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ERGO-MECHANICAL APPLICATIONS IN SMALL-SCALE SMAW WELDING TABLE DESIGN

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Abstract
SMAW (shielded metal arc welding) is a type that is widely used in almost all types of welding work including in small industries. In small industries, workers doing SMAW welding work are generally done by squatting. This work posture causes musculoskeletal complaints in workers as a result of unnatural work postures. The study aims to change unnatural work postures to be more natural through ergo-mechanical applications. Ergo-mechanical applications are carried out by making a welding table aid. Ergonomically based on worker anthropometric data, while mechanically selecting strong, lightweight, and affordable materials in terms of cost. The benefits of ergo-mechanical applications are the creation of effective, comfortable, safe, healthy, efficient, and sustainable work. The research method is carried out through participation or involving workers, namely anthropometric data of workers who do welding work with SMAW welding. The ergo-mechanical application to the SMAW welding table aid provides a decrease in musculoskeletal complaints in workers. Workers' musculoskeletal complaints can be reduced by 24.61%, from the medium category with an average of 51.6 to the light category with an average of 38.9. The application of ergo-mechanical will produce work tools that are comfortable for workers to use and meet technical standards related to specifications as a description of the technical characteristics of a work tool.

Key words: SMAW, Anthropometry, Musculoskeletal Disorders, Ergo-mechanical

INTRODUCTION

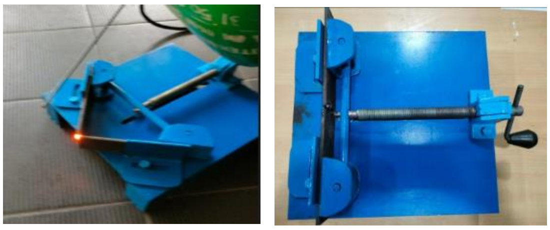
SMAW (shielded metal arc welding) welding is a popular method and is widely used on a home or small scale. SMAW is generally applied in a welding production process on various types of materials. SMAW welding is a low-cost, simple, and lightweight welding method (Tami Mutu Institute, 2022). In the field of SMAW welding, workers do their work with an unnatural working posture. Improving this working posture can be done through an ergo-mechanical application to design a workbench as a place for the SMAW welding process. Ergo-mechanical is used to solve work problems related to work tools, ergonomics, and occupational health and safety (Suarjana et al., 2022).

The table in the SMAW welding process is very much needed to facilitate workers in doing their work. In addition, the safety and comfort of workers are well maintained. SMAW welding workers are accustomed to using personal protective equipment such as glasses and gloves. However, workers who carry out their production process still have unnatural working postures, such as squatting and bending. This working posture causes pain in the worker's body parts, which is often referred to as a musculoskeletal disorder. Workers often experience musculoskeletal complaints and work manually. This is caused by the unnatural working posture, which is an impact of the lack of compatibility between the work tool and the worker. Unusual and unnatural work postures cause musculoskeletal complaints, and exposure increases the risk of work injuries (Bridger, 2003; OSHA-a, 2024). Manual handling, such as activities that produce vibrations, lowering, lifting, pushing, and pulling as activities that cause musculoskeletal disorders, indicate that workers have high ergonomic issues that can be helped through categorization of ergonomic equipment to select specific task risk analysis and posture analysis (Rajendran et al., 2021). Musculoskeletal disorders have symptoms such as upper and lower back pain, neck, shoulders, hands, wrists, ankles, elbows, and knees, which can be reduced by training workers in ergonomics and alternating work postures (Olowogbon et al., 2021; Barneo-Alcántara et al., 2021). The production process in small and medium industries is often done manually, and if done incorrectly, it can cause disorders in the tendon, nerve, muscle, and bone systems called musculoskeletal disorders (Lady and Nurae-ni, 2024; Evadarianto and Dwiyanti, 2017).

Figure 1. Workers Welding in a Squatting Position (Mindhayani, 2021)

Musculoskeletal disorders are also experienced by workers who do SMAW welding work, such as pain in the muscles, neck, back, knees, and feet. In addition, the welding process is carried out repeatedly. According to Mindhayani (2021), workers welding in a squatting position, as in Figure 1, is an unergonomic and uncomfortable working condition such as a squatting position, which can be at risk of causing musculoskeletal system disorders.

