Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management
Kuala Lumpur, Malaysia, January 22 – 24, 2011

ERGONOMICS AND DESIGN

Mohammad Iqbal[1], Salma A. Iqbal[1], A.N. Mustafizur Rahman[2] and A.H.M. Samsuzzoha[3]

[1]Department of Industrial and Production Engineering,
[1]Department of Chemical Engineering and Polymer Science
Shah Jalal University of Science and Technology, Sylhet - 3114, Bangladesh
[2]Department of Manufacturing and Material Engineering,
Kulliyah of Engineering, IIUM Jalan Gombak 53100 Kuala Lumpur, Malaysia
[3]Department of Production, University of Vaasa, PO Box 700, FI-65101 Vaasa, FINLAND

Abstract

Today, both workers and management are concerned about the quality of work lives, ergonomics and occupational safety and health. New development such as information and communication technologies and specialized work requiring repetitive tasks add up to a need for Ergonomics. By examining, designing, testing and evaluating the work piece and how people interact in it, ergonomics can create productive, safe, and satisfying work environment. Ergonomics is concerns with the study of the relationship between people and work environment. The scope for the application of ergonomics in our working environment is tremendous. Ergonomics has the essential role to play in increasing work efficiency and productivity by making the tool or machine fit the users and the worker's efficiency. Ergonomics developed into a recognized field during the Second World War, when for the first time, technology and the human science s were systematically applied in a coordinated manner [1]. The application of Ergonomics is very much in Europe and northern America. Recently Southeast Asian countries including Bangladesh are applying the concept of ergonomics industrial workstation design.
This paper focuses on the importance of ergonomics in product design, working environment, and its influence in industrial workstation design, the interdisciplinary nature of ergonomics and the implications of ergonomics in industrial engineering function. It also contains the importance of ergonomics for an industrial engineer to design product.

Keywords: Ergonomics, Design, Workstation, Product design, Industrial Engineering and Working Environment.

1. INTRODUCTION

Ergonomics focuses on human beings and their interaction with machines, materials, information, procedures and environments used in work and everyday living [2]. Human factors discovers and applies information about human behavior, capabilities, limitations, and other characteristics to the design of products, machines, systems, tasks, jobs, and work-environments for productive, safe, comfortable, and effective human use. The International Labor organization (ILO) has defined the term 'Ergonomics" as "the application of human biological sciences in conjunction with engineering sciences to the worker and his work environment, so as to obtain maximum job satisfaction, which at the same time enhances productivity" [3].
Ergonomics is the science of fitting the job to the worker. In a phrase, the task/job must 'fit the person' in all respects, and the work situation and environment should not compromise with human capabilities and limitations. In general human factors finds out the best possible match between the physical and mental demands of work and the capabilities of the individual members of the workforce in order to optimize both the productivity of the organization and the physiological cost of human beings. In a sense, the goal of human factors is to guide the applications of technology in the direction of benefiting humanity[3].

2. INTERDISCIPLINARY NATURE OF ERGONOMICS

Ergonomists come from a variety of professional fields. This mixed background is well demonstrated by the membership of the professional societies, which typically consists of engineers, physiologists, and individuals from the medical profession [4]. To successfully implement ergonomics in industrial functions and manufacturing system design and planning, it is often an advantage to be an engineer. Physiologists, medical doctors and industrial nurses can certainly diagnose many ergonomics problems relevant to industrial safety, but sometimes have an insufficient technical background to suggest how a technical system can be redesigned to optimize the physiological cost of human beings. Engineers with a background in ergonomics are ideal, as they can analyze different design alternatives for machinery and processes, make trade-offs in the selection of equipment and arrive at a better solution. Ergonomics is often implemented by work groups where the members have expertise in different areas. Groups composed of workers, engineers, managers and nurses can propose new design solutions. The establishment of such groups is typical of complex decision making found in modern manufacturing.

