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ERGONOMIC EVALUATION OF LOW COST ADJUSTABLE WORKSTATION FOR ASSEMBLY OPERATION

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Abstract- Ergonomics is the science and technology of fitting the activities and environment to the abilities, dimensions, and needs of people to improve performance while enhancing comfort, health and safety [1] The objective of the present study was to investigate the effects of an ergonomically designed adjustable workstation for performing a repetitive industrial assembly task on operator performance and productivity. Ergonomically designed fully adjustable assembly workstations could be expensive for companies to adopt, especially the small scale industries. Therefore, a low-cost, ergonomically designed adjustable assembly workstation was designed, developed and evaluated for assembly of a product in a manufacturing company. Experiments were conducted on the existing fixed height and on the newly designed ergonomic assembly workstation using five industrial assembly operators. The operator performance on the ergonomically designed workstation was 29% higher compared to the existing non ergonomically designed fixed height assembly workstation. The increased performance was due to flexibility and ergonomic design features incorporated in the workstation.

Keywords- *ergonomics; adjustable workstation; comfort; productivity*

I. INTRODUCTION

Ergonomics is the science and technology of fitting the activities and environment to the abilities, dimensions, and needs of people to improve performance while enhancing comfort and health and safety [1] The elements of a work system, such as the worker, equipment, environment, task, and organization interact when work is performed. Ergonomics aims to make sure that tasks, equipment, environment and the information suits the workers . Effective application of ergonomics in work system design can achieve a balance between worker characteristics and task demands. This can enhance worker productivity, provide worker safety, physical and mental well-being and job satisfaction. Many research studies have shown positive effects of applying ergonomic principles in workplace design, machine and tool design, environment and facilities design [1-12].

In the design of work systems in manufacturing industries, the primary concern has usually been the improvement of the performance of the equipment alone. Little consideration is given towards matching the abilities of the operator with the task requirements. Consequently, many industrial workstations are poorly designed, resulting in lower worker productivity and unnecessary injury at the workplace [2].

It was found that when a workplace is to be designed at a manufacturing company, most likely the task is assigned to a production engineer or a supervisor. The layout and the components selected to be included in the new workplace are typically chosen more or less according to a company standard or tradition. .The critical question is, how to introduce the element of ergonomics in these activities [10]. Therefore, in designing a manufacturing work station the objective should not only be to maximize worker productivity, but also try to improve worker satisfaction and minimize safety hazards. It is possible to achieve such a desirable goal through proper application of ergonomics principles and anthropometric data [3]. An ergonomics approach to the design of an industrial workstation attempts to achieve an appropriate balance between the worker capabilities and work requirements [2].

II. LITERATURE REVIEW

Modern industrial workstations are characterized predominantly by light but repetitive type of work. The aim of workstation design is to minimize the harmful postures and the design imposed stresses on the users. An obstacle in the implementation of the ergonomic recommendations in a real world design situation is the human variability in size and capability. It is a challenge to the designers to come up with solutions which will optimally fit the diverse anthropometry of the users and satisfy their task demands.[2] An engineering/structural anthropometry approach is used in determining the workstation dimensions. In different parts of the world the workforce is different and diversified; therefore, it is important to design the workplace based on the anthropometry of the users [5].

Many research studies in ergonomics have produced data and guidelines for industrial applications. The features of ergonomic design of machines, workstations, and facilities are well known (Grandjean, 1988; Das and Grady,[7] Sanders and McCormick, 1992) However, there is still a low level of acceptance and limited application of ergonomics

in industry, especially in developing countries. Neglect of ergonomic principles brings inefficiency and pain to the workforce. An ergonomically deficient workplace can cause physical and emotional stress, low productivity and poor quality of work (Ayoub, 1990a, 1990b)[8]

A workstation should be designed such that it minimizes the working area, so that while carrying out the operations, the worker can use shorter motions and expend less energy, thus reducing fatigue[6]. Das and Grady [7]reviewed the concept of workspace design and the applications of anthropometric data. They recommended that an adjustable chair and a workbench of standard size were highly desirable at the workplace. However, a standard height for the workbench could not be defined without the anthropometric data of the user population. It is therefore desirable that the worktable should also be adjustable.

A study by Yeow [9] concentrated on improving productivity as well as the health and safety of workers in a Printed Circuit Assembly (PCA) factory. The improvement involved the use of an ergonomically designed workstation with other ergonomic interventions, such as clear segregation of tested and untested boards to prevent mix-up, and retraining of operators by more qualified trainers. This had resulted in an improvement in the quality and productivity of the workers, a reduction in rejection rate and an increase in revenue.[7]

The use of an ergonomically designed workstation and better structured processes, along with other features, such as improved lighting, shelves and containers for parts and display boards, had helped solve the problems of assembly processes at a German company. (Anonymous, 2005).[10]

It was believed that the application of ergonomics in the design of repetitive assembly tasks, including redesigning workstations and tasks, would not only improve worker safety and work quality, but would also reduce the cycle time and thus improve worker productivity significantly.[12]

Cimino et al. [13] reported on effective ergonomic design of assembly workstation characterised by several ergonomic improvements in terms of energy expenditure and process time. Adjustable workstation design mainly focused on computer workstations and Video Display Terminal (VDT) placement units [14]. Assembly of products on fully adjustable and ergonomically designed workstation has not yet been explored.

