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# Evaluation of Work Posture and Postural Stresses of Welders: A Report

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## Abstract

Work related musculoskeletal disorders (WRMSD) are very common health problem in manufacturing sectors in all over India. Welding is one of the most important activities in manufacturing sector in our country. Higher risk of MSD occurs due to working in long period of time. A large number of workers are involved in welding units and also work in very bad work postures. Prolonged working hours and manual work in the working places are major causes of musculoskeletal disorders and other occupational health dieses among welders. In most of the cases Ergonomic principles are not applied while working in the small scale welding units in India. MSD risk is very high in most of the welding units. Productivities in these units are highly associated with the workers' health and safety. There is a necessity to adopt Ergonomic guidelines to reduce as well as prevent musculoskeletal injuries of the welding workers. The objective of this research work is to obtain distribution of intensity of stresses and Von- Mises stresses in the different joints and muscles during welding operation. A three-dimensional (3D) CAD model developed by Solid Works software was used here. It is clearly shown that there is a lack of Ergonomic planning in small scale welding units in our country. ANSYS R-17.0 Software was used for analysis of body stresses. This analysis shown that the intensity of stresses and maximum Von-Mises stresses were good injury indicators for the body muscles and bones with high cortical indices, independent of directions of load.

**Key words:** Musculoskeletal disorders, OWAS, RULA, Von-Mises stress, Welding

## 1.0 Introduction

Manufacturing is the backbone of any industrialized nation and so many workers are employed in this sector. They play an important role to develop a nation. Welding is one of the most important parts of manufacturing. Inappropriate work place design, ill structure jobs, mismatch between physical ability of the workers and job demands are the major problems in this sector (Singh et al., 2012). Bad working posture and unsuitable management programme also affects the production rate and quality of jobs. Production rate and quality of production is highly associated with physical ability and skill of the workers (Aaras et al., 1998). Welders are highly exposed to body fatigue due to work related problems. Occupational safety and health are also major concerns in this unit (Ali et al., 2012). It is observed that body strength of the welders does not remain immutable in awaking process. It also differs with their environmental, physical and mental state (Jafry and O'Neill, 2000).

The manufacturing operation consists of cutting and joining of various steel sections by welding process at various workstations. In different welding workstations the fixed layout are observed and found that there is scope of improvement with regard to the Ergonomics and industrial engineering aspects, as those are related to welding (Gangopadhyay and Dev, 2014). A major proportion of the works are involved and also worked in very bad postures in welding units. Welding is done on kneeling posture because the fixture that is used for welding generally placed on the ground. The worker has to sit on that posture and has to perform the welding continuously. The workers involved in welding give rise to the points that musculoskeletal symptoms are very common in welders and welding work entails an increased risk of shoulder. This particular strain in the musculoskeletal system comes from embarrassed postures and the static character of welding work. The complaints include pain due to inciting reactions in the rotator cuff (Jones and Kumar, 2010; Widanarko et al., 2012). It is static nature of work that causes elevated risk for chronic pain in the shoulder and neck. Static work is considered ergonomically unsound and has firm physiological basis for muscular pain (Choobineh et al., 2004 ; Mukhopadhyay and Srivastava, 2010). It concludes that if no ergonomics intervention taken among welders, occupational diseases will come and more quickly musculoskeletal system will be collapsed. Worker gets fatigued frequently due to continuous kneeling posture and it is observed that musculoskeletal problems are common (Meena et al., 2012; Nag et al., 2010). A human body model has been developed as an important tool to help assess occupant injuries and MSDs which cannot be evaluated with the conventional posture analysis tool. The finite element analysis is one such tool for injury analyses of body muscles, different joints and bones (Cheung et al., 2004). An inverse dynamical musculoskeletal model is simulated using data from an actual working condition to complement the accuracy of the muscular force.

