Ergonomics Based Recent Trends in Integrated and Flexible Manufacturing---A Critical Review

Shahnawaz Mohsin[1] Imtiaz Ali khan[2] Mohammed Ali[3]
[1,2,3]Department of Mechanical Engineering
[1,2,3]University Polytechnic, Aligarh Muslim University, Aligarh, India

Abstract— Nowadays the era of fully automatic industries has begun. As the high technology applications are getting more widespread at the global level, the problem associated with the introduction of this high technology has also been generating more and more of a concern. Major part of such a concern could be represented by the occupational stresses in the form of poor job performance, waste leisure time, low level of job satisfaction, high working stresses, low productivity etc. and by the anthropometric factor in the form of musculoskeletal disorders (MSDs). One of the important components of the high technology era has emerged in the shape of the Human-Computer Integrated Manufacturing (CIM) interface. Present paper made an attempt to put forward the problems of CIM industries from occupational stress and anthropometry point of view.

Keywords: Automation, Anthropometry, CIM, High Technology, MSDs, Occupational Stress

I. Introduction

The idea of "digital manufacturing" became prominent in the early 1970s, when Computer Integrated Manufacturing (CIM) was introduced in the year 1974 [1].

The CIM system, fractions every individual "center" of the factory into work cells. As work cells, they are then divided into individual stations. The stations are then broken down to the individual processes, and the processes are what metamorphoses the raw materials into actual products. This may seem complicated, but it streamlines the whole manufacturing process. With each division of the factory broken down in such a manner, it allows operators to make any necessary changes to the system without shutting down the whole system. Computer Integrated Manufacturing (CIM) is a very interactive, hands on the system. If it is applied correctly, it will enhance the productivity of the whole factory. It will link several departments and functions together. It is simple to install [2].

The concept of totally automated factory, in which all manufacturing processes are integrated and controlled by a CAD/CAM system. CIM enables production planners and schedules, shop floor foremen, and accounts to use the same database as product designers and engineers. This definition does not put much emphasis on the role of information. The Digital Equipment Corporation (DEC) has put much emphasis on the role of information. According to DEC, CIM is the application of computer science technology to the enterprise of manufacturing in order to provide the right information to the right place at the right time, which enables the achievement of its product, process and business goals. The above statement points out the importance of information in manufacturing enterprise, but unfortunately it does not give much emphasis to the very important concept of integration. Computer Integrated Manufacturing is a philosophy in operating a manufacturing company.

Computer Integrated Manufacturing is an operating philosophy aiming at greater efficiency across the whole cycle of product design, manufacturing, and marketing, thereby improving quality, productivity, and competitiveness. In order to stress the importance of integration, the Computer and Automation Systems Association of Society of Manufacturing Engineers (CASA/ASME) has described the CIM in the following way, CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with the new managerial philosophies that improves organizational and personnel efficiency. It should be pointed that CIM does not mean to replace human by machine or computer, so as to create a totally automatic business and manufacturing processes. The importance of human factors should be much emphasized. Human plays a very important role in CIM design, implementation, and operation. Although computer applications and artificial intelligence technologies have gained much progress, even in the future, the computer cannot replace people. In order to stress the importance, many researchers have presented the idea of human centred CIM [3],[4],[5],[6],[7],[8], [9],[10],[11],[12].

It is because of mainly above mentioned and various other factors that the ergonomics will play an important role as far as the better design of human-CIM interface is concerned. Various ergonomic factors, which will be considered for the effective and efficient design of human-CIM interaction system, are discussed in the following sections.

II. Role of Ergonomics in CIM Industries

Nowadays, in the era of automation, the products and systems are designed keeping in view the human and environmental factors, so that they should be used safely, comfortably, efficiently and effectively. With the emergence of CIM industries, the task left is an implementation of ergonomics by the industries to provide an increased productivity and reduced MSDs and other injury rates. In CIM industries ergonomics will be seen as an added advantage to reduce the costs for compensation claims by the workers in the case of mishap. Furthermore, with the application of ergonomics, the quality of work is also increased as the workers' morale is increased. In CIM industries, ergonomically designed and evaluated programs will result in long term benefits in the form of cost and injury reductions and enhancement of product quality and employee morale. Also in these industries employments of ergonomics will yield economic benefits.