2.1 Importance, aims and objectives of ergonomics

Ergonomics today has taken on a broader meaning with the advent of safer work rules, higher work efficiencies and superior design tools. Today engineers can study and design machines that are efficient to operate, maintain, build and transport. Engineering tools, new materials, improved industry standards and new technology allow a designer to model a machine and actually simulate operation under safer operating conditions. It is very important for any organization or workplace for proper ergonomics design to prevent repetitive strain injuries. These injuries can develop over time due to improper job and workplace design and can also cause disability. Ergonomics has two major objectives. The first is to enhance the effectiveness and efficiency with which work and other activities are carried out. This includes such things as increased convenience of use, reduced errors and increased productivity. The second objective is to enhance certain desirable human values, including improved safety, reduced fatigue and stress, increased comfort, greater user acceptance, increased job satisfaction, and improved quality of life. To develop the optimal conditions for the worker in work environment, to reduce physiological costs, to improve productivity, to facilitate instrument handling, to maximize the efficiency of operation and production system, and to minimize human errors ergonomics is essential.

2.2 What is Industrial Engineering

Industrial engineering deals with the analysis, design and control of productive systems. By a productive system is meant any system that produces either a product or a service. Industrial engineering tells how to analyze and design productive systems and about the control procedures (i.e., directing human effort) for efficiently operating such systems.

Industrial engineering is concerned with developing a production system efficiently that produces the required quantity of products at an appropriate cost and quality. It combines principles of human behavior with concepts of engineering procedure and analysis [5]. Industrial engineering combines the abilities of an engineer and manager. This employs an aptitude for mathematics, statistics, and economics as well as for the basic engineering sciences and interest in all kinds of jobs and the machines and the people who produce the products and the ability to analysis, synthesis and integrate technical knowledge in practical ways. In summary, it is necessary to know the technical details of each of the production processes in a productive system and then to integrate all the elements of a production system (workers, materials, equipment, information, management, etc.) so that a quality product can be made at the right time and at an appropriate cost (i.e., industrial engineering) [5].

2.3 Specialties of Industrial Engineering

Industrial Engineering is generally seen as a combination of four major areas. First is *operations research*, which provides application of scientific methods for the general analysis and design of integrated systems of men, machine, material, money, and management. Operation research (OR) includes optimization, decision-making science, stochastic processes, and simulation modeling. *Production* generally includes such aspects as economic analysis, production planning and control, quality control, facilities design, and other aspects of world-class manufacturing. Third is *manufacturing processes and systems*. Manufacturing process deals directly with machining science, i.e., materials removing as for example materials forming, cutting, shaping, planning, etc. and chip less and chip forming processes. Manufacturing systems focus on the integration of manufacturing processes, usually through computer control and communications (for example CIM and CIE). Manufacturing function represents assemblage of technical knowledge and skill to keep all the production processes under control in a productive system. And finally *Human factors* deals

with the human beings. Physical human factors view the human as a biomechanical device while informational human factors examines the cognitive aspects of humans.

2.3 Weaknesses of Production Engineer

Lack of proper knowledge in human factors causes problems to PE's in today's environment of productivity management, operations management and continuous productivity improvement approach. Many companies are seeing this weakness and are providing human factors engineering training to PE's. There is a major effort in manufacturing to improve health and safety, reduce injuries and workers physiological costs, which is foreign to traditional PE's. This can be affected by implementing human factors in production design and planning. Many companies are demanding industrial engineers with proper knowledge of human factors application in the design of equipment, workstations and working environment, systems and methods of products and of operation. Ergonomics or Human factors will give industrial engineers an edge over traditional PE's with high potential for job and work experience.
Effect of poor Ergonomics application on manufacturing are less production output, increased lost time
Higher physiological cost, Higher material cost, Increased absenteeism, Increased risk of accidents, Higher employee turnover, Low employee morale, Increased fatigue and injury rate and Increased risk of errors.
Application of Ergonomics in elimination of waste are Waste of rework & repair, Waste of work-in-process inventory, Waste of materials, Waste of waiting (delay),Waste of over production, Waste of motion and Waste of employee talent.
Indicators of Ergonomics weakness are High material waste, scrap and rework, Operators doing frequent mistakes, High number of employee complaints, High absenteeism and turnover, Incidents of near-misses of accidents, Employees taking frequent breaks, Supervisor constantly missing schedule, Employees requesting frequent job transfer, Workers complaining about aches & pains and Large number of employees wasting time.