The purpose of this research work is to develop a realistic three dimensional model of the human body and observe the stress distribution in different joint and muscles in particular work posture (Dalstra et al., 1995; Untaroiu et al., 2005). This study of stress distribution pattern in different body regions and joints would be relevant for a better diagnosis of low back pain Hence, this type of analysis of body stress and Von Mises stress may contribute to the whole understanding of the different joints at the time of operation (Pedersen et al., 1997; Sangeethkumar and Ramana, 2015; Wearsted and Westgaard, 1991). Investigations result should also be helpful in estimating the operating methods, commonly used in the treatment of different musculoskeletal diseases.

## 2.0 Kinematic modeling of human body

Human body is the combination of series of revolute joints. As per function, one joint can be modeled by 1-3 revolute joints. Each joint has its own joint coordinate, marked as $m_i$, with having joint limit. $m_i^U$ and $m_i^L$ are upper and lower limits respectively. So general coordinates will be $m=[m_1 \ldots m_i \ldots m_n]^T$ which is defined as a vector. It is represent as kinematic chain. There are 28 numbers of revolute joints responsible for main movements of human body. Worker's upper body is consisting of ten segments. These are trunk, clavicles, upper arms, forearms, hands and head [Figure 1]. This provides 20 degree of freedom in the upper part of the body i.e., three for neck, pelvis and shoulder, two for each elbow and wrist.

The movement and external effort can produce torque and force at the joints.

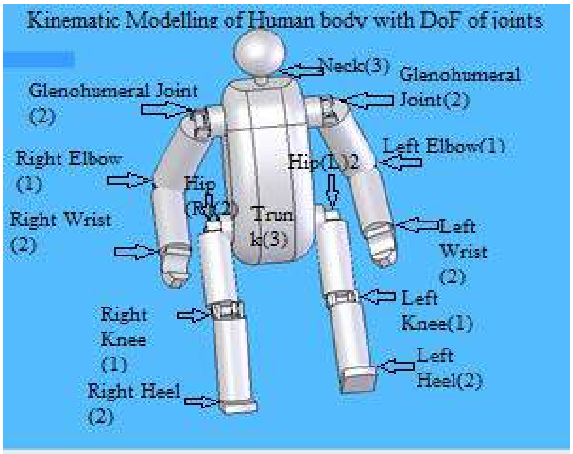

**Fig. 1. Kinematic modeling of human body with DoF of joints.**

### 3.0 Materials and Methods

### 3.1 Observation and activity analysis

The present research work has been done in different small scale welding units in West Bengal, India. The snapshots of more than 20 workers working in different welding units are obtained to analysis the body posture of the workers and it shows the different movements of the workers during their activities inside work stations. Data taken from different observations are used for postural analysis and MSD risk assessment of workers in this sector.

### 3.2 Questionnaires and interview technique

The Questionnaires consist of questions pertaining to different problems related to the particular operation. Daily activity of the worker, discomfort level of different body parts, working and resting periods are plotted and calculated. NIOSH body discomfort survey is used for mapping and plotting different areas of pain of the body with its intensity.

### 3.3 Postural Analysis

RULA and OWAS tools are used for postural analysis of work related musculoskeletal risk factor in these welding units.

#### 3.3.1 RULA Assessment

Rapid Upper Limb Assessment Method is a survey method for use in ergonomic investigation in the upper part of the body. It focuses on neck, trunk, and upper limbs of the workers body. It is very simple, easy and quick method to analyze the risk level of the human muscle. The score of RULA indicates that level of intervention required to reduce muscular risks.

#### 3.3.2 OWAS Technique

Ovako Working Posture Assessment System was developed in Finland in a steel industry company in 1977. It is widely used to identify and evaluate harmful working postures. This method is based on a simple and systematic classification of work postures combined with observations of corresponding tasks. Postures are recorded according to a coding system, such that the code for a posture is a record of the posture itself, the load or force used and the stage in the cycle or task. The higher the numbers, at any stage of the analysis, the further away from a desirable posture is the posture under consideration. Based on the code numbers of each limb, an action category value is then determined.

### 3.4 Body Stress

Body discomfort and injuries are associated with different joints 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 is 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 is done in ANSYS-R17.0 software to get von Mises stresses at particular load and posture.