Alireza et.al. [15] conducted a comprehensive study with the objectives of determination of MSDs symptoms prevalence and identification of major factors associated with MSDs symptoms in carpet weaving occupation. Working posture and weaving workstations were ergonomically assessed as well. It was found that the majority of ergonomics shortcomings originated from ill-designed weaving workstation. Based on the findings, some general guidelines for workstation design were presented.

An industrial workstation design objective is to ensure that the majority of the population of the intended user group can be accommodated comfortably, without any harmful posture. For the physical design of industrial workstations, the four essential design dimensions are: (a) work height, (b) normal and maximum reaches, (c) lateral clearance and (d) angle of vision and eye height[11]

Fixed workstations can pose limitations on anthropometric dimensions of assembly operators. It can impose stress on the musculo-skeletal system of the operator. Moreover, the flexibility to adjust his/her own workstation is highly desirable.[17] In most of the developing countries the anthropometric data is not available. Therefore, it is of utmost importance that the workstation be designed with flexibility so that the operators can adjust according to their comfort.

Most of jobs environment in industry applies standing or seated work. Standing workstations are usually applies when job requires workers to do activities that need frequent movements, handle heavy or large objects or exert large forces. Whereas seated workstation is chosen usually for long-term duration job. A seated workstation allows better controlled on arm movements provides a stronger sense and balance. Standing posture, however prolonged standing could be stressful that put excessive load to the body and may lead to body accumulation in the legs [11].

Table height of an assembly line may contribute to performance of workers when position is either standing or sitting. There are researches regarding the types of works and the height ideally for workers. Grandjean, 1988 [11], has made exploration work surface height for different kinds of jobs. He proposed precision work for men should be set at 100-110 cm, light work around 90-95 cm and heavier work around 75-90 cm.

To assess the fit between a person and his work, ergonomists have to consider many aspects like the job being done and the demands on the worker, the equipment used (its size, shape, and how appropriate it is for the task), the information used (how it is presented, accessed, and changed), the physical environment (temperature, humidity, lighting, noise, vibration) and the social environment (such as teamwork and supportive management) all the

physical aspects of a person, such as body size and shape, posture, fitness and strength, the senses, especially vision, hearing and touch, and the stresses and strains on muscles, joints, and nerves.

Shikdar and Al-Hadhrami [17] undertook a study to develop a fully adjustable and ergonomically designed workstation (smart workstation) for repetitive assembly tasks. Individual operator could tailor the workstation according to his/her own needs and it could be used as sit, stand and sit–stand workstations. Worker productivity on this workstation was significantly higher, 42.8%, compared to the existing non ergonomically designed and fixed workstation. However, this study used student operators for the conduct of the experiments, and therefore it required validation using industrial operators. Also, the cost of the workstation was considered high and could not be adopted by the company.

The present study was undertaken to develop a low-cost adjustable assembly workstation which is ergonomically designed according to the principles of motion study, considering the use of human body, layout of the workplace, arrangement of the tools and equipment. And evaluate its effect effects on worker performance. The individual worker could adjust the height of the workstation according to his/her needs and it can be used as a sit, sit-stand and stand workstation.

III. METHODOLOGY

A. Existing workstation

A large number of small scale industries operate in developing countries like India, manufacturing a number of components and parts and assemblies

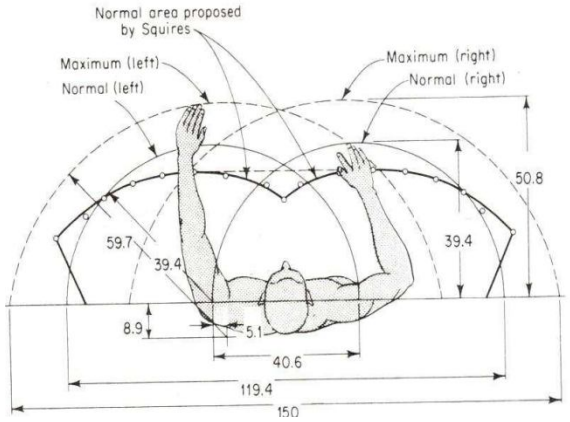

Fig. 1: Recommended working distance for the arms (Sanders and McCormick, 1993)

The present research focuses on the ergonomic evaluation of the existing workstation, in terms of worker comfort, postures and the output or assembly time. It also involved the design and fabrication of a adjustable assembly workstation and conduct of catering to the needs of the customers. These small scale industries also supply parts and components to major automotive, electrical and electronic appliances manufactures, acting as ancillary units. The workstations for assembly operations are designed according to the requirements of the task, or company standards or tradition.