The work process that is carried out repeatedly and continuously with an unnatural working posture has an impact on increasing complaints from workers and the risk of injury. To overcome conditions like this, ergonomic and mechanical principles can be applied, which are called ergo-mechanical principles. The ergonomic principle is carried out through the use of anthropometric data of workers who use work tools in the welding process. The mechanical principle can be carried out through the selection of materials used in the manufacture of work tools. In addition, mechanically, work tools are designed to be easy for workers to maintain and operate as users. Ergo-mechanical is a study system of synergy between ergonomic and mechanical systems, namely ergonomic synergy between workers and mechanical systems of work tools, to increase the productivity and efficiency of the workforce (Adnyana et al., 2015). The application of ergo-mechanical is to overcome work problems related to the fields of occupational health and safety, ergonomics, work tools, and ergonomic mechanical structures that are easy to use in various applications (Suarjana et al., 2022; Yong et al., 2019). Manual work on SMAW welding requires ergonomic handling, namely a welding table equipped with jigs and fixtures that can be adjusted to the shape of the object to be welded (90° angle and 180° angle). Welding at 90° and 180° angles is shown in Figure 2 (Hamdani et al., 2022).



(a) (b)

Figure 2. Welding at angles (a) 90° and (b) 180° (Hamdani et al., 2022)

The height of the welding aid table can be adjusted according to the anthropometry of the welding operator, thus providing comfort and reducing health risks in the form of musculoskeletal complaints. The design of this tool requires collaboration between ergonomics and mechanical engineering or ergo-mechanical. To create a match between the tool and its user, anthropometric data is needed to create an effective, comfortable, safe, healthy, and efficient working atmosphere (Sari et al., 2020). Ergo-mechanical is used to overcome work problems related to the fields of work tools, ergonomics, and occupational health and safety (Suarjana et al., 2022). The purpose of ergo-mechanical is to create an effective, comfortable, safe, healthy, and efficient work situation. This has an impact on the creation of mental and physical health, which improves the quality of sustainable production. Ergonomic interventions that include modifying work equipment to assist the production process have reduced physical demands, eliminated unnecessary movements, and reduced injury rates and workers' compensation costs (OSHA-b, 2024). The design or redesign of a work tool based on the application of ergo-mechanical as a system of implementing integrated ergonomic and mechanical principles so that ergonomic work tools are created, namely technical standards such as service requirements, products, and materials, as well as comfortable use by workers (Bawa Susana et al., 2024). The application of ergo-mechanical to a work tool produces an ergonomic design. The benefits of this research are the creation of effective, comfortable, safe, healthy, efficient, and sustainable work. This is done by changing the unnatural work posture to be more natural through ergo-mechanical applications carried out by making a welding table as an aid.

METHODS

The research was conducted through participation or involving workers who perform welding work with SMAW welding. The research was conducted on workers with working postures, as shown in Figure 3.

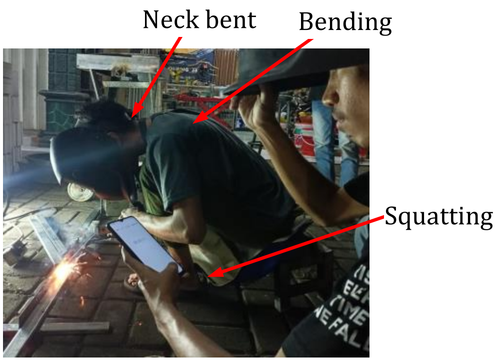


Figure 3. Welding with Unnatural Working Posture

The working posture, as in Figure 3, results in musculoskeletal complaints. To overcome this, the working posture is changed by adding a work table based on ergo-mechanical applications. The materials and tools used in this study include SMAW welding, Nordic body maps (NBM) questionnaires to measure the level of complaints experienced by workers, body dimension measuring tools or worker anthropometric data, supporting tools and materials in the design of the welding table such as grinders, drills, pliers, protractors, callipers, cutting blades, iron (hollow, elbow, U), iron plate, wheels, and electrodes. Anthropometric data measurements were carried out on all workers who work using SMAW welding with a sample size of 10 people. Measurement of workers' anthropometric data was carried out according to the important needs in the design of the welding table. Worker anthropometric data includes standing elbow height for the height dimension of the table, shoulder width for the width dimension of the gripping elbow, and hand reach forward for the base dimension of the work table (semicircular). The results of worker anthropometric data measurements were first applied to the percentile value. The use of percentile values is applied in calculating anthropometric data, and the percentile value indicates the number of parts per hundred people from a population that have a certain body size (Wignjosoebroto, 2008; Iridiastadi and Yassierli, 2019). After that, the calculation results from the percentile were used to calculate the dimensions of the welding table design. To determine the success of the SMAW welding table design, measurements of the level of musculoskeletal disorders were carried out before and after the completion of work on the welding process before and after the intervention. This study used the 50th percentile value to obtain a design with an average size. The calculation of the percentile of anthropometric data is based on the mean value and standard deviation of the measurement data.