**4.0 Description of operation**

This present research work is exploratory in nature in which the different body postures of welders are collected and musculoskeletal injuries of the workers are analyzed. 5 percentile smaller and 95 percentile larger workers are not included in this study. Workers under observations are working more than 4 years and 8-10 hours a day continuously. Welding in the industry is done on kneeling posture as the fixture used for welding is placed on the ground. Worker has to sit on that posture and has to perform welding continuously. The electrode holder has a weight 3.5kgs and even up to 5kgs with consideration of weight of the cables. Actual body postures of the workers are shown in the figure 2 at the time of operation. Both hands of the workers are engaged and they are simultaneously watching the movement of the electrode during operation. It is also observed that due to continuous kneeling posture workers get frequently fatigued and musculoskeletal problems are identified. High level of control, concentration and co ordinations are required in this operation.

**Fig. 2. Welding Operation.**

**5.0 Upper extremity**

Upper arm consist of five revolute joints these are glenohumeral, elbow and wrist joints. Each joint rotates around its own axis as shown in the figure-3. The function of each joint is described in the table and these are used to mobilize shoulder, elbow and wrist. The degree of freedom of glenohumeral, elbow and wrist joints are 2, 1, 2 respectively. The joint ranges are also shown in the table 1.

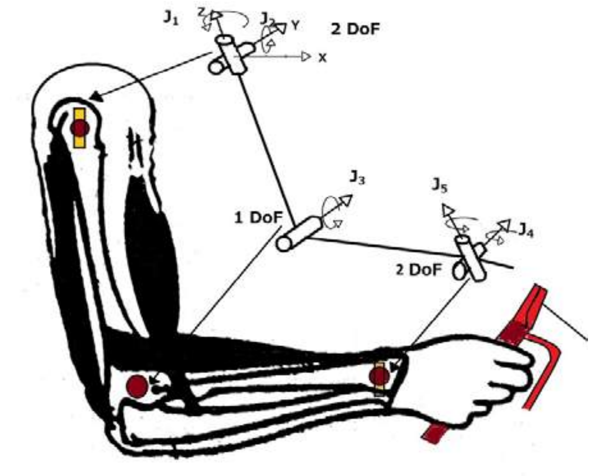


**Fig.3. Joints and DoF of Upper Arm.**

**Table 1. Joint symbol, Joint Function and Joint Range.**

| Joint symbol | Joint Function | Joint range |
|---|---|---|
| $J_1$ | Flexion and extension of shoulder | $-90^0 \le J_1 \le 90^0$ |
| $J_2$ | Adduction and abduction of shoulder | $-110^0 \le J_2 \le 120^0$ |
| $J_3$ | Flexion and extension of upper arm | $0^0 \le J_3 \le 150^0$ |
| $J_4$ | Flexion and extension of plum & Fingers | $-20^0 \le J_4 \le 40^0$ |
| $J_5$ | Adduction and abduction of plum | $-70^0 \le J_5 \le 80^0$ |

**6.0 Conceptual model explaining the pathways leading to musculoskeletal disorders**

The working life has been changed in industrialized countries and it is nowadays psychologically more demanding and more challenging than before. The physical demands of work have been increased, in that connection work related musculoskeletal disorders (WRMSDs) is still at a high level. Work related factors are known to cause and worsen MSDs, and it is important that work place preventive measures are taken seriously. To reduce MSDs and physical work demands, Ergonomic interventions have been implemented. In this flow chart tools, equipment, technology and environment exert physical demands on the workers but they may also effect work organization [Figure: 4]. Organizational factors also affect biomechanical and psychosocial strain. It would be possible to diminish physical demands, biomechanical and psychosocial strain by implementing change in tools, equipment and technology.