A survey was conducted by the authors to determine the level of awareness and acceptance of ergonomics in the small and medium industries. The results indicated that most of the organizations do not possess the expertise necessary for applying ergonomic principles to the design of industrial workplaces and products and even if it is available they are finding it difficult to use it for manufacturing activities in the existing form. Further, proper guidelines and procedures required for the application of ergonomic knowledge and data are not available.[4]

Most of the industries have worktables or workbenches which are fabricated locally without considering the ergonomics or anthropometry of the users. The material used for these work tables is complete wood, steel or a steel frame with wooden top. The layout of the assembly workstation was not arranged ergonomically and many deficiencies could be found. The bins containing the various parts to be assembled were not according to the normal and maximum reach as shown in figure 1.Therefore the workers were subjected to over stretching or bending for reaching the bins to pick up the parts for assembly. The workstation selected for study was used to assemble electrical plugs.(3-pin top). The workstation used by the workers for assembly operations was evaluated ergonomically.

experiments to evaluate the workstation in terms of worker performance and productivity.

The existing workstation was thoroughly analysed to identify ergonomic deficiencies. Some of the deficiencies investigated were with respect to work height, work areas, sequence of work, seating, posture, clearances, hand tools and layout. It was found that no ergonomic consideration was given to the design of existing workstation. The workers performed the task in a sitting posture, using a chair that did not have appropriate cushioning, an adjustable back support or a tilt mechanism.

The work table was a fixed height that was too low with inadequate work surface for laying out components. The layout of the bins were not arranged in proper sequence and the operators were unable to maintain a smooth rhythm or natural work posture. In most of the cases the work between the two hands was not balanced. Working under such conditions for prolonged period could lead to shoulder stress and

back pain[11]. The hand tools used were poorly designed and not suitable for operator's ease of use and comfort. These were not ergonomically designed, sometimes the file was used without a proper handle and an inadequate handle for the screwdriver. The work environment was not given adequate consideration as the noise levels were high and the assembly was carried out in poor lighting.

The overall layout of the workplace did not consider any systematic ergonomic guidelines. The bins containing various components were placed on the work table in a straight line without considering the normal and maximum work areas. The incoming bin and outgoing bin were placed on the same side of the table. Some of the bins were laid outside the maximum reach area.

B. Ergonomically designed adjustable workstation

The assembly workstation was then redesigned using ergonomic principles of motion economy and data. The available anthropometric dimensions of the Indian population (Debkumar chakrabarti,) were considered in the design [18].Considering the nature of the assembly task, it was decided to provide a fully adjustable ergonomic chair and an height adjustable table so that the work could be performed in a posture that relieved the operator from unnecessary motions and fatigue. The adjustable mechanism used was simple hydraulic jack fitted to the frame of the table. The workers could easily adjust the table to their suitable heights by pressing a lever to raise or lower the table. The range of the height was from 75 to 110 cm. A foot rest was also provided that could be used by the worker while working in a sitting position. The existing hand tools were replaced with a air operated screw driver which decreased the assembly time drastically. The worktable layout was arranged according to the recommended dimensions on table height, seat height, thigh clearance and reach envelopes of normal and maximum work areas of male population (Sanders and McCormik)[19]. The worker had the flexibility to adjust the table height or the chair according to his comfort. The work method was improved by having a process chart giving the sequence of the assembly and this method was standardized.

C. Design of Jig

The purpose of a jig is to hold the plug's earth pin with cover in the proper position, so that the worker can assemble with both his hands moving to locate the components and secure into the jig during the assembly process. The jigs were designed based on practices followed by industry and each jig could hold two plugs at one time. Workstation design of an assembly may contribute to performance of workers when he or she performed his/her job on position either standing or sitting. Grandjean [11] has made exploration on work surface height for different kinds of jobs. He proposed precision work for men should be set at 100-110 cm, light work around 90-95 cm and heavier work around 75-90 cm. Since the assembly of plugs is considered as a light work, the workstation design for assembly was set at the height 90 cm for either standing or sitting position

D. Satisfaction questionnaire

The worker satisfaction was known through a Satisfaction questionnaire conducted at the end of both experimental conditions in order to measure worker satisfaction in using the existing workstation and the ergonomically designed adjustable workstations. It consisted of 21 questions in three areas: satisfaction with regard to workstation, satisfaction with regard to work/task method, and satisfaction with regard to comfort/health attributes. The Human Factor Satisfaction Questionnaire was modified to suit this particular study Carlopio, [20]. The specific questions measured actual worker perception in the attributes using a Likert-type scale of 1 to 5, with 1 being very dissatisfied to 5 very satisfied. An example of satisfaction question with regard to workstation was 'How satisfied are you with the work space on the table?'. The results of the questionnaire are summarized and shown in Figure 2.

