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Journal of Ergonomics Studies and Research

RESEARCH ARTICLE

Discomfort and Postural Analysis of Flux Cored Arc Welding Machine Operators

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Citation: Dinagaran D, Balasubramanian KR, Sivapirakasam SP, Gopanna K (2019) Discomfort and Postural Analysis of Flux Cored Arc Welding Machine Operators. J Erogonomics Stud Res 1: 103

Abstract

Welding is one of the major fabrication process employed in industries where the workers are subject to work in awkward body positions. In this study discomfort and postural analysis of flux cored arc welding (FCAW), machine operators are carried out. A total of 40 welding machine operators in a heavy equipment manufacturing industry are identified for the discomfort survey (all male), from ages 28 to 51. Initially, a questionnaire survey is carried out to predict the level of discomfort faced by the welders while performing their job at different postures. Rapid Upper Limb Assessment (RULA) and Ovako Working Posture Analysing System (OWAS) are used to identify the severity of posture. Then software analysis is performed based on the welder postures. The postures are mimicked using the software to assess the level of discomfort. After the application of suggested methods, the discomfort level in every hour is equally disseminated to whole working shifts, all the parts of body experience moderate type of discomfort, and it is safer level compared to previous evaluation results. The scores obtained are very much in satisfaction with RULA and OWAS criteria of score less than or equal to 4 which is an acceptable level for the welding operators to work without much muscular discomfort. To reduce Work-related Musculoskeletal Disorders (WMSD)'s in workers, it's important to implement and follow the ergonomic guidelines as mandatory. This will benefit the organizations to accomplish improved quality and enhanced productivity.

Keywords: Ergonomics; RULA; OWAS; Risk Analysis; Safety of Welders; Discomfort Analysis; Postural Analysis; Flux Cored Arc Welding

Introduction

The definition for Welding is according to American Welding Society as "a localized coal essence (the fusion or growing together of grain structure of the materials being welded) of metals or non-metals produced by heating the materials to required welding temperature with or without application of pressure alone and with or without the use of filler metals". In other words, "Welding is a method of joining the same metals by using heat with or without the use of pressure and along with filler metals". The result is a continuousness of similar material, of the composition and physiognomies of dualistic parts joined together.

Flux Cored Arc Welding

Flux Cored Arc Welding (FCAW) is the welding process in which the flux material is placed in the core of the electrode. The FCAW electrode is an incessant electrode ranging from 15 kg to 200 kg packs and 1.6mm in diameter which is fed through the wire feed rollers to the arc where it is melted down and deposited to the melted pool in the parent metal.

Welding is the major manufacturing process used in fabrication industries. Welders often work in awkward postures and prior knowledge on body mechanics, human factors and ergonomics are essential to avoid working in awkward postures. Work-related musculoskeletal disorders occur by common activities like lifting, pushing, pulling, gripping, forceful pinching, holding for a long period of time, intensive typing which are not harmful but are hazardous when the movements are repeated for several time without providing recovery time, rest or performed in a faster manner (Figure 1).

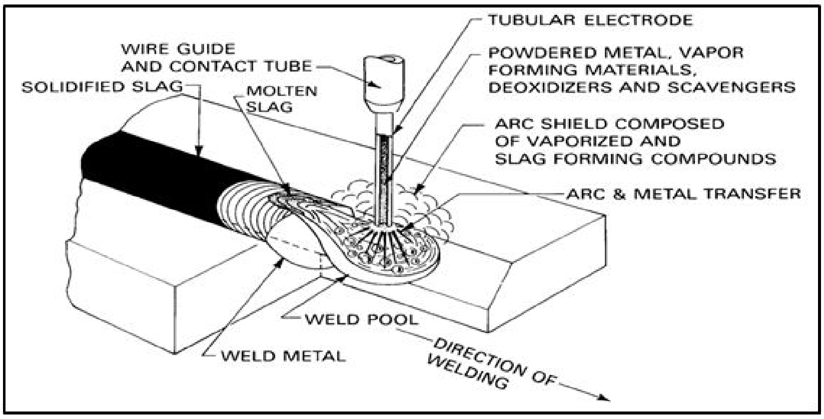


Figure 1: Flux Cored Arc Welding (FCAW)

In this research, a detailed study is carried out in a membrane panel welding unit of heavy equipment manufacturing company in India. The thermal power boiler furnace panel is being fabricated using the flux cored arc welding process. The FCAW welding machine has 6 welding torches for the formation of membrane panels by welding simultaneously. Welding electrode is having a diameter of 1.6mm which comes in 200kg marathon packs and CO_2 gas is used as the inert gas. Tube and flat fins are joined together by the FCAW process. Length of the membrane panel ranges up to 24 meters and width is about 2.25 meter. The Risk factors among the workers can be classified as physical, individual and psychosocial. Among the risk factors, working in improper body posture and doing in repetition comes under the physical category. Occupational stress, low organization care, asking for more work and dissatisfaction are cases of individual and psychosocial issues [1]. WMDS can be assessed using self-report, observational and direct-measurement methods [2,3].

WMSDs are related with the factors like work postures/movements, repetitive work, the force of movements, awkward postures, worker's body beyond their ability to recover, vibration, temperature, lack of control over one's job, increased work pressure, monotonous tasks and perception of low support from supervisor or workmate. Exposure to these workplace risk factors puts workers at a higher level of MSD risk which causes injuries and disorders that affect the human body's movement or musculoskeletal system (i.e. muscles, tendons, ligaments, nerves, discs, blood vessels, etc.).

OSHA defines MSD as an injury or disorder of the muscles, nerves, tendons, joints, cartilage and spinal discs. A few well-known examples of this are carpal tunnel syndrome, bursitis, and tendinitis. MSD's can occur in various parts of the body so that it should be prevented before it pledges. MSD's can be reduced by improved work methods, proper work posture, using proper Personal Protective Equipment's (PPEs), adequate training, using appropriate tools and equipments.

The Ergonomic Hazard Reasons Related To FCAW Machine Welding

- Lifting weighty objects (CO_2 gas cylinders, clamping, welding wires, etc.).
- Difficult physique positions (awkward position of arms, improper posture of head and neck, kneeling).
- Motionless body postures (lengthy period of tasks, labor-intensive accuracy).

Many researchers adopted different methods to identify the WMSD in workplaces. Ergonomic interventions for workers should consider gender and should focus on work sectors with high risk for MSDs, with multiple ergonomic risk factors, and with the largest number of workers [4]. The clinical study of the welder's painful shoulders shows that the senior workers have shoulder discomfort with prolonged tendinitis on the rotator cuff [5]. The discomfort study of confined space in shipyard welding, conclusion proposes that localized muscle fatigue may be condensed by changing the wire welding process [6].

Value-adding tasks comprised 30% of the total working time, and implied higher postural exposures for the head, arm, trunk, and wrist, as well as fewer opportunities to recover, as compared to non-value-adding tasks [7]. The constraints of the welders and characterized as postural and behavioral risks makes to understand the need for ergonomics study in machine welders. Effective and sustainable prevention of work-related musculoskeletal disorders remains a challenge for preventers and policymakers [8]. The analysis is carried in the sequential order. Initially, a survey among the welders was carried out using the set of questionnaire to collect the data of the welders. Muscular discomfort is identified and analyzed with the current working body posture in the software. Based on the output, better working posture is implemented by the welders and reassessed using RULA scores.

