Examine if you can change a one man – one machine system to a one man – '*n*' machines, and so on to improve the productivity.

One Man-One Machine Systems

.....

.....

.....

One Man-'*n*' Machine Systems

.....

.....

.....

'*n*' Men-One Machine System

.....

.....

.....

'*n*' Men-'*n*' Machine Systems

.....

.....

.....

15.9 CRITERIA FOR EVALUATION OF MAN-MACHINE SYSTEM

It is based on the following two aspects. Depending on these two criteria, the system can be evaluated or judged :

(a) System Performance.

(b) System Reliability.

System Performance

Depending on the type of system, an effective parameter on which the system can be evaluated is to be first established. Then a criterion is to be devised or generated. Against it, for an individual system or subsystem, the system performance is judged.

For example, in traffic system, the average waiting time of various vehicles at interceptions could be effective a parameter and a criterion such as a suitable queuing model can be used to judge the system performance.

For a data entry operator- computer system, speed or errors in typing etc. can be powerful parameters to judge the system performance.

For generating a corresponding system, some information of existing system can be useful. This evaluation is systematic and quantitative. Criterion in man-machine systems is based on sub-systems and for this purpose sometimes experimental model may be developed.

Sometimes, human parameter is taken as basis for the purpose of evaluation. It is a well-known fact that human criterion is quite complicated. However, the following four relatively distinct types of sub-criteria may be used to indicate human behaviour.

(a) Human Performance Measurement

(b) Physiological Indices

(c) Subjective Responses

(d) Accident Frequency.

We shall now discuss each of the sub-criteria.

Human Performance Measurement

Strictly speaking, human performance measurement is not possible particularly it is in terms of human activity, such as various sensory and mental activities. For practical purposes, human performance can be rated or compared under the conditions in which the task and associated equipment conditions are uniform

Physiological Indices

It is quite important index for evaluating man-machine systems. Few of the indices are Consumption of oxygen, blood pressure, respiration rate, heart beat rate, blood sugar, brain waves etc.

Subjective Response

It includes quantitative rating, people opinion, etc.

Accident Frequency

Safety of human being is an important parameter in any man-machine system. Thus, the number of accidents or injuries or deaths or amount of loss, etc. can provide good criterion for transportation system.

System Reliability

Reliability is defined as the probability of not failing in given time under specified conditions of operation. In other words, the term reliability means some measure of dependability of the system or its component in performing its functions satisfactorily. Simply speaking, the reliability of the system is the probability of successful performance. It can also be expressed as function of mean time between failures.

The basic relationship in such a case may be described as the reliability of the system or the probability of successful operation as a function of time.

$$R(t) = e^{-\frac{t}{m}}$$

where t = operating time, and

m = mean life or mean time between failures.

In order to test the reliability of the system, its sub-systems could be tested. Commonly the sub-systems may either be in series (sequence) or parallel or a combination of both.

System with Series Components

If the components are in series then the system reliability is given by

$$R_{\text{system}} = R_1 \cdot R_2 \cdot R_3 \ldots R_n$$

where $R_1, R_2, R_3 \ldots R_n$ are the reliabilities of individual sub-systems. It is obvious that the reliability of the systems expressed as, percentage of successful functioning is reducing.

If a system has 10 sub-systems and each sub-system has a reliability 0.95 then

$$R_{10} = 0.95 \times 9.5 \times \ldots 10 \text{ times} = 0.5987$$

The reliability of a system would decrease exponentially and hence the rate of failure is associated with time exponentially.

System with Parallel Components

$$R_{system} = 1 - (1 - r)^m \cdot n$$

where r = reliability of subsystem,

m = number of components in parallel for each function, and

n = number of functions.

15.10 THE DESIGN FACTORS IN MAN-MACHINE SYSTEM

The operator cannot be overlooked while designing any equipment. In fact, the design should be oriented with a system approach and the operator should be considered an integral part of the system. In this reference, designing means laying out the equipments around the operator in such position which will ensure that his posture is adequate and he can see what he has to do and can operate his controls in the most effective way and so on. Most of the design considerations required for a product are given in Unit 14, Ergonomics and Product Design of this Block 4. The Design factors of inter-related aspects are focused here in this unit. Further, some more aspects of design due to environmental effects are separately dealt in the same Block 4, in the next unit, i.e. Unit 16, Environment and Human Productivity.