3. INDUSTRIAL ENGINEERING APPROACH VERSUS ERGONOMICS APPROACH

Industrial Engineering approach is based on principles and techniques of scientific management developed by Fredrick Taylor. It is based on the analysis of operations using method-time-motion study on elements of the task. Fatigue factor is provided by standard allowance to develop the production rate whereas ergonomics/human factors approach uses physiology & biomechanics to identify fatigue factors that are neutralized by engineering & administrative controls [3]. The approach of human factors is the systematic application of relevant information about human capabilities, limitations, characteristics, behavior, and motivation to the design of things and procedures people use and the environment in which they use them [2]. This involves scientific investigation to discover relevant information about human beings and their responses to things, equipment, procedures, and work environments, etc. The human factors approach also involves the evaluation of the things designed to ensure that they satisfy their intended objectives.

3.1 Implications of Ergonomics in Industrial Engineering Field

Ergonomics has a wide application in everyday living and domestic situations, however there are even more significant implications for efficiency, productivity, safety, health, and comfort in work settings. For example: human factors plays the following basic roles:

a. Methods and operation design
b. System and interface design
c. Product and equipment design
d. Task and job design
e. Workstation and work arrangement design
f. Information design
g. Working environment design.

Case Study: Analysis of Ergonomics interface at a Computer workstation

A human-machine system is any system in which men and machines interact in performing a function to bring about, from given inputs, some desired output. A man-machine system is a closed-loop system because it calls for continuous interaction between the man and machine. When considering man-machine interface, it is useful to consider them as a complete information flow loop. If efficient work is to be achieved, all parts must function properly.

There are common problems in the workplace and workstation where it is necessary to take broad approach like integration of industrial engineering and human factors engineering approach. For example, the introduction of computers in the workstation presents a variety of design problems as given in the table 1. To effectively solve a problem related to man-machine interface in visual display terminal (VDT) workstations, an industrial engineer with background in human factors must be able to recognize and analyze a variety of problems and suggest design solutions. This leads to the first maxim: the primary purpose of human factors is design.

Table 1: Design problems arising from the introduction of computers in the workstation

Problem	**Knowledge required to solve problem**
Work posture	Anthropometry and biomechanics
Keying	Biomechanics
Size of screen characters	Perception, vision research
Layout of screen information	Cognitive aspects of human factors, cognitive science
Designing new system	Systems design and cybernetics
Environmental factors	Working environment design including illumination, noise, heat stress and cold stress

The problem can be illustrated by a human-machine system as shown in the figure 1. Here a human operator perceives information on a display. The information is then interpreted and an appropriate action is selected. The action is executed manually as a control input, which in turn affects the information status on the display. Consequently the display of computer serves as stimuli for the human operator for next action to be taken.