Discomfort Survey

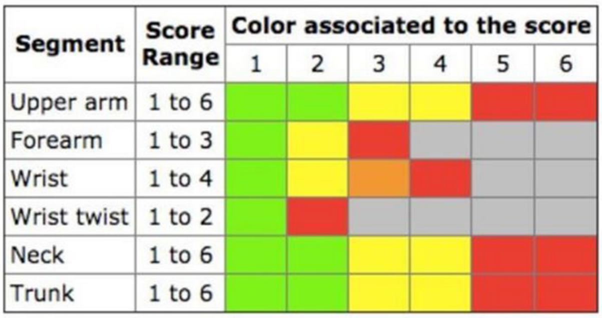
An exhaustive analysis of the discomfort of various body parts examined with a standardized questionnaire for the analysis of musculoskeletal symptoms in an ergonomic health context is presented [9]. Effective risk management needs to accurately identify, assess and control the most relevant WMSD risk factors for a particular job [10]. A cross-functional study in a Public Sector industry at various CNC work centers was analyzed operators discomfort using discomfort study working with various panel heights [11]. The critical characteristics of existing crane cabins linked to visibility and posture (seat and armrest problems) were identified using users' opinions and Pareto analysis to propose a methodology for the ergonomic assessment of crane cabins based on drawing board mannequins and kinematic modelling [12].

A survey of Malaysian mold making industry explored to identify the prevalence of work-related musculoskeletal disorders among the worker with structured interview using Cornell Musculoskeletal Discomfort Questionnaires (CMDQ) [13]. In a small scale industry where the Workers performing welding operations were observed and awkward postures were identified in towers/ structure required for transmission, telecommunication, and railways fabrication. RULA and OWAS used to analyze the difference of comfort before and after the ergonomic suggestions along with checklist survey to see the variation over the time period of work in three intervals [14].

The literature survey showed that the method used for analyzing the welding operator's postures can be analyzed through a questionnaire survey based on either the Standard Nordic type or the Cornell MSD type. Very few papers have preferred Electromyography/ CATIA tools and other similar software. This work aims to show the viability of using software to verify the questionnaire survey. In recognition of this opening, it was aimed to predict the factors for that influence the work posture such as welding positions (tack welding), control switch operating method, and clamping method in FCAW machine welding. The goal is to show that more accurate ergonomic evaluation and suggestions can be developed using the software analysis and to suggest a suitable body posture to avoid WMSD. The software analysis provides the options to choose better body posture to reduce WMSD which is difficult by experimentation where more time and money required. In this study, the following tools are used to access the FCAW machine welding operator posture.

RULA (Rapid Upper Limb Assessment)

The RULA Assessment Tool is used to assess the exposure of individual workers to ergonomic risk factors associated with upper extremity MSD. This tool studies biomechanical and postural load requirements of job tasks on the neck, trunk and upper extremities (Figure 2). To assess required body posture, repetition, and force, a single page worksheet is used. Based on the evaluations, scores are entered for each body region in section A for the arm and wrist, and section B for the neck and trunk. After the data for each region is collected and scored, tables on the form are then used to compile the risk factor variables, generating a single score that represents the level of MSD risk. The RULA was designed for easy use without the need for an advanced degree in ergonomics or expensive equipment. Using the RULA worksheet, the evaluator will assign a score for each of the following body regions: upper arm, lower arm, wrist, neck, trunk, and legs. After the data for each region is collected and scored, tables on the form are then used to compile the risk factor variables, generating a single score that represents the level of MSD risk as outlined below:



Segment	Score Range	Color associated to the score					
		1	2	3	4	5	6
Upper arm	1 to 6						
Forearm	1 to 3						
Wrist	1 to 4						
Wrist twist	1 to 2						
Neck	1 to 6						
Trunk	1 to 6						

Figure 2: Chart Summarizing the Range of Scores for Different Body Part as Per RULA

Score	Level of MSD Risk
1-2	negligible risk, no action required
3-4	low risk, change may be needed
5-6	medium risk, further investigation, change soon
6+	very high risk, implement change now

Figure 3: Chart Summarizing the Level of MSD Risk as Per RULA

OWAS (Ovako Working Posture Analysing System)

The OWAS technique (Ovako Working Posture Analysing System) developed by a Finnish steel company of Ovako is a method used for the evaluation of postural load during work. This method is depending on assessments of working positions, OWAS finds 4 working postures for the back, 3 for the arms, 7 for the lower limbs, and 3 categories for the weight of load handles or amount of force used. The method categorizes blends of these 4 groups with their impact amount of on the musculoskeletal system. The OWAS calculation is based on the number of activities done by each worker like meandering, snaking, and both meandering and snaking in working shifts. The posture grouping system is based on the body parts like the lower arm, upper arm, trunk, wrist, neck, and legs. The degrees of the assessed harmfulness of posture–load combinations are grouped into four acting categories, which indicate the urgency for the required workplace interventions.

The Ergo Fellow software has 17 ergonomic tools to evaluate and improve workplaces conditions, in order to reduce occupational risks and increase productivity. The software is very useful for ergonomists and for all professionals in the area of occupational safety and health. This software was used in this study to assess the postures using OWAS .

Back	Arms	Legs																				
		1			2			3			4			5			6			7		
		Load			Load			Load			Load			Load			Load			Load		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4

INTERPRETATION OF THE RESULT

1 - No actions required

2 - Corrective actions required in the near future

3 - Corrective actions should be done as soon as possible

4 - Corrective actions for improvement required immediately

Green: No action required.

Yellow: Corrective action in the near future.

Orange: Corrective action should be done as soon as possible.

Pink: Corrective actions for improvement required immediately.

Figure 4: Chart Summarizing the Range of Scores for Different Body Part as per OWAS

Methodology

The literature review suggests that the welding operators in many cases are unaware of the proper postures during working. In order to assess the current postures a checklist survey along with posture analysis, ergonomic software is used. The results are analyzed to improve body postures and revalidating them with the same tools. The ultimate objective of our study is to inspect the postural discomfort in the flux cored arc welding (FCAW) machine workers, and its connection to welding postures and welding process controllers, according to the anthropometric reference (Table 1). The following steps are used for the study

Step 1: Investigate work postures at existing FCAW machine operators
Step 2: Explore potential design to avoid WMSD
Step 3: Develop new FCAW working methods

Table 1: Steps Followed for the Ergonomic Study

Survey of FCAW Machine Operators

The Questionnaires consist of questions related to different problems associated with this particular operation. Daily activity of the worker, discomfort level of different body parts, working and resting periods are plotted and calculated. Body discomfort level can also be calculated with the help of this method. A total of 40 welding operators in the heavy manufacturing industry are identified for the discomfort survey (all male), from ages 28 to 51. The experience of the machine welders ranging from 3 years to 8 years, height ranges between 154 centimeters to 182 centimeters, and the weight ranges between 50kg to 93kg.

Since the job rotation is mandatory in this industry, experienced welding machine operators also not having work experience more than 8 years in the same kinds of welding machine because the industry having welding machines like Submerged Arc Welding (SAW), Gas Metal Arc Welding (GMAW), Straight Tube Butt Welding (STB), Flash Butt Welding (FBW), Induction Pressure Welding (IPW) and Orbital TIG Welding (OTG) apart from FCAW machine. The welding operators involved in FCAW machine are identified to be ergonomically more challenging. The FCAW machine operators are informed about the study and acquired consent from them to participate in the study. All operators are good in a health condition that is likely to participate in the study (Table 2).