$$\text{Percentile } 50 = \bar{X} \quad (1)$$

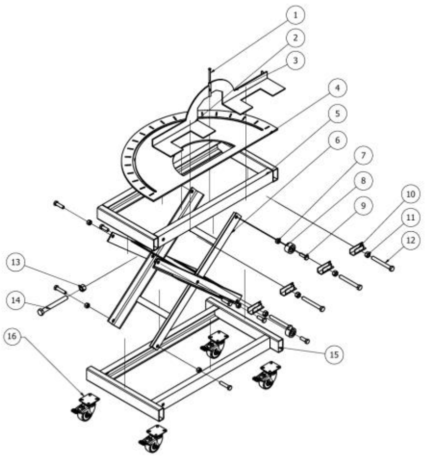
$\bar{X}$ is the mean and SD is the standard deviation as shown in Equation 2.

$$SD = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \quad (2)$$

x_i is measurement data, $\bar{X}$ is the average of the measured data, and n is the number of measured data.

RESULTS AND DISCUSSION

The results of the welding table design in this study were generated based on anthropometric data of SMAW welding workers. The sample was 10 workers with a work period of one to 4 years and male gender. The results of the ergo-mechanical application in the design of the welding table in SMAW welding through the anthropometric data of workers as users are shown in Figure 4.



1. Pins, 2. Jig 1, 3. Jig 2, 4. Table, 5. Upper Frame, 6. Frame Legs, 7. Nut 18, 8. Roll Wheel, 9. Bolt 18, 10. Press Elbow, 11. Nut 18, 12. Bolt 18, 13. Nut 22, 14. Bolt 22, 15. Lower Frame, 16. Wheel

Figure 4. Welding Table Design in SMAW Welding Based on Worker Anthropometric Data

Figure 5 shows a prototype SMAW welding table. Testing is done by measuring the level of workers' musculoskeletal disorders. The level of musculoskeletal complaints is shown in Figure 7. The 10 samples used in this study show that before the intervention using ergo-mechanical, the musculoskeletal complaint score (MSDs-1) showed a moderate risk level. This was experienced by all samples used. Workers, after using the welding table designed based on the ergo-mechanical application, experienced a decrease in the level of musculoskeletal disorders.

Figure 5. Welding Table Prototype in SMAW Welding Based on Worker Anthropometric Data

The welding table, as shown in Figure 5, is then used for testing by involving workers in the SMAW welding process. This sample was also measured for musculoskeletal complaints before and after finishing work on the old tool and the tool after the intervention. Anthropometric data and percentile value calculations are presented in Table 1.

Table 1. Worker Anthropometric Data

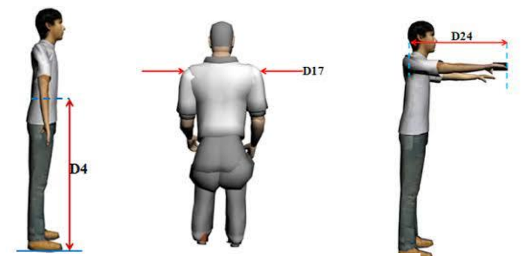
No	Sample	Standing Elbow Height	Shoulder Width	Forward Hand Reach
1	1	101	40	65
2	2	105	40	71
3	3	108	47	77
4	4	99	44	70
5	5	103	41	72
6	6	107	42	65
7	7	103	45	63
8	8	107	42	75
9	9	99	41	65
10	10	109	45	75
Mean		104.1	42.7	69.8
Standard Deviation		3.477068	2.282542	4.770744

The percentile values based on data from Table 1 are as shown in Table 2.