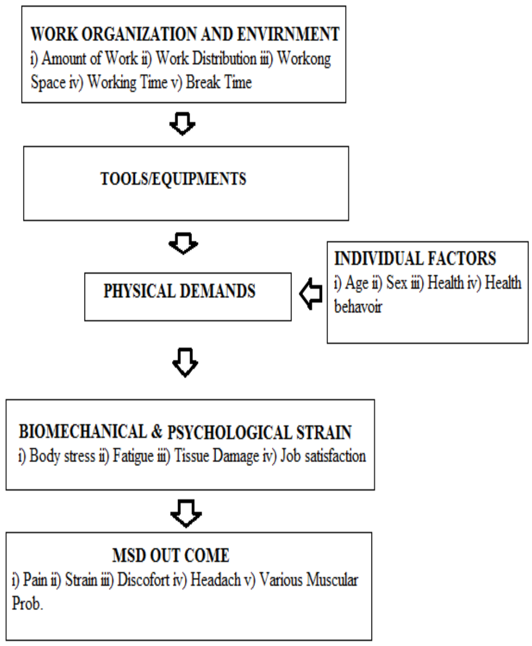


**Fig. 4. Flow chart of pathways leading to musculoskeletal disorders of welders.**

### 7.0 Result and Discussion

The data are analyzed in terms of response to each question. Result indicated specific ergonomic problem exist in these types of units. Physical information of the workers (male) is listed in the table: 2 and table: 3 shows the mean duration of work and rest per day with average no of working days in a week.

### 7.1 Postural evaluation

#### 7.1.1 RULA Score

Evaluation of posture is one of the most important criteria in this research work. It helps to finding the muscular problems that the workers are facing in the working environment. The actual RULA score from the figure: 5 shows that posture scores of most of the workers is very high so immediate change or ergonomic intervention is needed to minimize MSDs. It is also observed from the present research that work related incident affects different body parts of the workers. From proposed and modified work posture, it is observed that if postural positions of the workers be changed, it will automatically reduce RULA score. Level of discomfort, musculoskeletal disorder and body stresses will also be reduced.

**Table 2. Demographical data of the workers (n=20).**

| Variables | Workers (sd) |
|---|---|
| Age (years) | 26.5 ±5.52 |
| Height (cm) | 163.35± 3.56 |

**Table 3. Mean duration of work and rest per day with average no of working days in a week.**

| Workers | Duration of work /day (hr.) | Duration of rest /day (hr.) | No. of absent in a week (in days) | No. of working days in a week |
|---|---|---|---|---|
| Welders | 9 ± 2.23 | 1.5 ± 1.0 | 2.1 ± 1.07 | 6 |

#### 7.1.2 OWAS Score

According to the OWAS's classification, working postures of workers required more attention. The majorities of harmful postures for jobs are classified and level of score increased significantly in real life workstation which may damage the muscle of workers body in the long run. The percentages of observed postures and results shows that the harmful categories for the handling of jobs in welding operations caused by the workers may be reduced and eliminated partially due to the modified work posture. Most of the workers are getting trouble in their wrist, hand and neck due to inappropriate body posture. The workers are doing work mainly in sitting and forward bending postures. More than 70% of workers having pain in their neck, trunk, elbow and wrist due to long term task.