Parameters	Lowest	Highest	Mean	Standard deviation
Age	28	51	33.75	5.04
Experience(years)	3	8	6.88	0.98
Height(cm)	154	182	165.99	4.34
Weight(Kg)	50	93	65.70	6.71
BMI (Body Mass Index)	16.9	34.2	23.9	2.41

Table 2: Welding Machine Operator Details

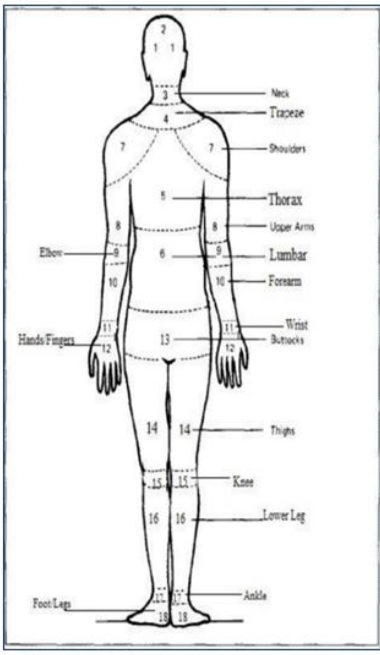
Anthropometric Data

Figure 5 shows the checklist of questionnaire survey sheet used for collecting the data from welding machine operators. The checklist consists of the body parts details for both left-side and right-side of the body with the evaluation time intervals of a 1st hour, 4th hour and 8th hour of the task performances. All the 40 welding operators are requested to fill the form with their genuine feedback to obtain better results. The anthropometric data to be collected is decided based on the requirement to analyze the welding postures among the FCAW machine welding operators .

CHECKLIST FOR SURVEY OF WELDING OPERATORS

NAME		BMI	
AGE		EXPERIENCE	
HEIGHT		WELDING TYPE	
WEIGHT			

SL NO	FREQUENCY	EVALUATION
1	1-2 TIMES PER WEEK	NO DISCOMFORT
2	3-4 TIMES PER WEEK	MILD
3	EVERY DAY (ONCE)	MODERATE
4	EVERY DAY (MANY TIMES)	SEVERE
5	EVERYDAY (ALL DAY LONG)	INSUPPORTABLE



SL NO	PARTS OF THE BODY	FREQUENCY	SIDE		EVALUATION HOUR		
			LEFT	RIGHT	1ST	4TH	8TH
1	EYES						
2	HEAD						
3	NECK						
4	TRAPEZE						
5	THORAX						
6	LUMBER						
7	SHOULDER						
8	UPPER ARM						
9	ELBOW						
10	FORE ARM						
11	WRIST						
12	HANDS/FINGERS						
13	BUTTOCKS						
14	THIGH						
15	KNEE						
16	LOWER LEG						
17	ANKLE						
18	FOOT/LEGS						

Figure 5: Questionnaire Survey Sheet for Welding Machine Operators

Discomfort Analysis

The below-mentioned assumptions are anticipated for ergonomic investigation of the welding operators: -
1. The machine operators responded to the survey as precisely as possible.
2. This research work is restricted to small sample size.

Sl. No	Body Parts	1st Hour	4th Hour	8th Hour	Rank
1	Eyes	1.08	2.416	3.583	1
2	Head	1	1.45	2	13
3	Neck	1	2	3.5	2
4	Trapeze	1.091	2.4	2.916	7
5	Thorax	1.091	2	2.583	10
6	Lumber	1	2.2	2.83	8
7	Shoulder	1	2.36	2.916	7
8	Upper Arm	1	2	3.25	3
9	Elbow	1.091	2.5	3.083	5
10	Forearm	1	2	2.5	11
11	Wrist	1.091	2.1	2.833	8
12	Hands	1	2.27	2.833	8
13	Buttocks	1	2	2.416	12
14	Thigh	1.083	2.0909	2.5	11
15	Knee	1.083	2	3	6
16	Lower Leg	1.083	2	2.66	9
17	Ankle	1.083	2	2.58	10
18	Foot/Legs	1.083	1.909	3.166	4

The Checklist data analysis results showed that (Figure 4) the major discomfort is found in the body parts like Eyes, Neck, Upper arm, Elbow, Knee, and Legs due to

- **Eyes:** Frequent visual inspection by rotating the eyes into strained position to obtain the desired welding quality
- **Neck:** During visual inspection, neck rotated frequently to see 6 welding torches at a time
- **Upper Arm**: Frequently used to remove the welding slags for visual inspection and welding torch adjustments
- **Elbow**: Frequently used to remove the welding slags for visual inspection and welding torch adjustments
- **Knee:** Frequent movement to welding control zone for fine adjustments to the visual inspection zone
- **Legs:** Frequent movement to welding control zone for fine adjustments to the visual inspection zone

Table 3: The Checklist Data Analysis Results

Figure 6 shows the severity level of eye, neck, upper arm, knee and foot/legs are found to be high due to the awkward working posture while working with FCAW welding machine throughout the shift. The severity level of eye, neck, and upper arm, knee and foot/legs which is a high 8th hour of the shift. The First hour it is observed that no discomfort and at fourth-hour mild discomfort is felt by the FCAW machine operators.

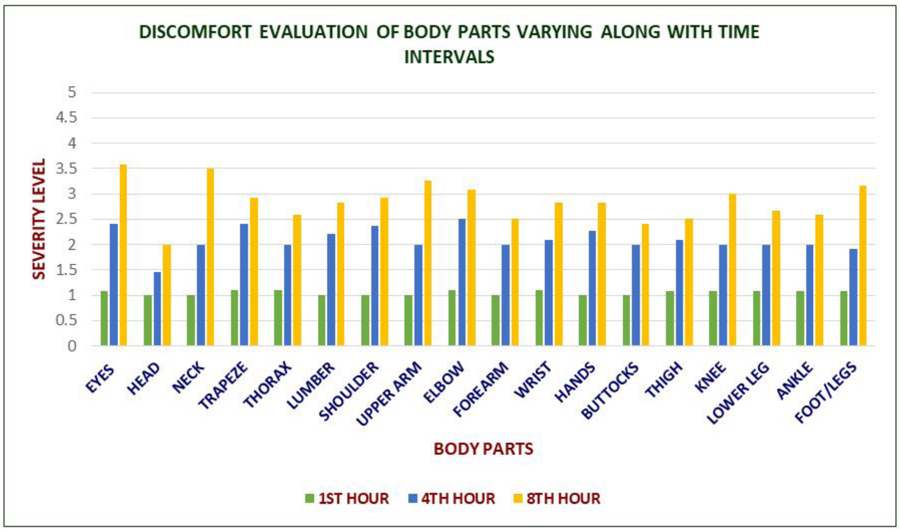


Figure 6: Bar Diagram of Discomfort Evaluation of Body Parts Varying along with Time Intervals

In this study, RULA and OWAS are used to identify the severity of posture. By using the RULA, it examines the risk factors and rates the severity level in scores that range from 1 to 6. The data displayed is combined with a color indicator zone. The color of this zone changes from green to red based on the total score. The score report consists of basic mode and advanced mode. In the basic mode, the scores 1 and 2 (Green color) indicates that the posture is acceptable if it is not maintained or repeated for long periods of time. The scores 3 and 4 (Yellow color) indicates that further investigation is needed and changes may be required. The scores 5 and 6 (Orange color) indicates that investigation and changes are required soon. Score 6 (Red color) indicates that investigation and changes are required immediately. The score indication of advanced mode for different body parts is indicated in the Figure 1 and 2.

Posture Analysis

RULA Analysis for Flux Cored Arc Welding Machine Operators

The RULA analysis for the FCAW machine operators is conducted. The following diagrams show the welding machine control panel and working posture of the welding machine operator's score.

Figure 7 shows the FCAW welding machine operator posture while operating the welding control panel. Here hand and head are in an unsafe position, which inferred that corrective action is required in the near future.

Figure 8 shows the welding operator posture while tack welding the job. Here welding is performed in an awkward posture. So the corrective action should be taken as soon as possible.

Figure 9 shows the welding operator posture while setting a job for welding. This working posture is also an awkward position, so it infers that the corrective action for improvement is required immediately.

Figure 10 shows the welding operator posture while adjusting welding torches with a toggle switch. This working posture is also an awkward position, so it infers that the corrective action is required immediately.