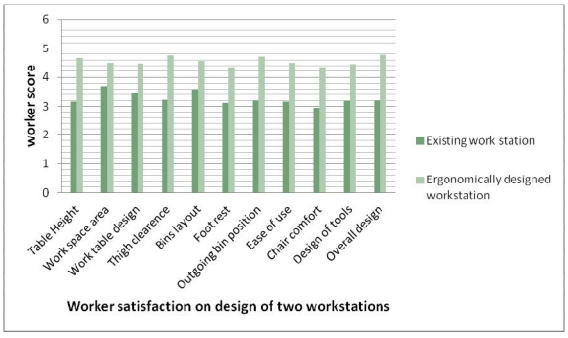

Fig 2: Worker satisfaction with design attributes on two workstations

IV. RESULTS AND DISCUSSION

A Time study was conducted to determine the standard time for assembly of one unit of the product and hence the number of plugs that can be assembled in one hour on both the workstations can be established. The ergonomically designed adjustable workstation was set up and installed in the Ergonomics Lab. Experiments were conducted at random on both the workstations and methods. Participants were given a demonstration and then trained for one hour in both existing and height adjustable workstations and methods before starting the experimental sessions.

Each participant assembled the electrical plugs for a duration of one hour under each experimental condition, chosen randomly. The output was recorded and the data were summarized and analyzed using

SPSS. The mean of the number of units assembled in one hour under the two experimental conditions are presented in Figure 3. The average number of units assembled under the existing workstation design was 81.35 units per hour, with a standard deviation of 8.7 units, whereas the average number of units assembled under the ergonomically designed adjustable workstation condition was 110.2 per hour, with a standard deviation of 10.9 units. The improvement in the performance was 35.46%

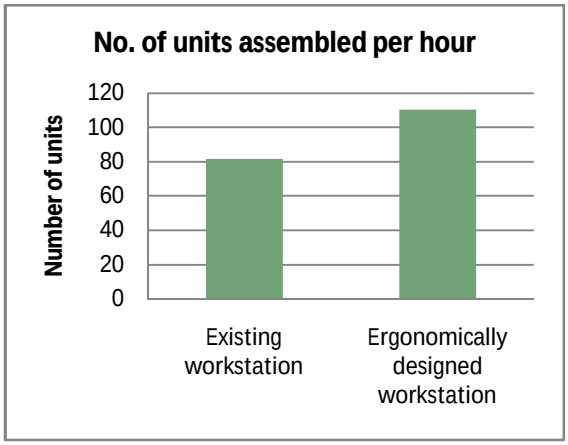

Figure 3: Mean output for two workstations

V. FINDINGS AND CONCLUSION

Improving worker productivity, while maintaining occupational health and safety in repetitive tasks remains a major challenge in industries. Ergonomically designed workstations have been found effective in reducing injuries and health symptoms and improve performance. Adjustable computer workstations are widely used in office environment. Seldom adjustable workstation is found in industries. Ergonomically designed and adjustable workstations are more advantageous and could be used for repetitive assembly tasks in manufacturing.
A fully adjustable and ergonomically designed assembly workstation was developed and installed in the company manufacturing electrical fittings. Worker productivity improvement was highly significant on this workstation compared to the existing non ergonomically designed workstation. Workers adjusted the workstation according to their comfort and posture. The low-cost assembly workstation was designed, developed and evaluated in terms of operator performance in the assembly shop of the company.

The cost of the ergonomically designed adjustable workstation was about one-third of the cost of the smart workstation (which has electrical motors for height adjustment mechanism) . But compared to the existing workstation the cost was higher (about 45%), and it was acceptable to the company for implementation in phases, considering the worker comfort and higher productivity and significant future benefits. The worker performance improved significantly on the ergonomically designed adjustable assembly workstation compared to the existing non-ergonomically designed workstation for performing an industrial task. The improvement in performance was about 35%.

The adjustable ergonomically designed assembly workstation was preferred by the workers, and they adjusted and organised the workstation to their comfort. Workstations for assembly tasks should be designed such that any operator can adjust to his/her comfort to relieve physical stress, improve posture and performance. The ergonomically designed assembly workstation is a solution to ergonomic and productivity problems in the workplace.

The authors have undertaken a long term plan to investigate further in order to accomplish benefits from this research by conducting studies in assembly of different products for a longer time to validate the benefits, and to consider the workers's perception with regard to safety, health, work environment and postural analysis with the ergonomically designed adjustable workstation.

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