Analysis of human factor and musculoskeletal strain associated with welders in bicycle fabrication

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Abstract : Introduction: In bicycle fabrication plants, welding operators welds com-plex shape in bicycle frames using TIG welding. Because of continuous change in working posture and repetitive activities without adequate rest, welding operators quite often face discomfort in neck, shoulder and lower back of the body which results in Work Related Musculoskeletal Disorders. This eventually leads to a de-cline in the quality of the health, work and productivity. Methodology : Musculoskeletal injuries are identified and assessed by Electromyography (EMG). It is used to measure the amount of fatigue through programming in MATLAB. Work related upper limb disorder risks is detected and displayed. The image of the welding operator was taken and the work envi-ronment is simulated in CATIAV5. RULA scoring was made on different simu-lated work posture of operators. CATIA ergonomic analysis is performed to ana-lyze, predict the human safety and performance of 3D virtual welding environment. Analysis were performed on the whole body and segmented post-ure context to welding and workplace design. Results : In the Frequency Vs Time graph, maximum fatigue occurs at forearm is 190Hz and minimum fatigue occurs at arm is 40Hz obtained through experimentation of EMG. Using CATIA simulation, overall RULA result shows that operators were at medium and high hazard level in upper arm, forearm, wrist and neck. Conclusion : Both approaches of EMG and CATIA simulation shows that welding operators felt discomfort and facing musculoskeletal disorder is to be reduced by achieving the optimized condition.

1 Introduction

Welding operators facing health problems due to poor workstation in a manu-facturing plant. Musculoskeletal disorder occurs in forearm muscles, vertebrae, shoulder and lower back of the body. Muscle fatigue occurs due to awkward body posture with respect to time among the workers. Health hazards are vision, exposure to UV radiation and lung problem. It can be minimized by applying ergonomics in welding process to provide better comfort to workers. Industrial er-gonomics is the application of human factors data in the systems used by human beings. Research in experimental psychology for human performance and their systems design, human factors was originated.

According to physical aspects, we should consider body size and shape, fitness, strength, posture, the stress and strains on muscles. Human factors and er-gonomics (HFE), a systematic approach is necessary for design and analysis [1]. In HFE, designing the system, organization, job machine, tool, products by using the knowledge of human capabilities and limitations in a environmental con-straints. So that it is effective, reliability and safe to use [2]. It is important to clas-sify body postures to improve the design of job and work places by various me-thods to evaluate musculoskeletal problems. Ovako Working Posture Assessment System (OWAS), Rapid upper limb Assessment (RULA), loading analysis by load lifting, push/pull analysis, carry and biomechanical analysis. Above methods helps to create the workstations in accordance with health and safety and to maximize the safety and comfort.

Electromyography (EMG) evaluates and records the electrical activity produced by skeletal muscles by electromyograph. Signals are analyzed to detect medical abnormalities and biomechanics of human movement [3,4,5]. CATIA er-gonomic analysis is performed to analyze and to predict the human safety and productivity [6]. Both EMG and CATIA approach provides better solution for finding the discomfort in the upper body and lumbar vertebrae.

2 Methods

2.1 Electromyography (EMG) Method: In a bicycle manufacturing plant, Muscle pain and tenderness during daily cyclic work is one of the problems affected by the forearm muscle. The technique of surface electromyographic (sEMG) signal analysis is a established tool [7] in ergonomic evaluation . Workstation design is the most important cause of MSDs. Musculoskeletal injuries is identified and assessed by ergonomic evaluation using EMG. EMG is a method used for evaluating and recording the electrical activity produced by skeletal muscles using an instrument Biopac System 150 is shown in figure 1. The signals can be analyzed to detect medical abnormalities and to analyze the biomechanics of human involved in the industry. It is determined by performing a maximal voluntary contraction (MVC) of the muscle is being tested. If the action of the muscle is completed, then the muscle are activated. Any signal that comes from the electrodes signifies that the muscle is active. The sum of all this electrical activity is known as motor unit action potential (MUAP). It is use to measure the amount of fatigue in a muscle [8]. Monitoring the changes of different frequency changes the most common way of using EMG to determine levels of fatigue [9]. Monitoring the changes of different frequency changes the most common way of using EMG to determine level of fatigues. Thus the level of tension in muscles can be determined [10]
The quality of the acquired signal depends on the Sensor location (upon the middle of muscle belly), Sensor characteristics, Electrode-skin interface (good skin preparation), Cross-talk from other muscles and Noise contamination.

