RESEARCH OVERVIEW

This chapter portrays an overview of the research. It sketches the background of the study, the problem statement, the research objectives, the research questions and the outline of the thesis.

1.1 Background

This study is all about understanding how the anthropometric factors affect performance in a human-CNC machine interface environment. Historical evidences suggest that many of the injuries in manufacturing are musculoskeletal disorders caused by cumulative trauma. These injuries that result from cumulative wear and tear are called 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 automated 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 ergonomic design of CNC machines and their interfaces.

In the literature, the discussions on impact of anthropometric factors on human performance figured prominently. Some of the studies worth mentioning are: Kee and Karwowski (2004);
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Reid et al. (2010); Kee and Lee (2012); Peterson and Rayan (2011); Cadogen et al. (2011); Suprak (2011); Kim et al. (2009); Genaidy et al. (2005); Straker et al. (2008); Kong-King and Der-Song (2007) and Westgaard et al. (1988) etc. There are quite a number of studies in respect of cognitive performance as well, e.g. Layer (2009); Chikhaoui and Pigot (2010); Genaidy and Karwowski (2003); Bedny et al. (2001); Feigh (2011); Phillips and Madhavan (2011); Anderson et al. (2005) and Ferris et al. (2008) etc. Some of the important studies highlighting the effects of age and sex on human performance are: Jimenez-Jimenez et al. (2011); Endrass et al. (2012); Chung et al. (2010); Contreras et al. (2012); Trent and Davies (2012); Huang and Wang (2010) and Hazlett et al. (2010) etc.

Although the studies are quite meaningful, there has been overwhelming stress on anthropometric, cognitive, age and sex aspects of industrial behavior and broad measures of human performance viz-a-viz the role of ergonomics in the design of systems and interfaces. They offer inadequate understanding of these aspects in the design of CNC machine systems and their interfaces. Worldwide nowadays, CNC machine tools are extensively used in the manufacturing environment. The human-machine interaction plays a vital role across the entire production process. Therefore, the CNC machine system should be reliable in operation, safe, accepted by users and last but not least cost-effective. It is therefore necessary to figure out how CNC machine systems and their interfaces be designed in the rapid technological changes and international commitments. In view of the above, we have selected CNC Machine Tools for the purpose of this thesis. The specific objectives of the present work can be enunciated as follows:

1.2 Research Objectives

- To evaluate performance in a human-CNC machine interaction environment considering anthropometric, cognitive, age and sex aspects,
- To design a CNC machine which is reliable in operation and safe,
To develop an ergonomic database for effective and efficient human-CNC machine interface.

1.3 Research Questions

- Why the CNC machines and human-CNC machine interfaces should be ergonomically designed?
- How should the CNC machine system and their interfaces be designed?
- How the ergonomic design affects performance of the human beings?

1.4 Relevance of the study

The study is relevant for a variety of reasons. First of all, it is the first study in a human-CNC machine interface environment based on load cell concept used to measure human performance in terms of both cognitive and motor actions simultaneously. This potentially enhances the understanding how realistic performance measure works in the context of ergonomic design of systems and their interfaces. This thesis attempts to provide a systematic analysis for developing a detailed ergonomic database for the optimum utilization of CNC machines and their interfaces. The study targeted the CNC machine system, keeping in view the exponential growth of the automation nowadays, and the use of CNC machines in manufacturing and design. The performance measurement system designed for the study may be replicated for other fields where systems are operated through control panels and also where responses of mentally retarded human-beings (or the human beings with the symptoms of Alzheimer disease) are to be observed and evaluated. In addition to theoretical relevance, it has practical relevance too. The study is relevant for the Machine Tool Industries to plan/implement accordingly, the strategies and actions regarding design of CNC machines and their interfaces.
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1.5 Research Methodology

Present study could be categorized as an applied research since it is aimed to provide action-oriented recommendations (Saunders et al., 2000). It is primarily an exploratory quantitative research. The concepts/techniques from one camp to another need to be blended together for imparting better credibility to the findings. This research is considered to be an applied research having a learning towards phenomenology (philosophical position), exploratory (purpose of research), empiric inductive (research approach), qualitative (research method), focused synthesis (method of data collection) and quantitative (analysis of data).