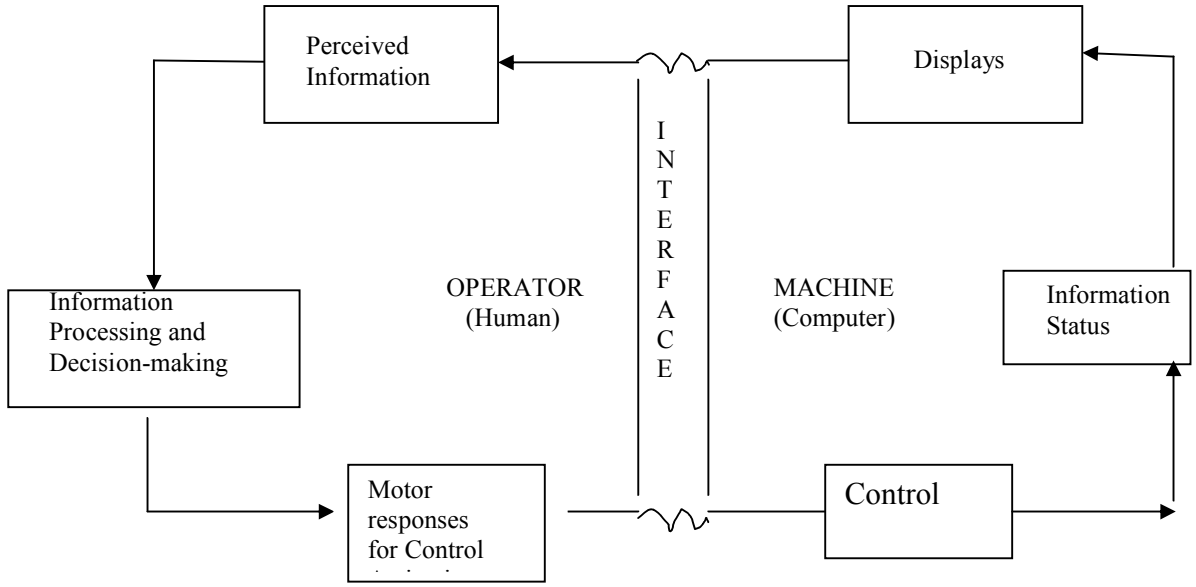

Figure 1: Analysis of the human-machine interface requires interdisciplinary knowledge of biomechanics, Cognitive Ergonomics and systems design methodology.

It follows from the above figure that interdisciplinary knowledge is required: (1) to formulate systems goals, (2) to understand the functional requirements, (3) to design a new system, (4) to analyze the system, and (5) to implement the system. The existing situation must, therefore, first be analyzed, design solutions must be generated and these design solutions must be analyzed for implementation.

4. INTEGRATING ERGONOMICS INTO THE DESIGN PROCESS

The design process should be structured methodically. Indeed, it is generally accepted today that 75% of the total cost involved in the development and industrialization of a product is determined at the very outset of the design process. Method in a design process (Figure 2) involves an approach in which different ‘‘models’’ (language, technical experience, know-how, etc.), on the one hand, and different ‘‘tools,’’ on the other hand, are brought together. By tools here is understood all the techniques involved in the analysis of the functioning of a part or the whole of the design process.

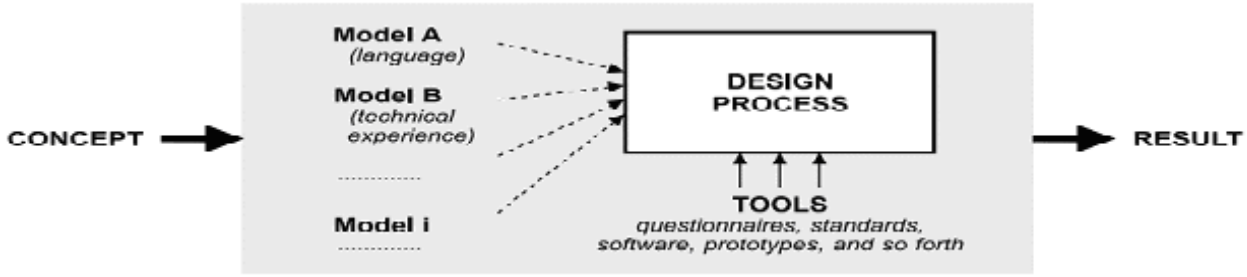

Fig 2: Method Structure [7].

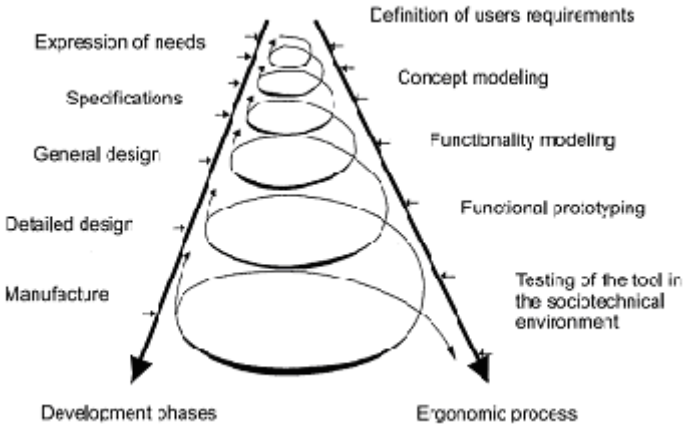

Fig. 3: Spiral model for an ergonomics development process [7].

A general design procedure involves a group of project participants (marketing, design, and manufacturing) and a number of phases (definition of needs, specifications, general and detailed design). The approach adopted must achieve the highest possible integration of these different elements if the project is to run smoothly. The spiral model (Figure 3) makes use of both functional analysis and prototyping techniques. It allows for the integration of all project participants before completion of each design phase. In addition, prototypes—which are intermediary objects that each project participant readily understands— re-enter attention on the product and improve communication in general.