III. OCCUPATIONAL STRESSES IN HUMAN-CIM INTERACTION ENVIRONMENT

Occupational stress is considered to be a major cause of mental, cardiac and stomach disorder. Stress is having a significant effect on both leisure and work activities. According to The National Institute of Occupational Safety & Health, Occupational stress is the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources or needs of the worker. Work performance improves when the workers are put under manageable stress. However, it is when that stress or pressure becomes too great and becomes unmanageable, that workers start to experience fatigue, exhaustion, ill-health, panic and ultimate breakdown and burnout. It is pointed out by [13], that the knowledge economy and the explosion of information technology have resulted in many computer-based workers who experience discomfort, cumulative trauma disorders, and tend to have a higher body mass index than manufacturing workers. The process of redesigning workstations to address these issues should include a study that evaluates the impact on productivity. It was also explored that the productivity evaluations of potential designs can utilize simple, low-cost methods of assessing productivity with an input task based on Fitts' Tapping test. Furthermore, in this work the authors compare three computer workstation designs (seated, standing and walking) and shows that walking adversely affects productivity yet comparing seated and standing postures yields mixed results. For more simple tasks, the ideal posture is sitting while for more complex tasks the worker should be standing for improved productivity.

[14], find out the different effective techniques of managing stress as perceived by workers in developing countries. In this work a case study was conducted at Rock Chemicals Fillers (Private) Limited, a company that is located in the Chegutu industrial area of Zimbabwe. The study used both qualitative and quantitative research methods. The target population were employees at the manufacturing company and a sample of 35 participants was identified using the convenience sampling technique. The researchers used two research instruments; a questionnaire and an interview guide. Findings revealed that workers agree with the concept of counselling, body exercise and sport as techniques for managing stress at the workplace. To this end, the study recommends employers to ensure counselling of employees at the workplace, sport and recreation at the workplace to ensure the effective management of stress at the workplace.

It was explored by [15] that the success in managing and preventing stress will depend on the culture in the organization. Stress should be seen as helpful information to guide action, not as a weakness in individuals. A culture of openness and understanding, rather than of blame and criticism, is essential. Building this type of culture requires active leadership and role models from the top of the organization, the development and implementation of a stress policy throughout the organization, and systems to identify problems early and to review and improve the strategies developed to address them. The policy and its implementation should be negotiated with the relevant trade unions and health and safety committees. Moreover, the researcher pointed out that interventions should be evaluated, so that their effectiveness can be assessed. Ideally, the method of achieving this should include a high response rate, valid and reliable measures, and a control group. Two measures that provide a comprehensive analysis of work stress and have been widely used are the Job Content Questionnaire, which includes measures of the predictors of job strain.

Although connections between cognitive deficits and age-associated brain differences have been elucidated, relationships with motor performance are less understood. [16], review age-related brain differences and motor deficits in older adults in addition to cognition action theories. Age related atrophy of the motor cortical regions and corpus callosum may precipitate or coincide with motor declines such as balance and gait deficits, coordination deficits and movement slowing. The study concluded that in general, older adults exhibit involvement of more widespread brain regions for motor control than young adults.

[17], investigates the effects of intelligence, perceptual speed and age of intra individual growth in attentional speed and attentional accuracy over the course of a 6-minute testing session. The study concluded that the intelligence was not associated with the ability to learn to perform the attention task quickly and accurately. Also, age differences were mainly related to baseline performance. Results indicate that the concurrent performance aspects, speed and accuracy, are distinct in the shape of growth.

With the accelerated pace of installation of computerized machine tools and use of human machine interaction systems, the role of ergonomists in automated industries has become crucial. The ergonomists possess not only behavioural but also technological skills and knowledge, which is a requirement for better design of the human machine interaction environment. In future industries, ergonomists will be involved in the development of effective research methodologies which could enhance significantly the productivity, product quality, quality of working life and standard of living [18].

Keeping in view the above findings a conclusion can be drawn that ergonomics in CIM industries should be applied to minimize occupational stresses for an efficient and effective design of human-CIM interaction environment.

IV. HUMAN-CIM INTERFACE AND ANTHROPOMETRIC CONSIDERATIONS

Many of the injuries in manufacturing are musculoskeletal disorders caused by cumulative trauma. These injuries that result from cumulative wear and tear are identified as cumulative trauma disorders (CTDs). Back injuries, tendinitis and carpal tunnel syndrome are some examples of common CTDs. Work place risk factors for CTDs include repetitive motions, high forces, awkward postures and vibration exposure. Work related musculoskeletal disorders (WMSDs) remain a widespread and growing issue of concern in CIM industries. It is estimated that over five million workers sustain overextension injuries per year. Through ergonomic intervention, workplaces can be designed so that workers do not have to overextend themselves and the manufacturing industry could save billions in worker's compensation. Manufacturing companies once thought that there was a bottom-line trade-off between safety and efficiency. Now they embrace ergonomics because they have learned that designing a safe work environment can also result in greater efficiency and productivity. Recently, U.S. laws requiring a safe work environment have stimulated great interest in Ergonomics from ergonomic furniture to ergonomic training. But it is in the design of the workplace as a whole where the greatest impact can be seen for both safety and efficiency. The easier it is to do a job, the more likely it is to see gains in productivity due to greater efficiency. The success of automated industries is based on the effective and efficient ergonomic design of Computer Integrated Manufacturing (CIM) system and their interfaces.