Sl. No	Working Posture	Hazard	RULA-Evaluation Result
1	Welding machine operator posture while operating a welding control panel	Neck, Trunk and Leg posture is in an awkward condition	**Final Score: 4** Investigate further
2	Welding machine operator posture while tack welding the job	Muscle, Neck, Trunk and Leg posture is in an awkward condition	**Final Score: 6** Investigate further and change soon
3	Welding machine operators posture while setting the job for welding	Neck, Trunk and Leg posture is in an awkward condition	**Final Score: 4** Investigate further
4	Welding machine operators posture while adjusting welding torches	Neck, Trunk and Leg posture is in an awkward condition	**Final Score: 5** Investigate further and change soon

Table 4: The RULA Evaluation Result in Various Working Posture

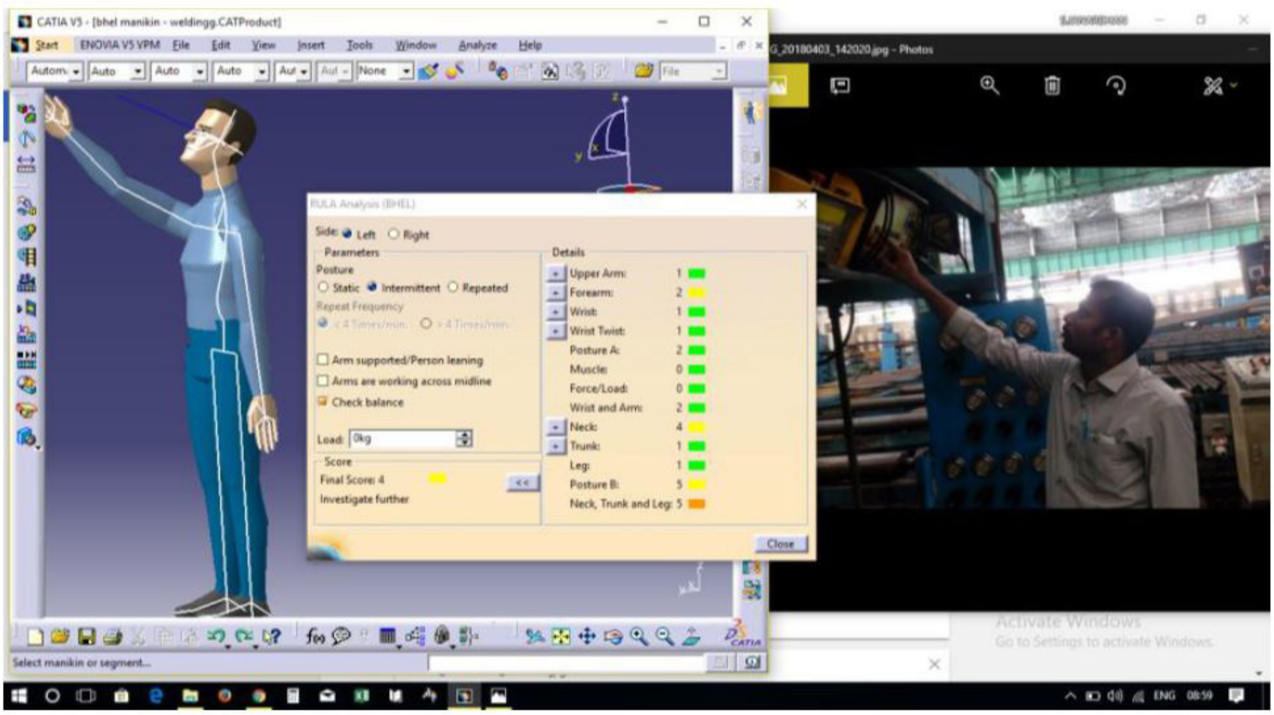


Figure 7: Welding Machine Operator Posture While Operating Welding the Control Panel