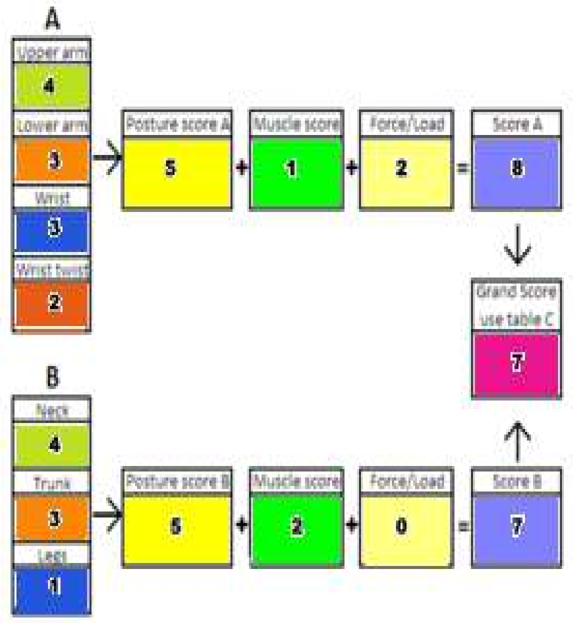


**Fig. 5. Actual RULA Score of welders.**

### 7.3 Analysis of body stress of welder

#### 7.3.1 Stress Intensity

A poor posture contributes to stress and stress donates to poor posture. When the body is stressed, the muscle of human body tense up. Different joints of human body and muscles are the most effected parts due to poor posture. Stresses in the joints are maximum which are shown by different colours. Unit of stress is Pascal ($P_a$) and its range maximum 4.7537 x $10^7$ $P_a$ to minimum 43.005 $P_a$ in a particular work posture and load. 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 as lower body specially if the welders body is not supported [Figure 6].

A human's head weights 11-12 pounds approximately, when balanced above the spine. As the neck bends forward and down, the weight increases placing a greater demand on the cervical spine. At $15^0$ the cervical spine must support aprox. 25 pounds and $30^0$, 40 pounds and so on. The trapezius muscles in the neck in to compensate, which affect the back muscles. For a long period of working back muscles weaken the stomach muscles, which truncates the breath.

Body stress due to poor work posture can cause other 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.

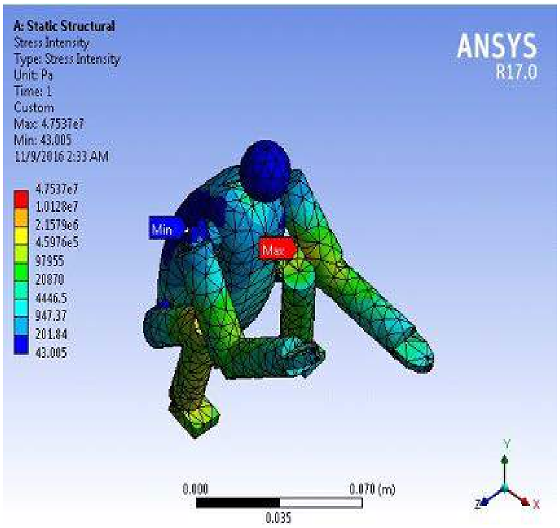


**Fig. 6. Stress intensity at different body parts of welder.**

#### 7.3.2 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 modeling idealizations, such as point constraints and point loads. In terms of the principal stresses, Von Mises or Equivalent stresses is calculated as.

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

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 is used for stress analysis. This analysis indicates 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 7. It varies from minimum 849.41 Pa to maximum 4.1249 x$10^5$ Pa in a particular welding posture.

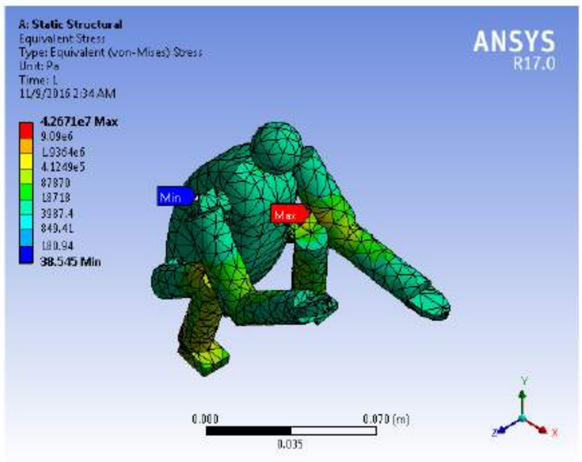


**Fig. 7. Von-Mises Stress at different body.**

**8.0 Conclusions**

It can be concluded that MSDs are present in the activities carried out in welding units where major number of workers were involved in bad body postures. There is a lack of Ergonomic planning and methods in this sector. The modified and comfortable body posture can reduce the RULA, OWAS score and body stresses. Rotation among workers can also be minimized body stresses and MSD. The purpose of the present research work is to give the researchers a better understanding about the different joints of the upper extremity of the human body and the most stressed muscle during welding operation. The Finite Element Method (FEM) analysis is done to investigate the Von Misces stresses in the different joints and muscles of welders. The physical and mental fatigue of workers for dynamic working process can be validated and then integrated in to work evolution system in the future.

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