• Stage 1: Definition of user requirements (see Figure 3) and expectations after detailed observation of the work process and work context. Employee characteristics (training, anthropometrics measurements, etc.) are also defined during this phase. Product specifications finally emerge from the study of user needs and work processes. Stage 2: Design of a new product prototype based on tool specifications and laboratory simulation and study of the biomechanical solicitation produced by the new product by comparison with the product previously used. This stage includes all other phases—that is, concept modeling, functionality modeling, functional prototyping (see Figure 3)—relating to product function, styling, and so forth. Stage 3: After formal completion of the second stage, test of prototypes by a large sample of users in real workplace situations. The trial should be conducted over a sufficiently long period (several weeks) and feedback on the user's perception of the new product should be regularly sought according to a procedure similar to that used in the first phase. If satisfactory results are obtained, the product can then be considered duly certified for those situations in which it has been tried and tested. Users must be trained and encouraged to use the prototypes over a sufficiently long period before final judgment is given.

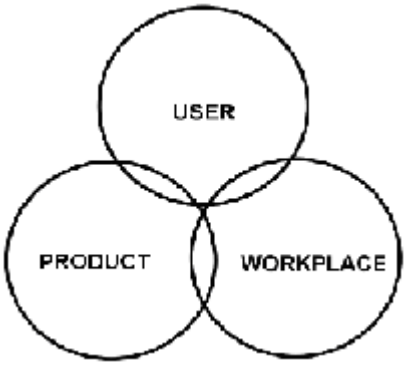

Fig.4: The user, the product and the workplace interact with one another and they should be taken into account in an ergonomic product design process.

Figure 4 indicated the inter relationship among users, products and workplaces. Users application depends on the product according to the workplace position and environment need. So product design depends on the users need and workplace requirements.

4. CONCLUSIONS

As technology becomes more complex, so ergonomics is undoubtedly destined to play an increasingly important role in industrial engineering, production system design, planning and control, and industrial health and safety. We know, Industrial engineering involves the synthesis and application of scientific principles to analysis, design, installation and improvement of integrated systems of people, materials, equipment and management to provide the most efficient and effective operating and work environment. And ergonomics works for the comfortable, convenient, user acceptable, and productive work environment. So for greater system efficiency, increased productivity, and improved quality of life the importance of ergonomics in industrial engineering is profound. The multi-disciplinary nature of ergonomics immediately obvious. The ergonomist works in a team, which may be composed of variety of other professionals: design engineers, industrial engineers, manufacturing engineers, computer analysts, industrial physicians, health and safety practitioners, and specialists in human resources. The overall aim is to ensure that the knowledge of human characteristics and limitations is brought to bear on practical problems of human beings at work and the environment in which they work.

An industrial engineer comprehending the field of ergonomics and capable of implementing concepts, techniques and principles of human factors engineering is undoubtedly the obvious person in workstation design and analysis, for the design of controls and displays of VDTs in any human-machine system and for the safe design of consumer products and working environments. The increased rate of technological development of recent decades has created the need to consider ergonomics early in the design and development phase, and in a systematic manner. Because of the complexity of many new and modified systems, it frequently is impractical to make changes after they are actually produced. The cost of retrofitting frequently is exorbitant. Thus, the initial designs of systems, products, equipment, and environment must be as satisfactory as possible in terms of ergonomics consideration.

REFERENCES

1. Bailey, R., 1982, Human performance engineering: A guide for systems designers, NJ: Prentice-Hall.
2. Sanders, Mark S. and McCormick Ernest J, 1992, 7th edition, Human factors in engineering and design, McGraw-Hill, Inc.
3. Helander, Martin, 1995, East-West Press edition, *A guide to the Ergonomics of manufacturing*, pp. 1-6
4. Bridger, R.S., 1995, International editions, Introduction to Ergonomics, McGraw-Hill, Inc.
5. Hicks, Philip E.,1994, International editions, Industrial engineering and management – a new perspective, McGraw-Hill, Inc.
6. http://ergoweb.com/
7. Laprie, J.C., 1996. Guide de la sûreté de fonctionnement [Dependability guide]. Toulouse, France: CEPADUES éditions.