Table 2. Percentile Value

No	Data Types	Percentile	Results (cm)	Description
1	Standing Elbow Height	P50	104.1	Table Height
2	Shoulder Width	P50	42.7	Grip Elbow Width
3	Forward Hand Reach	P50	69.8	Table Mat

Measurement of anthropometric data such as elbow height, shoulder width, and hand reach forward in a standing position as shown in Figure 6.



(a) (b) (c)

Figure 6. a) Standing Elbow Height (D4), b) Shoulder Width (D17), and c) Forward Hand Reach (D24) (Antropometri Indonesia, 2024)

The values presented in Table 1 are used as the dimensions of the welding table. The table height using the worker's anthropometric data based on the standing elbow height is 104.1 cm. The width of the gripping elbow is 42.7 cm, based on the 50th percentile. The radius of the semicircular work table base is 69.8 cm. These dimensions are based on the 50th percentile of anthropometric data measurements on the worker's forward hand reach. Anthropometric data applied to the 50th percentile in this study aims to ensure that the average normal operator can use the welding table. The use of anthropometric data applied in percentile values provides dimensions for the design of work tools that are appropriate for the user or worker. This has an impact on the level of worker comfort in doing their work. Anthropometric data creates an effective, comfortable, safe, healthy, and efficient working atmosphere as a result of the creation of a match between the tool and its user (Sari et al., 2020).

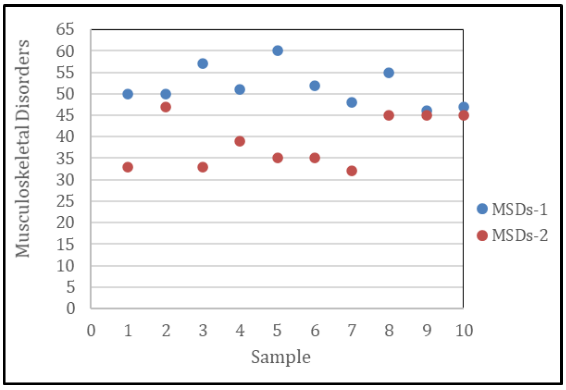


Figure 7. Comparison of Musculoskeletal Disorders Before (MSDs-1) and After Ergo-Mechanical Intervention (MSDs-2)

In some parts of the worker's body that are predominantly used in SMAW welding work, such as the left knee, the decrease in musculoskeletal complaints reached 24.61%, namely from an average of 51.6 (MSDs-1) to 38.9 (MSDs-2). The musculoskeletal complaint score of 51.6 is included in the moderate risk level and requires corrective action on the work tool. Meanwhile, the musculoskeletal complaint score of 38.9 is included in the low-risk level and does not require any repairs to the work tool (Tarwaka, 2019). The application of ergonomics in designing a work tool has been proven to be able to reduce workers' musculoskeletal complaints. This is the impact of changing the worker's posture to be natural. Natural work posture can provide comfort for workers who have an impact on increasing productivity. An ergonomic assessment is important to increase productivity and reduce risks in physical work (Bawa Susana et al., 2022). Current ergonomic interventions have an impact on reducing musculoskeletal disorders (MSDs) complaints widely (Benos et al., 2020).

Application of ergonomic principles related to humans as the centre of a job to reduce occupational health and safety risks (Imada, 2000; Burgess-Limerick, 2018). Work tools are designed ergonomically through the participation and anthropometric data of workers who use the work tools. Mechanically applied through engineering drawings, mechanical planning, and work tool materials to obtain a strong, light, safe work tool from hazardous substances and according to technical specifications. Ergo-mechanical can be used as a guideline in designing or redesigning work tools to produce effective, comfortable, safe, healthy, efficient, affordable, light, strong, and easy-to-use work by workers so that the worker's work posture becomes natural. Application of ergonomics in work tool design based on worker body dimensions or worker anthropometric data.

CONCLUSIONS

The application of ergo-mechanical in the design of small-scale SMAW welding tables provides a natural worker posture as an impact of the use of worker anthropometric data in designing the welding table. In addition, workers' musculoskeletal disorders after the intervention decreased by 24.61%. Before the intervention, workers' musculoskeletal disorders reached a score of 51.6, which was included in the moderate risk level and required corrective action. After the intervention, musculoskeletal disorders had a score of 38.9, and this score was included in the mild risk level. This shows that the welding table provides comfort to workers. With ergo-mechanical applications, the work tools produced can be claimed in the specification sheet as ergonomic work tools.

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