It is a technique for evaluating and recording the electrical activity pro-duced by the skeletal muscles. An EMG signal detects the electrical potential gen-erated by the muscle when these cells are neurologically or electrically activated. The electrical source of the muscle membrane potential is about -90mv.Measured EMG signal potentials range between less than 50 micro volts and upto 20-30mv depending on the muscle under observation. A muscle at rest is normally electri-cally inactive. When voluntarily contracted action potentials begin to appear nor-mal results is obtained. Abnormal results is obtained when EMG is used to diag-nose such as neuropathies, myopathies and neuromuscular junction diseases [11].
2.2 CATIA V5 Simulation Methods: Ergonomics is the science of arranging or designing things for efficient use. Ergo-nomics is also called Human Factors Engineering. It involves making the workplace fit the needs of workers. There are many ergonomic challenges in the fabrication industry. These challenges are to be recognized and ergonomically evaluated by CATIA V5 simulation [12]. Workers often use awkward body posi-tions during fabrication. Body position and time are key factors in causing inju-ries. Posture evaluation of virtual human model on workstation using ergonomics and its influences are explained by Dan La

Mkull [13].

It explains how manual handling can be avoided or reduced through bet-ter planning, consultation and systematic management. It provides ideas for solu-tions to different manual handling issues. Many well-known accidents might have been prevented if ergonomics and human factors had been considered in designing people's jobs and the systems they worked in [14]. Implementation of safety management for healthy working conditions creates positive impacts on economic and social development [15].

3 Experimental Work

Ergonomics is mainly projected to present optimal comfort and to avoid any stress, constant worry or injury. An understanding of the use of sEMG transcends many areas of knowledge including physiology, instrumentation, recording tech-nology, and signal processing and analysis. Only few studies have experimented different ergonomic aspects of the forearm muscle with respect of sEMG. As a re-sult our on-going research will identify the muscle activeness of the forearm mus-cle, Upper arm, Wrist and Neck.

3.1. EMG Biopac System: The EMG provides important information about physiological status of skeletal muscle and nerve supply. Biopac System MP150 is connected to comput-er using ACKNOWLEDGEMENT software.

In the ACKNOWLEDGEMENT software, muscular activity of the welding operator is measured and analyzed using MATLAB. Frequency graph shows that amount of muscular fatigue in welding operator using MATLAB pro-gramming code and varies from each other.

3.2. Photographies of Operators: The examination of risk among operators was discovered by performing the Rapid Upper Limb Assessment(RULA) to four frequently adopted postures. Therefore, different working postures of welding operators were photographed are shown in figure 2.

It is subjected to further investigation to determine the associated risks. The photographs of the frequently adopted working postures PA, PB, PC and PD were inserted in the AUTOCAD software and the basic working angles of the op-erators were inferred are shown in figure 2.

4. Results And Discussion

4.1. EMG Fatigue Results

4.1.1. Person A Arm And Forearm: In the Frequency Vs Time graph, muscular fatigue of arm is 130Hz and forearm is 100Hz are shown in figure 3. When the frequency increases, muscular fatigue increases. Every person fatigue value differ from each other. Thick brow-nish color resembles the fatigue value of suitable frequency.

4.1.2. Person B Arm And Forearm: In the Frequency Vs Time graph, muscular fatigue of arm is 140Hz and forearm is 180Hz are shown in figure 4. When the frequency increases, muscular fatigue increases. Every person fatigue value differ from each other. Thick brow-nish color resembles the fatigue value of suitable frequency.

4.1.3. Person C Arm And Forearm: In the Frequency Vs Time graph, muscular fatigue of arm is 40Hz and forearm is 70Hz are shown in figure 5. When the frequency increases, muscular fatigue increases. Every person fatigue value differ from each other. Thick brownish color resembles the fatigue value of suitable frequency.