It is proposed to undertake studies to provide answers to some of the basic issues related to the use of CNC machine tools. In all, four studies were planned to investigate human performance on CNC machine tools under the impact of machine panel height, panel angle and working distance. Out of these four studies, the first one (Study-1) investigated the effects of younger, 19-23 years age group male operator’s performance on CNC machine tool. In the second study (Study-2), the effects of female, 19-23 years age group operator’s performance on CNC machine tool were examined. The third study (Study-3) explored the effects on human performance when middle age group 32-36 years male operators interacted with the CNC machine tool. Finally, fourth study (Study-4) investigated the effects of higher age group 42-46 years male performance when they operate a CNC machine tool.

As regards to the evaluation and trustworthiness of the designed research, search time, motor action time and applied force were selected as response variables to evaluate the CNC machine operator’s performance. A full factorial design of experiments consisting of 27 (3³) experiments was used to collect data for human performances. The collected data were analyzed using grey relational analysis and analysis of variance (ANOVA) and F-test. ANOVA was carried out using Design-Expert software. The designed research has achieved a reasonable degree of validity through performing confirmation test.
1.6 Organization of the Thesis

This thesis is organized into seven chapters, comprising an introductory chapter, a theoretical chapter, a chapter on machine tool industry and sensor technology, one chapter on related researches, a methodological chapter, a chapter on experimental investigations and a concluding chapter presenting overall synopsis, findings of the study and scope of further research.

The introductory chapter, chapter one, presents the overview of the research in terms of background, research objectives and research questions, research methodology and outline of the study. Chapter two builds the theoretical foundation of the study. It begins with discussion on the role of ergonomics in the design of human-CNC machine interface. It leads to three overriding questions that dominate our discussions: first, why should the human-CNC machine interface be designed?; second, how should the human-CNC machine interface be designed? and third, how the ergonomic design affects performance of the human beings? We identify the answer of the ‘why’ based on the rationale of ‘musculoskeletal disorder’. The ‘how’ is established by synthesizing the ‘reactive’ and ‘proactive’ perspectives. In the process, definition of interface design and its elements have been developed. It is followed by conceptualization of interface design for CNC machine tool industry.

Chapter three describes machine tool industry and sensor technology. It begins with a brief introduction to machine tool followed by discussion on the evolution, structure and production and trade of the world machine tool industry. The following section analyses structure, growth and production and trade of Indian Machine Tool Industry in general and CNC segment of the industry in particular. The chapter is supplemented with discussion on sensor technology and its application in performance measurements. The last section presents the conclusions.

Chapter four analyzes the findings of previous researchers in the field of musculoskeletal discomfort, anthropometry and cognition. The discussion has been presented in five sections. Following introduction and brief historical background, it begins with studies on working
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postures. The second section reviews the literature related with cognitive performance. Third section analysis the studies on the effects of age on human performance. The fourth section attempts to analyze the studies on the effects of sex gender on human performance. The concluding section is presented in the form of motivation for the present work.

In chapter five we describe the problem formulation and research methodology. It comprises of research plan and objectives. To begin with, the chapter describes the formulation of problem for the present work. The experimental design is undertaken in two distinct but important steps, first, grey relational analysis and second, analysis of variance and F-test. It is followed by a detailed description of the subjects used and stimuli and the experimental task. Then it presents the road map of experimental setup. It is supplemented with general experimental procedure. At the end conclusions are drawn.

Chapter six endeavors to present detailed experimental investigations. For each study, it is presented in four distinct but interrelated sections. First, we analyze the purpose of the studies undertaken. Secondly, the experimental method is described in detail. Third section analysis the experimental results in three sub-steps: determination and discussion of optimal parameter combination; analysis of variance; confirmation test. Fourth section presents discussion and conclusion. At the very last, it is supplemented with general discussion and conclusions.

Finally chapter seven concludes the thesis. It presents the overall summary, conclusions and scope of further research. To begin with, following introduction the chapter describes the objective of the thesis i.e. what I wanted to do? Then it presents the road map of the thesis i.e. how did I proceed? It is followed with the presentation of what did I discover i.e. the general findings and final conclusions. The limitations and agenda for further research come next. The last section expatiate the research contribution and final remarks.