Analysis of Postural Stresses of Different Muscles and Joints of Welders during Welding

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Abstract—Bodily injuries are highly related with different joints and muscles in welding operation. Knee, wrist, hip, elbow and glenohumeral joints are the mostly used joints in human framework. Joints strengths are the critical aspects which are provided by the different muscles and ligaments. For injury analysis, the location of different joints & muscles is one of the major concerns during welding operation. The aim of this present research work is to obtain the intensity & spreading of stresses in the different joints & muscles during welding. The 3D CAD model of the entire human body was developed in Solid Works software and FEM was used for stress analysis. The maximum Von-Mises stresses were also noticed in this work. It was noticed that the intensity of stresses and the Von-Mises stresses were good injury indicators for the body muscles and joints independent of direction of load. This present research work provides broad information to the researchers for better understanding about the most stressed muscles and joints during welding.

Keywords— ANSYS, CAD Model, Intensity of stress, Von-Mises Stresses, Welding

I. INTRODUCTION

In manufacturing industries workers play an important role to develop a country. Welding is one of the most essential parts in manufacturing sectors of our country. Awkward working posture and unsuitable management programme also affect the production rate and also hampered quality of jobs. Production rate and its quality are highly related with physical ability and skill of the workers. Welders are highly exposed to body fatigue due to work related problems [1] [2]. Occupational safety and health are also main concerns in this unit. It is noticed that physical strength of the welders does not remain immutable in awaking process.

It also varies with their environmental, physical and psychological states [7]. The higher involvement of the workers in this unit give rise the points that musculoskeletal symptoms are very common among them. The body stresses comes from embarrassed work postures and the static nature of welding work. Static work is considered ergonomically unsound and has firm physiological basis for muscular pain [4, 9].

II. DESCRIPTION OF OPERATION

This research work is exploratory in nature in which the body postures of welders were recorded and musculoskeletal injuries of the workers were analyzed. The 5 percentile smaller and the 95 percentile larger workers were not included in this study. The working experience of the workers under observations was more than 4 years and working period was 9-11 hours a day. Welding is done in kneeling posture because the fixture used for welding is placed on the ground. Welders need to remain in this posture and have to perform their work continuously. The electrode holder has a weight of 4kgs and even up to 6kgs with consideration of the weight of the cables. Figure 1 shows the actual body posture of the worker at the time of operation. Both the hands of the worker are engaged and simultaneously he needs to watch the movement of the electrode during the operation. It was also noticed that due to continuous kneeling posture, they become frequently fatigued and musculoskeletal problems could be identified.

If no Ergonomics interventions are taken among welders, work-related diseases & sickness will occur and more quickly musculoskeletal system will be affected. A worker become physically fatigued frequently due to static & continuous kneeling musculoskeletal system will be affected. A worker become physically fatigued frequently due to static & continuous kneeling posture and it is observed that musculoskeletal problems are common in these types of units [6][8]. Finite element analyses assess the occupant injuries and MSDs which cannot be evaluated accurately with the conventional posture analysis tools [10]. FEM is one such tool for injury analyses of body muscles, different joints and bones [3]. The objective of this present work was to develop a realistic three dimensional model of the human body and to observe the stress distribution in different joint and muscles in a particular work load and body posture of welders [5]. The study of stress distribution patterns in different body region and joints would be relevant for a better diagnosis of low back pain and shoulders [11]. Hence, this type of analysis of body stresses and Von Mises stresses may contribute to the whole understanding of the different body parts and joints at the time of operation [5].
High levels of control, attention and synchronization were essential in this operation.

![Figure 1: Working Posture of welder](image1)

**III. METHODOLOGY**

**A. CAD Modeling:**

In order to know the performance of muscles & joints of human body, realistic and detailed model is required to develop. A 3-D CAD model of human body was done in Solid Works for analysis of stresses in ANSYS software. Figure 2 shows the CAD model of human body with degree of freedom (DoF) of different joints. This human model was divided into 13 active bodies which consisted of 27007 node points connected through 13810 elements.

![Figure 2: CAD model of human body with DoF of joints](image2)

**B. Material Properties:**

Results obtained in any analysis depend upon the material properties. Table 1 explains the material properties and dimensions used in different muscles and joints in this analysis.