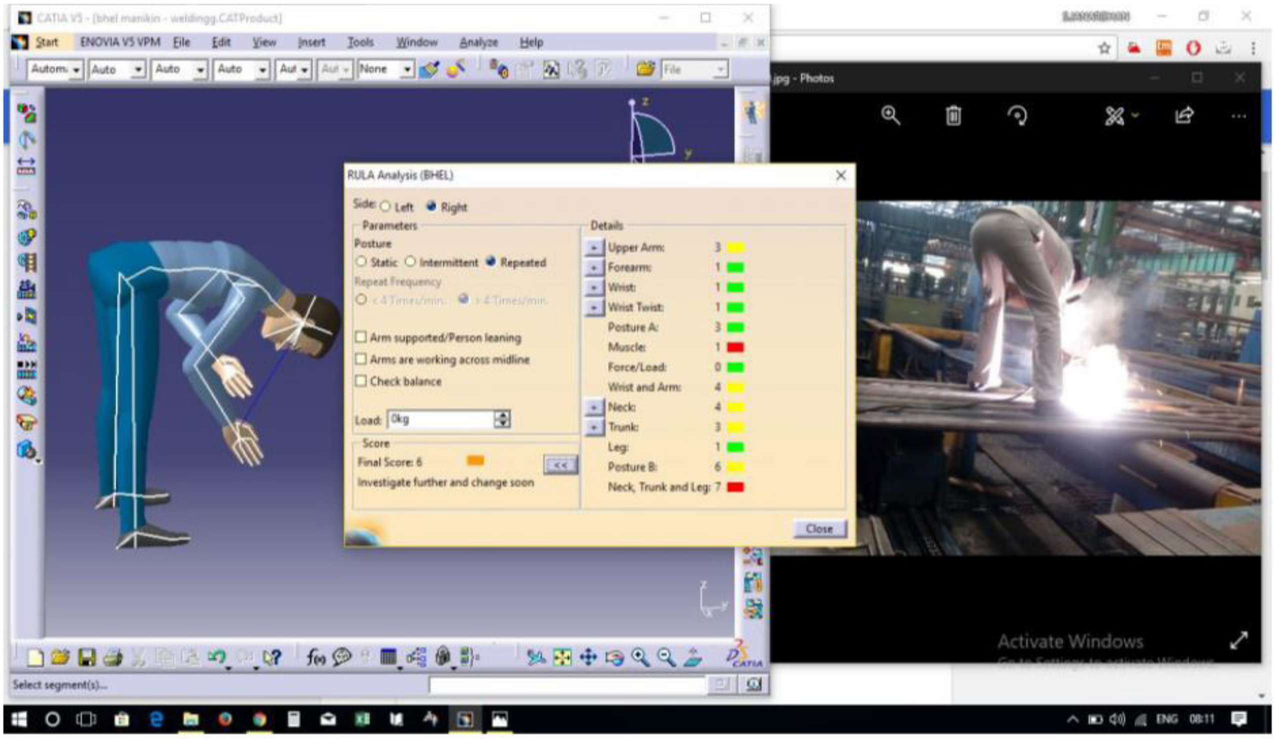


Figure 8: Welding Operator Posture While Tack Welding the Job

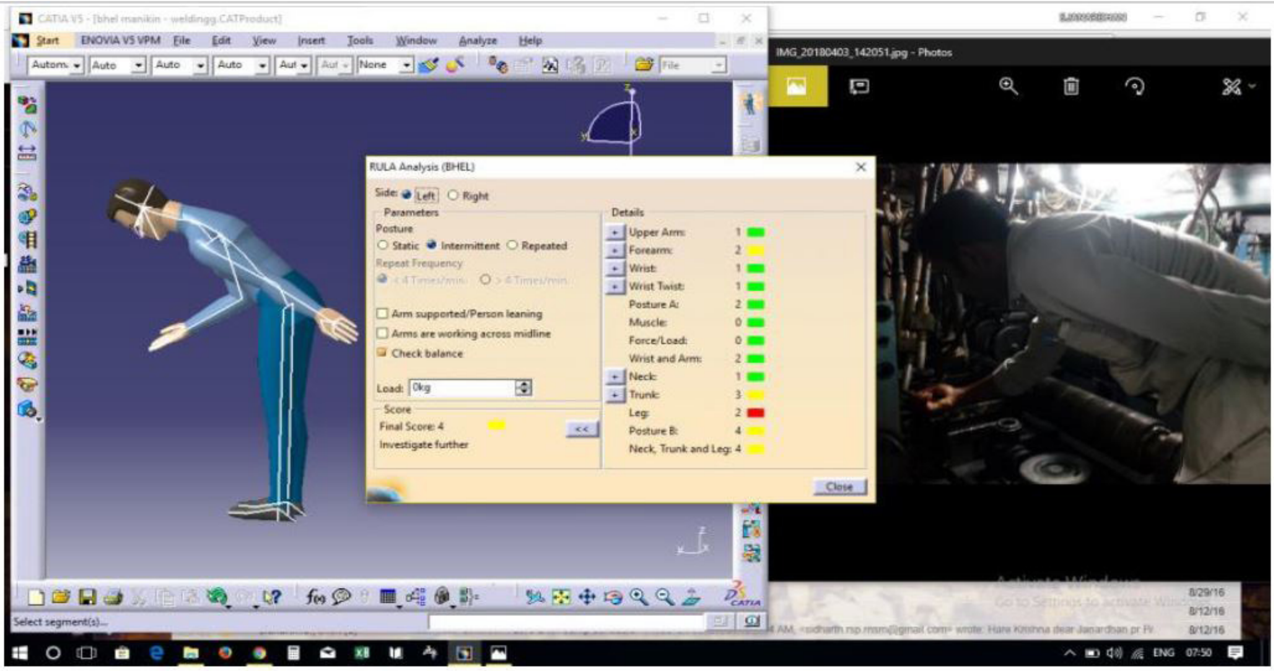


Figure 9: Welding Operator Posture while Setting the Job for Welding

As it is observed from the RULA analysis from the previous Figures 6,7,8 and 9 if the final score is found to be 7, then further investigations are required and changes have to be made immediately or if the score is 5, investigation and changes are needed. The score is arrived using RULA score sheet which is an inbuilt facility in the CATIA software. Additional input for the RULA test (Input Based on Direct Observation) is given based on the feedback from the operators.

1. Lower arm: working through the midline of the body or out of the side.
2. Wrist: wrist is bent dislocated from the midline.
3. Wrist twist: wrist is abnormal from handshake position.
4. Neck: The neck is twisted and bends inside.
5. Trunk: trunk is bent inside.
6. Legs: legs and feet are not equally stable and supported.
7. Muscles use: repeated posture (>4 times/min)

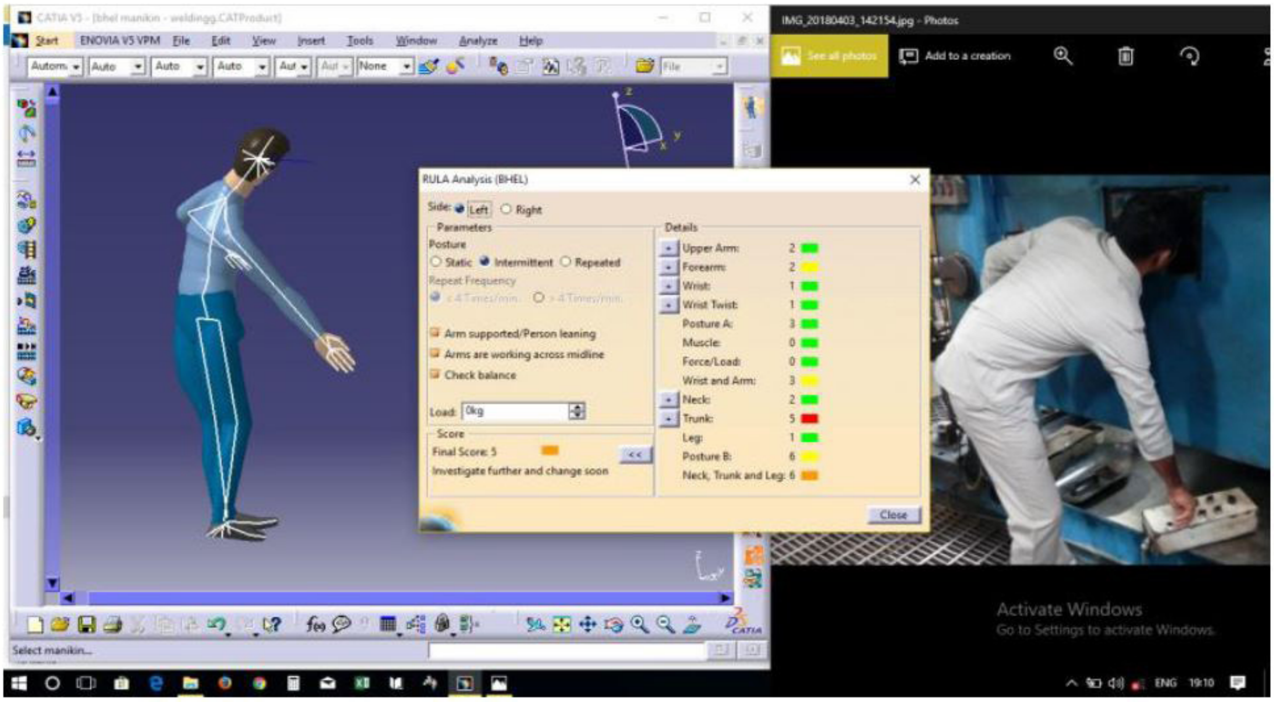


Figure 10: Welding Operators Posture while Adjusting Welding Torches with a Toggle Switch

OWAS Analysis for FCAW Machine Operators

The OWAS analysis for the working posture of the FCAW machine operators was also conducted. The similar working posture analyzed in RULA was analyzed with OWAS. The scores for the same postures using OWAS can be seen below in Table 5.

Sl. No	Working Posture	Hazard	OWAS-Evaluation Result
1	Welding machine operator posture while operating a welding control panel	Hand and head are in an unsafe position	**Yellow:** Corrective action is required in the near future.
2	Welding machine operator posture while tack welding the job	Welding is performed in an awkward posture	**Orange:** Corrective action should be taken as soon as possible
3	Welding machine operators posture while setting the job for welding	Working posture is in an awkward condition	**Pink:** Corrective actions for improvement required immediately
4	Welding machine operators posture while adjusting welding torches	Working posture is in an awkward condition	**Pink:** Corrective actions for improvement required immediately

The OWAS analysis showed similar results as that of RULA analysis with scores of yellow, orange and pink which meant that the corrective action is required and the improvement in the posture should be done.

Table 5: The OWAS Evaluation Result in Various Working Posture

Proposed Procedures for Better Posture to the FCAW Machine Welders

The FCAW machine operating method should be intended to safe posters to avoid ergonomic risk factors and to minimize the injury chances. Wherever it is possible, it's desirable to apply engineering controls otherwise administrative or work practice controls may be suitable where engineering controls cannot be implemented. Using of PPEs has an only limited advantage in connection to ergonomic hazards. The guidelines by OSHA for the welding operator to reduce the discomfort level are as follows: -

- For lifting, use a proper device and relocate weighty things to reduce the force.
- Minimize the heaviness of weight to reduce force exertion
- Relocate a task performing area to avoid a lengthy/unnecessary reach and try to work in neutral postures
- Use separating conveyors for other than mainline to minimize the repetitive tasks.
- Set up diverters on conveyors to direct materials toward the worker to avoid unnecessary leaning or reaching
- Modify equipment's to achieve neutral postures
- Create job rotation methods to workers task to minimize the period of frequent exertion, tedious motions, and awkward postures.
- Provide insulation to minimize direct contact with hard, piercing, or vibrating surfaces

- Use equipment's like trolleys, and rollers to reduce manual handling
- Provide Suitable ventilation to escape pollutants in gases, vapor during welding
- Educate to avoid awkward postures like raising the arms beyond shoulder level,
- Evade static task positions to avoid reduced blood supply to muscles

By considering data obtained from posters of welding operators along with OSHA guidelines, all the welding operators were given appropriate training for better posture while operating the FCAW machine as mentioned below

- To maintain the neutral posture for the better body alignment and balancing while sitting or standing, placing minimal stress on the body and keeping joints aligned during task performance to reduce the stress applied to muscles, tendons, nerves, and bones.
- To sit or stand in a neutral body position with a relaxed posture that requires no stressful angles or excessive reaching to complete tasks.
- To allow the body for Movement and Stretching because working for long periods of time in a static position will cause your body to fatigue.
- To decrease excessive force for minimizing the fatigue and risk of an MSD.
- To reduce contact stress to avoid localized pressure for a small area of the body, this can inhibit blood, nerve function, or movement of tendons and muscles.
- Executives and supervisors also requested to monitor the welding operators to maintain this ergonomic technique for a healthy and productive work environment among the FCAW machine operators.