It is a minimum thing that any designer should think to see that the controls that the operator uses are located at relevant positions within the reachable area easily for the operator. Unfortunately this modest requirement is not always met perfectly in some systems while not at all given a thought in some other cases. It seems that first the equipment is designed and then the operator is asked to handle and adapt himself for the existing design. This causes subjection of undue stresses and thereby operational breakdown or some fault in operation. This situation may arise either because the importance of designing equipment round the operator has not been realised. This change in equipment design concept could be realised and better understood by looking at flash back of the models of various machines and then the modifications made on them to bring them into the relatively better design, which we presently are witnessing.

Arrangement of Machines Control/Assembly Work

In several systems, both the machine controls and assembly work have to be dealt together because many principles can be applied on both. In such cases the designer may require data regarding – laying out the areas for vision, for controls, for sitting body dimensions etc. Another interesting point to be settled is whether the operator will stand or sit or lay down so as to enable to do both. The designer also has to think of number of design factors such as design of a seat, foot pedals, foot rest, control panel, handles, etc.

Control Panels

Control panels are needed in all types of systems. In almost all man-machine systems, the man function is basically that of monitor. The importance of the monitoring function will depend on the extent to which controllers have been installed. Depending on the type of system such as open or closed, or automatic or manual etc., and degree of control required, various principles have been laid down.

Design of Displays

A device or an instrument or event which gives information about a situation which is likely to occur or occurring or has occurred, is called display. Instrumental displays are of two types. These are :

(a) Visual Display, and

(b) Auditory Displays.

Visual Display Systems

These systems are most common and versatile displays in practice. These instruments display the information either by means of an index or by means of light, shutters which give data directly in numerical figures in certain designed units. The relevant information measured by the instrument in the form of certain physical quantity is converted by a transducer into suitable form of physical quantity to be displayed or read. The choice of a display will depend on the nature of information which is to be given, the type method of transduction and the accuracy of information. Wrong information provided by displays can lead to disaster. The commonly used visual display systems in practice are :

Systems with Dial Type Display

These are the most common type of visual displays with the graduated scale on which the indication of a value is given by means of a pointer, called Dial type displays, e.g. dial indicators of pressure meter, ammeter, voltmeter, etc.

Indicators

Pointer type instruments may have no graduated scale and may show state of the system, e.g. A sign board showing the direction, traffic signals, LED indicators for a particular value is open or closed, off or on.

Warning Devices

This type will call the attention operator of the operation to change in the system. It may be a warning signal, caution signals, etc. are included in this type.

Counter or Digital Display

This type of device gives direct display of information in numerals.

Applications of Visual Displays

The visual display systems can be applied in the following five different ways:

(a) For quantitative reading – e.g. clock or watch, ammeter.

(b) For check reading – indication for necessary action.

(c) For qualitative reading.

(d) For comparison.

(e) For warning.

Displays Used with Controls

In addition to the above, these display systems can also be used the following three ways when they are extended with certain controlling devices :

(a) For controlling – to check if there is any deviation from a value (true value or a predetermined fixed value).

(b) For setting – to set at a particular predetermined (static) point, for example setting the generator to a desired voltage.

(c) For tracking – to follow continuously or to compensate for a changing indication for a (dynamic) point – common in military equipments while not very common in industries.

Auditory Displays

These display systems play a significant role in our daily lives. The systems such as telephone bell, motor horn, alarm clock, door bell, etc. are included under this category.

Characteristics of Controls

Controls are the integral parts of the man-machine systems and have their greater utility in industries. It is a way in which a man conveys his instructions to a machine in the man-machine system. The researches on the characteristics of the control systems lead us to follow two lines.

Static Characteristics

Shape, Size, Range, accuracy, precision, Inertia, Friction, etc.

Dynamic Characteristics

Control dynamics, Performance, etc.

While designing the controls system, it is required to consider the anatomy of limbs used in operation in order to obtain the optimal static and dynamic characteristics. The analysis is to be carried out for various possible alternatives. From this, we determine the best type of limbs used in operation and hence, design the best type of control for different uses.

Choice of Controls

The choice of control depends on various factors such as technical, managerial, economic, and human aspects. However, the human factors are the imperative and essential to consider while selecting a type of a control for a man – machine system. The general principles of design can be derived from the anatomy and physiology of the body. When a muscular movement is made, two or more groups of muscles act in conjunction, and in this way fashion the control of muscular action is obtained.

The choice of controls generally one of the following three types viz. Rotary control, reciprocating control and press type controls :

Rotary Controls

Three principal types are crank, hand wheel and a knob, but greater accuracy cannot be achieved.