<table>
<thead>
<tr>
<th>Properties of Materials</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>1.4791e-005 m³</td>
</tr>
<tr>
<td>Mass</td>
<td>1.1711 kg</td>
</tr>
<tr>
<td>Length X</td>
<td>2.6e-002 m</td>
</tr>
<tr>
<td>Length Y</td>
<td>1.4e-002 m</td>
</tr>
<tr>
<td>Length Z</td>
<td>1.4e-002 m</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.44</td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>4.2 M Pa</td>
</tr>
<tr>
<td>Density</td>
<td>1000Kg/m³</td>
</tr>
</tbody>
</table>

**C. Method of Body Stress Calculation:**

Bodily injuries are highly connected with different joints and muscles of the human body. To get accurate results, the distribution of stresses in different body parts, muscles and joints in a specific work posture and particular work load is required. It is important and also necessary to develop realistic model to understand the performance of human body. The muscles stress during the welding was studied in details by developing a 3D model in Solid Works software and analysis of body stress and muscles is done in ANSYS-R17.0 software. The FEM analysis was done in ANSYS-R17.0 software to get von Mises stresses at particular load and work posture [13] [14].

**IV. RESULT ANALYSIS**

The data were analysed in terms of response to each question. Result indicated specific Ergonomic problem exist in these types of units. Demographic data of the workers is listed in the Table 2. Table 3 shows mean duration of work and rest per day with average no. of working days in a week.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Workers (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>26.5(±5.62)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.35(±3.56)</td>
</tr>
</tbody>
</table>

![Table 2: Demographic data of the workers](image3)
Table 3 Mean duration of work and rest/day with avg. no of working days in a week

<table>
<thead>
<tr>
<th>Work /Day(hr.)</th>
<th>Rest /Day(hr.)</th>
<th>Absent in a week(in days)</th>
<th>Working days in a week</th>
</tr>
</thead>
<tbody>
<tr>
<td>10(±2.23)</td>
<td>1.6(±1.2)</td>
<td>2.3(±1.09)</td>
<td>7</td>
</tr>
</tbody>
</table>

A. Intensity of Stress

A poor posture contributes to stress and stress donates to poor posture. When the body is stressed, the muscle of human body tense up. The different joints and muscles of human body are the most affected parts due to poor posture [12]. Sitting in a slouched position in the shop floor for an extend period of time put a great deal of stresses of upper as well lower body specially if the welders body is not supported [Figure 1]. Poor work posture increases body stresses and other physical problems as well. Human body is designed to stand strong and erect, effortlessly. Poor posture leads to back pain during welding in long period of time. The joints like hips and knees don’t get the interplay with gravity needed to make enough synovial fluid to keep the joint lubricated.

From the figure-4 it is shown that the node numbers 6460 to 7600, 12919 and 17225 are marked highly stressed and also shown by red in colours.

B. Von-Mises Yield Stress

Equivalent Stress or Von Mises failure criterion is most widely used in theories of failure for predicting ductile failure. The square of the Von Mises stress is directly proportional to the distortion strain energy per unit volume. It is excluded from consideration portions of these regions with artificially high stresses due to modelling idealizations, such as point constraints and point loads. In terms of the principal stresses, Von Mises or Equivalent stresses is calculated as

$$\sigma_{\text{vm}} = \frac{1}{2}[(\sigma_{11} - \sigma_{22})^2 + (\sigma_{22} - \sigma_{33})^2 + (\sigma_{33} - \sigma_{11})^2]^{1/2}$$

Von Mises stress is identical to the octahedral shear stress that exists on a plane equally inclined to three principal stress directions.

The Software ANSYS R17.0 was used for Von-Mises stress analysis. This analysis indicated that the maximum Von-Mises stress is a good injury indicator for the muscles with high cortical indices, independent of load directions.
The Von-Mises stress distribution patterns are shown in the Figure. 5. It varied from minimum 86.395 Pa to maximum 7.4762x10⁸ Pa in a particular welding posture. The graph of maximum, minimum and average von-Mises stresses are plotted in figure 6 with respect to node numbers.

V. CONCLUSIONS

The purpose of this present research work was to analyse the stresses induced in different muscles, joints and body parts during welding operation. The finite element method was used to examine the intensity of stresses and von-Mises stresses in the different muscles & joints of the workers. During the 3-D FEM analysis thorac–lumber facia and gluteus maximus & gluteus medius muscles were found to be the maximum stressed muscles compared to the other muscles of the welder’s body. The torso, hip and elbow joints were also found to be the maximum stressed joints that are shown by different colours and node numbers. Ergonomic work posture and ergonomically designed work table can minimize the body stresses as well as increase the welder’s efficiency & job quality.

REFERENCES