The FCAW machine welders were given a live demonstration during the training at the workplace and their working postures monitored and repeatedly corrected until the desired safe working posture is obtained according to the guidelines.

Results

Results of RULA Analysis after the Suggestion

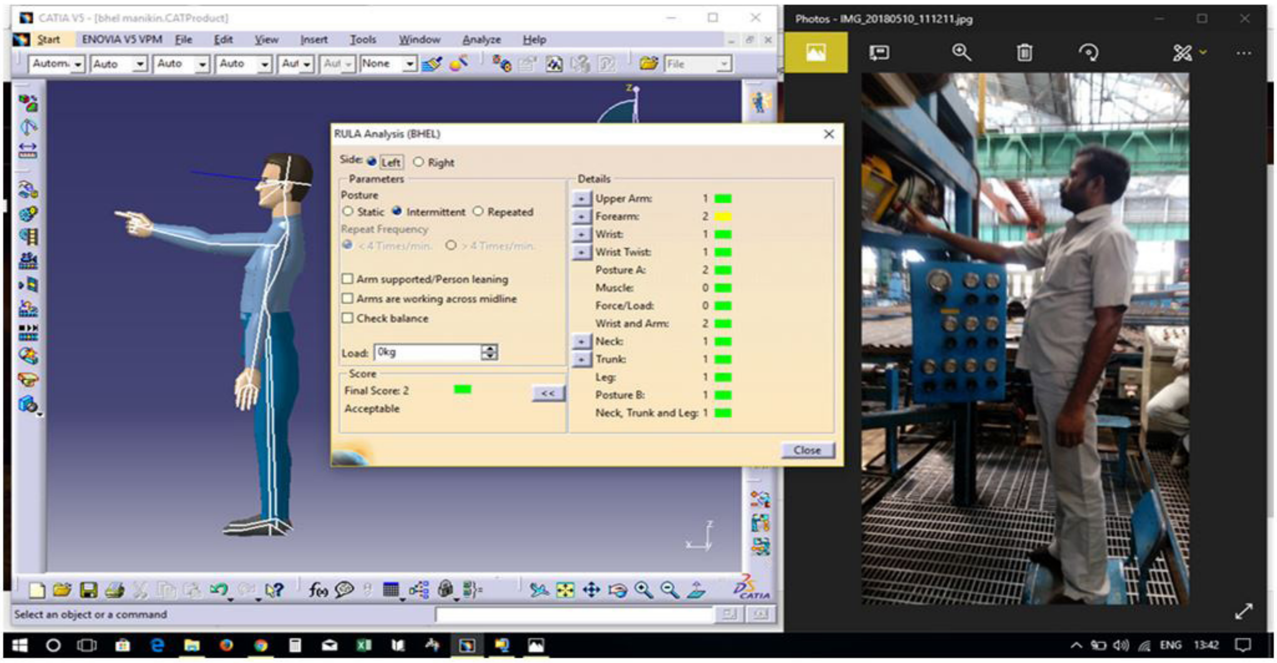


Figure 11: Welding Operator Posture while Operating Welding Control Panel

The RULA analysis is applied after implementing the above guidelines to the FCAW machine operators. They were demonstrated to work with neutral body posture wherever it is possible.

Figure 11 shows a rigid table is provided to maintain neutral body posture and safe working while operating a welding control panel. So that safe working posture is obtained and the RULA score obtained is 2 (acceptable working posture).

Initially, the tack welding was carried out with awkward posture after the suggestion it was done with safe working posture. Figure 12 shows that tack welding was done from the floor itself to ensure safe welding posture. The RULA score after the suggestion is 3 (investigate further).

Operator's posture while setting the job for welding also modified to the safe working posture. Figure 13 shows the suggested welding posture while setting a job for welding. A chair is provided for a comfortable position while setting the machine. The RULA score after the suggestion is 3 (investigate further).