4.1.4. Person D Arm And Forearm: In the Frequency Vs Time graph, muscular fatigue of arm is 160Hz and forearm is 190Hz. are shown in figure 6. When the frequency increases, muscular fatigue increases. Every person fatigue value differ from each other. Thick brownish color resembles the fatigue value of suitable frequency.

4.2. Scoring Analysis: RULA scoring was conducted on human model of posture PA, PB, PC and PD of 50%, 60% and 70% Percentile using CATIA V5 software are shown in fig-ure 7 and 8. From the simulation results of CATIA, RULA (Rapid Upper Limb Assessment) for different person of different percentile of different posture is ob-tained. From the RULA analysis, risk factors are number of movements, static work of the muscles, body posture by assembly executing and working time. All this factors are combined into the final score. Final score starts from 1to 7 and is also expressed in color.

From the results of RULA scoring of manikin using CATIA V5 of different post-ure of different percentile, it is found that upper arm, forearm, wrist and neck va-ries in RULA SCORE.

5 Conclusion

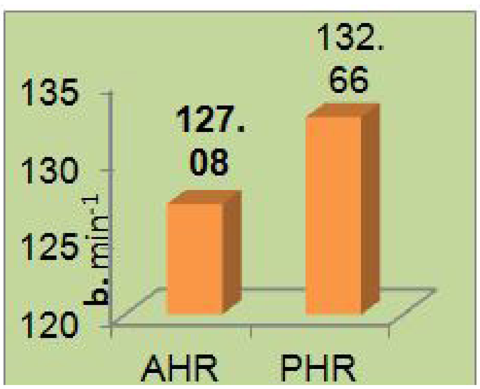
The professional welding operator's opinion about their discomfort felt in upper arm, Forearm, wrist and neck was evident based on the computer aided hu-man factor analysis. From the EMG experimental results, it is obtained that amount of muscular fatigue in forearm is higher than arm of different person with time period. The results obtained are useful for clinicians, electromyographer and researchers, especially those who are working on ergonomic activities. From the CATIA simulation, RULA is a survey tool investigated the workplace where dis-orders are obtained in Upper arm, Forearm, Wrist and Neck. RULA results shows that welding operators are in average and highest risk level of fatigue due to the working posture.

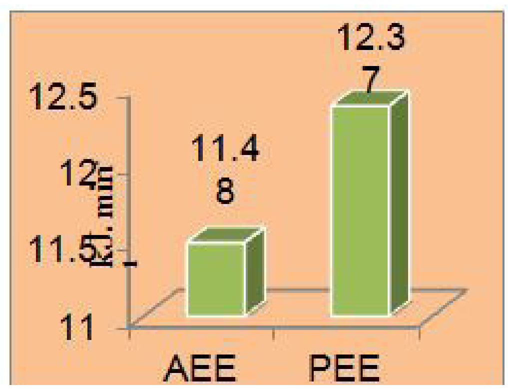
Both approach of EMG and CATIA simulation shows that welding oper-ators feels discomfort and facing musculoskeletal disorder is to be reduced by achieving the optimized condition. Workstation design that is ergonomic by keep-ing objects within a close range of motion helps the operators to put less strain on their muscles and joints. Operators do not have to deviate far from its posture helps to improve ergonomics.

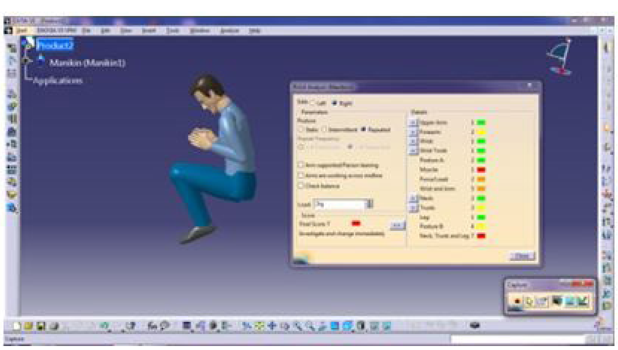
6. **Figures**

Table 1. Physiological parameters of storage of paddy by conventional basket

Physiological parameters	**Conventional basket**	**Mean ± SD**
Average resting heart rate (b.min^{-1})	77.85	77.85 ± 4.79
Average working heart rate (b.min^{-1})	127.09	127.09 ± 2.60
Average peak heart rate (b.min^{-1})	132.66	
Average energy expenditure (kJ. min^{-1})	11.48	11.48 ± 0.41
Peak energy expenditure (kJ. min^{-1})	12.37	
Total cardiac cost of work(TCCW) (beats)	2337.54	2337.54 ± 357.10
Physiological cost of work (PCW) (b. min^{-1})	61.51	61.51 ± 9.39
Average RPE	4.22	4.22 ± 0.32
Physiological workload		
Average	Heavy	