Reciprocating Controls

Levers and Joysticks. Levers give control in one dimension while Joysticks in two dimensions. Both types of control can give speed and accuracy. Both can be used in a no. of positions in relation to the body and to some extent their operational characteristics depend on the position chosen.

Press Type Controls

The press buttons, push buttons, push pull buttons, mouse type buttons and with the advent of the new technology in computers an electronics the touch – screen display systems have come up. These are highly accurate and delicate.

Computerised Work Measurement

The contributions of F. W. Taylor in the field of scientific management and work measurement have been the effective and basic tools for productivity improvement. Unfortunately, the task of work-measurement needs considerable manual effort and time in data collection, statistical analysis and generation of operational details to be used by employees, etc. This time consuming tasks do not leave enough time for analytical creativity, thus has an adverse effect on the accuracy of the work-measurement. Therefore, to improve the accuracy of time standards, their own productivity the application of computers in work-measurement has become advantageous, and thus the complete process turns out to be more economic and comprehensive.

The scope for application of computerization and automation in work-measurement can be found in the following areas :

(a) Automatic data collection in time-study, work-sampling and so on.

(b) Statistical/mathematical analysis of work-measurement data including rating factor, allowances, etc.

(c) Development and organisation of standard data.

(d) Development and standard data using statistical/mathematical techniques.

(e) Documentation of methods of operation & relevant information.

(f) Control of work measurement inputs, and other related information.

(g) Storage of data.

(h) Maintenance and updating of work-measurement.

(i) Computation of index for optimisation of labour standard.

(j) Utilisation of work-measurement system.

Automation in data gathering is very important in this context. It consists of the following basic steps :

(a) Designing the study,

(b) Observing activity,

(c) Recording observations,

(d) Analysing the data, and

(e) Reporting results.

All these steps of work measurement are being carried out by integrating electronic data generating devices with computers. Automated data gathering system however must have the following characteristics :

(a) Ability to accept inputs from stop watch time-study.

(b) High speed, accuracy, reliability of data acquisition.

(c) Portability.

(d) Ability to provide interface with a computer for data transfer, analysis and storage.

(e) Ability to capture analyst's observations relevant to study.

(f) Capacity to prompt the observer, etc.

(g) Sufficient data storage capacity.

(h) Ability to audit the data being gathered.

After gathering the data automatically of manual elements of work, the data regarding the rating factor and various allowances are to be fed to the computers which ultimately deliver the standard time of manually controlled work elements according to the instructions fed.

SAQ 4

(a) Explain the role of system performance in Man-Machine relationship.

(b) What do you understand by the term System Reliability? What is the role of system reliability in Man-Machine relationship?

(c) Discuss the design factors in Man-Machine system?

(d) Write the types of the visual display systems and its applications?

Activity 3

Explain the mechanism of following sub-system activities in a car and driver Man-Machine System

(a) Visual

.....

.....

.....

(b) Audio

.....

.....

.....

(c) Brakes

.....

.....

.....

(d) Clutch

.....

.....

.....

15.11 SUMMARY

At the outset, the preliminaries of work science are reviewed as it forms the strong background of the evolution of Man-Machine System. The basic model and characteristics of Man-Machine System are explicated. Further, the functions of Machine as a component of Man-Machine Systems are described. The Man's role as a component Man-Machine System, the functions of Man element due to muscular performance and the mechanism is narrated with suitable examples. Various types of (Man-Machine) Systems and the Man-Machine Relationships have been discussed exhaustively. The criteria and the design factors of Man Machine System are elucidated.

15.12 KEY WORDS

Man-Machine System : Operation of one or more men with one or more machines.

Sensing Device : Device which minimizes stimuli from sources and links these signals to project a complete picture.

Open Loop System : Open loop system is one, which activates but needs no further control.

Closed Loop System : Closed loop system is one, which activates but needs continuous control.

Manual System	:	A system in which all actions performed by human using non-powered devices.
Semi Automatic Systems	:	Certain functions of system are performed by a machine component under human control.
Man-Machine System	:	A Machine working by a Man is called Man-Machine system.
Men-Machine System	:	A Machine working by more number of humans is called Men-Machine system.
Men-Machines Systems	:	Many Machines working by many number of humans is Called Men-Machines system.
System Performance	:	Criteria which evaluate the performance of a system.
System Reliability	:	The reliability of the system is the probability of successful performance.

15.13 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.