It was pointed out by [19], that the design of workstation needs to take into account the adjustability of the working platform, clearances under work surface, system panel and displays support surfaces. The effectiveness with which operators perform their tasks at consoles or instrument panels depends in part on how well the equipment is designed to minimize parallax in viewing displays, allow ready manipulation of controls and provide adequate space and support for the operator. In the past, studies were conducted to investigate physical impairments caused to the operators due to various factors related to the machining operation. Discomfort might be used as a measure for quantifying postural stresses.

[20], in their work describes an emotional human-machine interface as an anthropomorphic social agent able to exhibit simulates emotions and react to emotional stimuli. The researchers propose a Neuro-biologically inspired agent implementation that is based on mechanics of chemical and physiological processes within the human brain. Implementation of model features simulation of neuromodulators such as dopamine, serotonin, and noradrenaline. Demonstration of emotions is achieved via combining aforementioned neuromodulators in different proportions. The Lovheim cube of emotions is used for this purpose. In conclusion, the authors have proposed a realistic computation model allowing to visualize agents' mimics in sync with his speech, and have made a working prototype of the aforementioned model.

[21], explored in their study that the fourth industrial revolution faces the technological change of Human-Robot cooperation in the manufacturing process. The aim of this study was to investigate the effectiveness and user's acceptance of a passive exoskeleton for upper limbs. In this work three different tests, involving static and dynamic tasks, were performed by 29 automotive operators without and with the exoskeleton. Main aspects and results of the testing campaign briefly addressed potential issues associated with the introduction of these auxiliary devices in the automotive industry, together with the open questions on how to assess the biomechanical workload risk, especially in the design phase.

It is pointed out by [22], that the past efforts have been made to design single-user workstations to accommodate users' anthropometric and preference distributions. However, there is a lack of methods for designing workstations for group interaction. The authors introduce a method for sizing workstations to allow for a personal work area for each user and a shared space for adjacent users. The researchers first create a virtual population with the same anthropometric and preference distributions of college aged students. Members of the virtual population were randomly paired test if their extended reaches overlap, but their normal reaches do not. This process was repeated to estimate the total percentage of groups with the populations that be accommodated for a work station size. The researchers apply method to two test cases first, size polygonal workstations for two populations and second, dimension circular workstations for different group sizes. This work mainly concluded that a proper side length should be selected for an optimal multiuser work station design.

[23], describes the results of an experimental study conducted to investigate the effects of assembly of a product on operator performance. A fully adjustable, ergonomically designed assembly workstation (smart workstation) was used for the experiment. Ten college students (five boys group and five girls group) randomly assigned into three experimental conditions (table adjustments, chair adjustments, and gender) performed the assembly task. Performances of the participants assembling a product are: operator production rate representing in how many assembly products per unit time (units/hour). The result of this work shows that females are more productive than male. [24], explored that workstation's ergonomic design is dependent on considering the nature of tasks to be completed, the preferred posture of the operator and the dynamics of the surrounding environment.

Based upon the above findings, it can be emphasized that the anthropometric considerations will play a key role as far as the design of a better human-CIM interaction environment is concerned.

V. CONCLUSION

With the accelerated pace of installation of computerized high technology machine tools and use of human-CIM interaction systems, the role of ergonomics in CIM industries has become crucial. In upcoming CIM industries ergonomics will be involved in the development of efficient and effective research methodologies which could significantly enhance the productivity, product quality, quality of working life, standard of living and employees' morale. The ergonomics possesses not only behavioural but also technological skills and knowledge, which is a pre-requisite for better design of human-CIM interface environment. Also a good common sense for technical know- how is substituted through the ergonomics. The behavioural basis of ergonomics has also been expended to include greater emphasis on computerized high technology machine tools. Keeping in view the above literature and discussion, it can be concluded that for future CIM industries with accelerated application and use of human-computer communications, various aspects should be ergonomically designed and evaluated in order to have an effective, efficient and improved human-CIM interaction environment.

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