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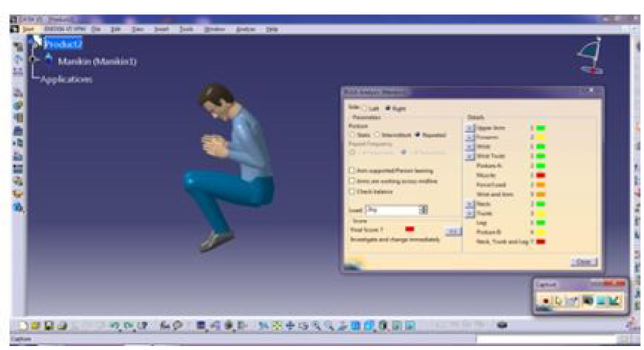

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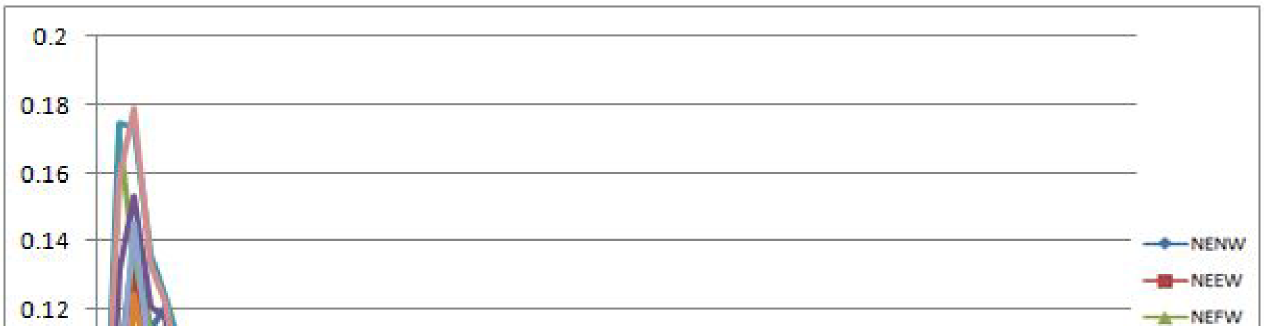

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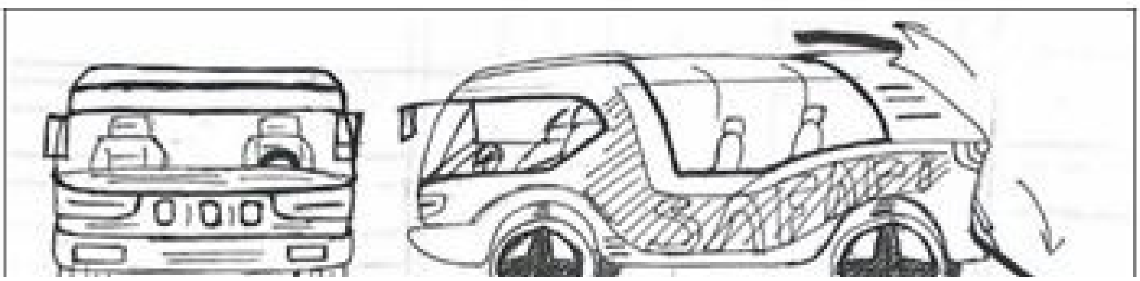

e f

Fig. 4 screenshot of RULA scoring by 50%, 60% and 70% percentile of manikin posture a, b, c- Posture PA of 50%, 60% and 70% respectively d, e, f- Posture PB of 50%, 60% and 70% respectively

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