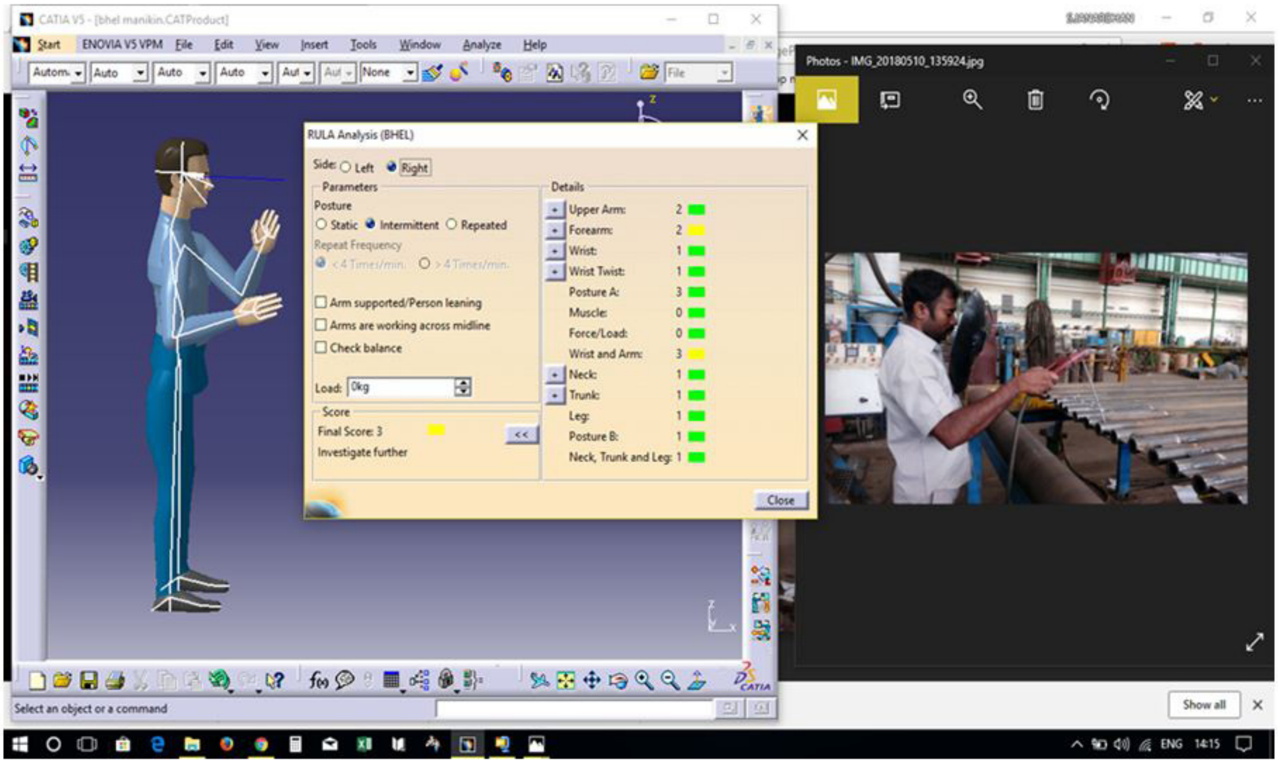


Figure 12: Welding Operator Posture while Tack Welding the Job

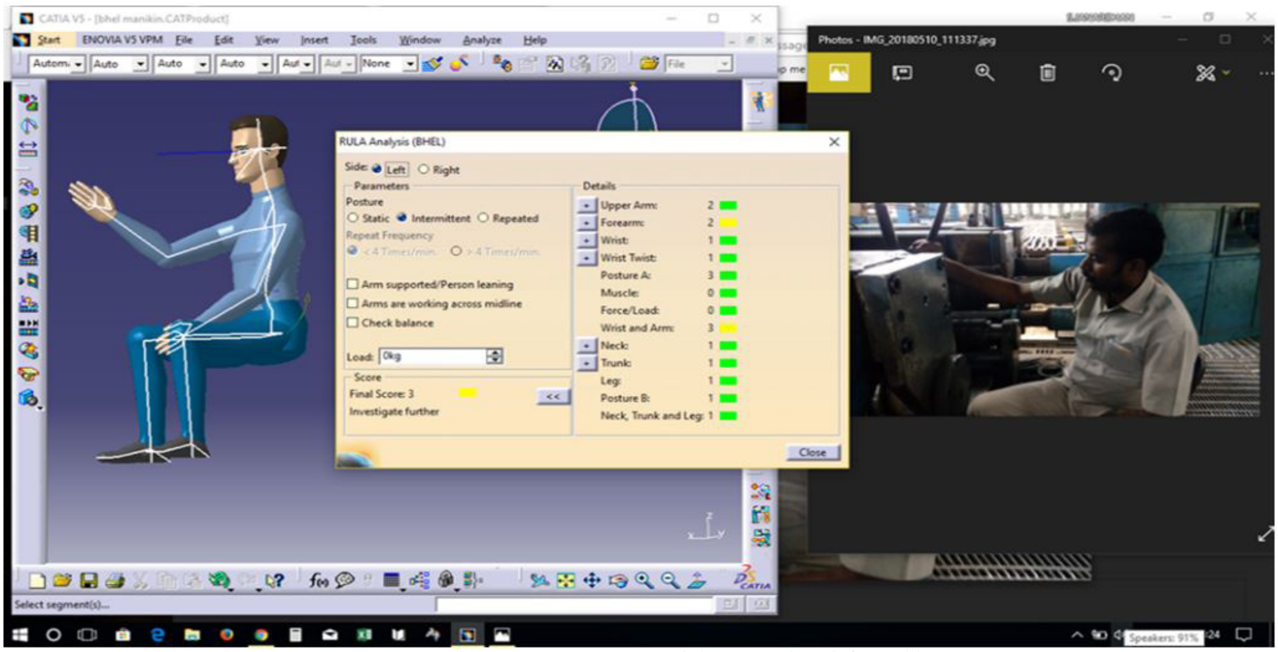


Figure 13: Welding Operators Posture while Setting the Job for Welding

The welding torches fine adjustment for quality welding is a repetitive task. It has to be done with adjusting the toggle switches in awkward posture before the suggestion. Figure 14 shows the welding operators posture while adjusting the welding torches after the suggestion. A rigid chair is provided for a comfortable position while adjusting welding torches. The RULA score after the suggestion is 3 (investigate further).

After the application of suggested methods, the discomfort level in every hour is equally disseminated to whole working shifts, all the parts of body experience moderate type of discomfort, and it is safer level compared to previous evaluation results. The scores obtained are very much in satisfaction with RULA criteria of score less than or equal to 4 which is an acceptable level for the welding operators to work without much muscular discomfort (Table 6) [15,16].

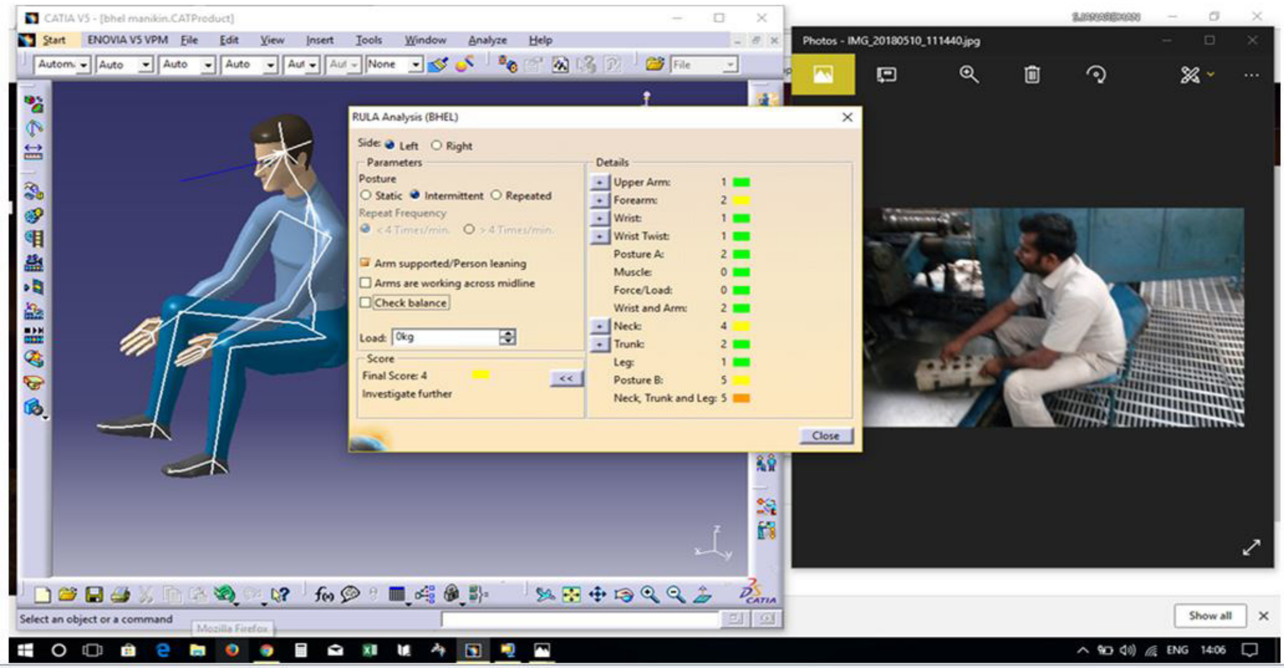


Figure 14: Welding Operators Posture while adjusting Welding Torches

Sl. No	Working Posture	Hazard	RULA-Evaluation Result
1	Welding machine operator posture while operating a welding control panel	Neck, Trunk and Leg posture is in the safe condition	**Final Score: 2** Acceptable
2	Welding machine operator posture while tack welding the job	Muscle, Neck, Trunk and Leg posture is in the safe condition	**Final Score: 3** Investigate further
3	Welding machine operators posture while setting the job for welding	Neck, Trunk and Leg posture is in the safe condition	**Final Score: 3** Investigate further
4	Welding machine operators posture while adjusting welding torches	Neck, Trunk and Leg posture is in the safe condition	**Final Score: 4** Investigate further

Table 6: The RULA Evaluation Result in Various Working Posture after the Suggestion

Results of OWAS Analysis after the Suggestion

The OWAS analysis is also applied after implementing the above guidelines to the FCAW machine operators. The same is done with the OWAS evaluation method which yielded the following results as shown in Table 7.

Sl. No	Working Posture	Hazard	OWAS-Evaluation Result
1	Welding machine operator posture while operating a welding control panel	Hand and head are in a safe position	**Green:** No action required
2	Welding machine operator posture while tack welding the job	Welding is performed in safe working posture	**Green:** No action required.
3	Welding machine operators posture while setting the job for welding	Working posture is in the safe condition	**Green:** No action required.
4	Welding machine operators posture while adjusting welding torches	Working posture is in the safe condition	**Green:** No action required.

Table 7: The OWAS Evaluation Result in Various Working Posture after the Suggestion

Discussion

This research work is based on welding machine operators working in FCAW machine. In their various work postures, the postures like operating welding control panels, tack welding the job, setting the job for welding, and adjusting the welding torches with toggle switch are identified to be related with work-related risk. According to the analysis of the mean discomfort level for the various parts of the body during periodical breaks for the various age group operators, it is discovered that operators felt musculoskeletal discomfort and was a peek at the end of the shift and least at the start of the shift. After suggesting appropriate ergonomic guidelines, the results found better RULA result is obtained (Figure 10,11,12 and 13).

Earlier the severity level for older welding operators slightly higher than the younger welding operators. The shorter welding operators faced discomfort in the upper arm, elbow, knee, and foot than taller welding operators. The taller welding operators faced little more discomfort in neck and eyes than the shorter welding operators. Higher BMI indexed welding operators faced more discomfort than lower BMI indexed welding operators. Because of that, they felt more operator fatigue after completing their routine work. After suggesting appropriate ergonomic procedures, the assessment results show better improvement in welding postures. The FCAW welding machine operators willingly adopted the ergonomically safe working postures for their better task performance.

Figure 15 Shows the bar diagram of severity level and discomfort assessment of the different body parts varying along with time intervals after suggesting guidelines after suggesting ergonomic guidelines. The severity level of eye, neck, elbow, upper arm, knee and foot/legs are found to be less than the earlier result of 8th hour shift. The first and fourth hour it is found that very less discomfort is felt by the FCAW machine operators. While the comparison with the values before the implementation of ergonomic guidelines the values have dropped below 2.5 overall while 8th hour after the corrections, it is hovering before the implementation of ergonomic guidelines around 3 and above.

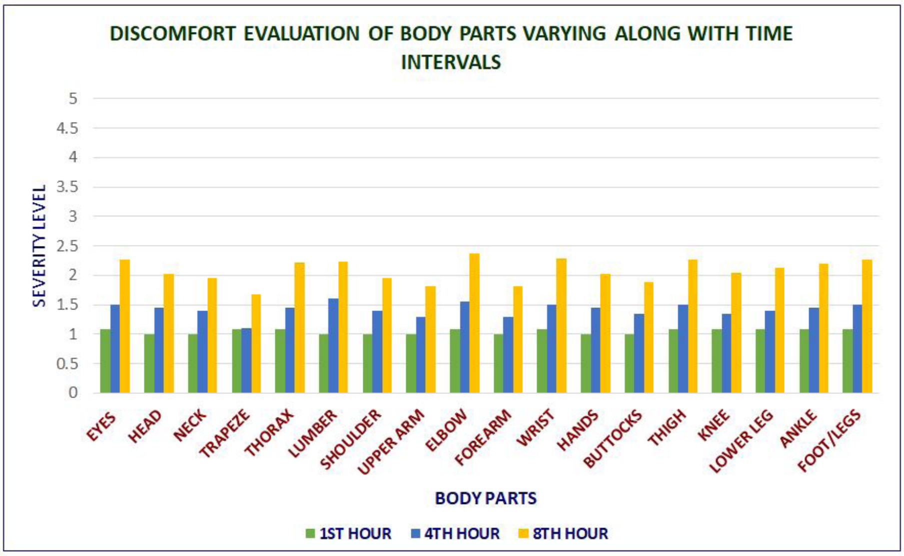


Figure 15: Checklist Survey Results after Implementing Ergonomic Guidelines

The OWAS suggests improvement in workers amount of work. The RULA shows significant progress in working methods. The OWAS analysis shows all the postures score to be green which is ergonomically agreeable and also matching the RULA analysis, which indicates the enhanced progress related to earlier time result [17].

Conclusion

The following are the observation made during the ergonomic analysis of welder posture during FCAW welding.

- It is observed from the study that the FCAW machine operators are unaware of ergonomically safe working aspects among workers and they are ignorant of musculoskeletal disorders.
- From the different kinds of working postures at FCAW machine operators, the working postures in awkward condition are originate to the occupational perils.
- A simplified method for the identification of discomfort by the standard ergonomic tools and appropriate operational atmosphere using essential strategies is suggested and established.
- The working Postures practiced while the machine welding operations are observed over the snapshots and manikin model in ergonomic design and analysis in the workbench module of CATIA V5 is performed.
- RULA and OWAS analysis for the different kinds of FCAW welding machine operating postures are analyzed. Based on the analysis, it is observed that the working postures at FCAW machine operators during machine welding operation were risky and objectionable.
- Software analysis and ergonomic assessment tools as found to be the finest method to recognize the discomfort levels of the workers to provide suitable answers for WMDs.
- WMSD is obvious that the noteworthy health concern. To reduce WMSD's in workers, it's important to implement and follow the ergonomic guidelines as mandatory. This will benefit the organizations to accomplish improved quality and enhanced productivity

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

The authors are grateful to the management of Bharat Heavy Electricals Limited, Tiruchirapalli, India, for their support and consent to carry out the study.

References

1. Peppoloni L, Filippeschi A, Ruffaldi E, Avizzano CA (2016) A Novel Wearable System for the Online Assessment of Risk for Biomechanical Load in Repetitive Efforts. Int J Ind Ergon 52: 1-11.

2. David GC (2005) Ergonomic methods for assessing exposure to risk factors for the work-related musculoskeletal disorder. Occup Med 55: 190-9.

3. Wang Di, Fei Dai, Xiaopeng Ning (2015) Risk assessment of work-related musculoskeletal disorders in construction: State-of-the-art review. J Constr Eng Manage 141: 04015008.

4. Jungsun Park, Yangho Kim, Boyoung Han (2018) Work Sectors with High Risk for Work-Related Musculoskeletal Disorders in Korean Men and Women. Safety Health Work 9: 75-8.

5. Herberts P, Kadefors R (1976) A Study of Painful Shoulder in Welders. Acta Orthop Scand 47: 381-7.

6. Lowe BD, Wurzelbacher SJ, Shulman SA, Hudock SD (2001) Electromyographic and discomfort analysis of confined-space shipyard welding processes. Appl Ergon 32: 255-69.

7. Kazmierczak K, Mathiassen SE, Forsman M, Winkel J (2005) An integrated analysis of ergonomics and time consumption in Swedish 'craft-type' car disassembly. Appl Ergon 36: 263-73.

8. Roquelaure Y (2016) Promoting a Shared Representation of Workers'Activities to Improve Integrated Prevention of Work-Related Musculoskeletal Disorders. Int J Saf Health Work 7: 171-4.

9. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F (1987) Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon 18: 233-7.

10. Oakman J, Chan S (2015) Risk management: Where should we target strategies to reduce work-related musculoskeletal disorders?, Safety Sci 73: 99-105.

11. Muthukumar K, Sankaranarayanasamy K, Ganguli AK (2012) Discomfort analysis in computerized numeric control machine operations, Int J Saf Health Work 3: 146-53.

12. Spasojevic Brkic VK, Klarin MM, Brkic AD (2015) Ergonomic design of crane cabin interior: The path to improved safety. Int J Saf Sci 73: 43-51.

13. Rahman MNA, Hui UJ, Haq RHA, Hassan MF, Arifin AMT, et al. (2015) Musculoskeletal discomfort among workers in mould making manufacturing industry. Int J Eng Appl Sci 10: 6269-73.

14. Mahendra KC, Gouda HV, Gouda AT (2016) Ergonomic Analysis of Welding Operator Postures. Int J Mech Prod Eng 4: 9-22.

15. Human Activity Analysis. 5: 1-65.

16. Human Builde. 5: 1-357.

17. American Welding Society (2008) Ergonomics in The Welding Environment. Safety Health Fact Sheet 13.