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EVALUATION OF SMAW WELDING PROCESS TIME USING AN ERGO-MECHANICAL WORKTABLE

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Abstract. The manual welding process can be influenced by the conditions of the work facilities used by the operator, particularly in tasks that require adjustments to the working posture during welding. This study aims to analyze welding time characteristics following the implementation of an ergo-mechanical workbench for 90° and 180° joints. Testing was conducted on 10 workers, with three repetitions for each condition, specifically, without and with a worktable. The experiment involved 10 workers from small-scale welding workshops who had practical experience in SMAW welding but did not hold formal welding competency certificates. The data analyzed included welding time, standard deviation, Coefficient of Variation (CV), and the percentage reduction in time. The results showed that the average welding time for 90° joints decreased from 57.90 seconds without a workbench to 41.33 seconds with a workbench, while for 180° joints, it decreased from 47.03 seconds to 35.13 seconds. The percentage reductions in time reached 28.62% and 25.30%, respectively. The coefficient of variation (CV) increased from 11.10% to 19.80% for the 90° joint and from 14.69% to 22.07% for the 180° joint, indicating greater relative variability in welding time compared with the mean and less uniform process time responses among workers and repetitions under the worktable condition. The increase in CV was associated with higher standard deviations and reduced mean welding times, indicating greater relative variation among workers. Overall, this study provides an experimental evaluation of the previously developed ergo-mechanical worktable by demonstrating its potential to reduce SMAW welding process times for both 90° and 180° joint configurations. However, the increased coefficient of variation indicates that time reductions were not equally uniform among workers and repetitions. Thus, the main contribution of this study is the quantitative assessment of welding process time and its variability under working conditions with and without the previously developed worktable.

Keywords: ergo-mechanical; worktable; welding; processing time; coefficient of variation.

1 Introduction

Welding is a manufacturing process that is widely used in fabricating and repairing metal components. This process not only requires technical skills to produce suitable joints but also involves interactions between workers, workpieces, equipment, and the work environment. From an ergonomic perspective, work systems need to be designed by considering the balance between human needs and the technical aspects of the work, including the interaction between workers and the equipment used within the system [1]. In welding activities, physical demands and workstation conditions can influence both ergonomics factors and task execution. Recent research on overhead arc welding indicates that shoulder, elbow, and wrist positions affect various ergonomic responses and task times, therefore, ergonomic aspects and process time characteristics need to be considered simultaneously when evaluating welding tasks [2].

One approach to improving welding working conditions is through the design or modification of workstations tailored to worker characteristics and process requirements. Research on welding workstation design indicates that the application of anthropometric dimensions and ergonomic evaluation can reduce risks

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associated with working postures, as evidenced by lower RULA and REBA scores following workstation improvements [3]. Ergonomics interventions at welding workstations also demonstrate that modifications to work facilities, such as adjusting table height and other supporting elements, can improve workers' posture and reduce musculoskeletal risks [4]. Beyond ergonomics considerations, the use of auxiliary tools or welding fixtures can benefit the execution of the process. Manggala et al. developed a welding fixture for the inner joint welding process with the aim of reducing non-conforming products and shortening production time, demonstrating that welding support equipment can be utilized not only to maintain the workpiece position but also to enhance process performance [5].

In addition to ergonomics considerations, the use of jigs and fixtures is an approach to enhancing the precision and consistency of workpiece positioning during the welding process. These devices serve to establish the position, maintain the orientation, and secure the workpiece while the process is underway, thereby minimizing variations associated with manual placement [6]. In the development of welding fixtures, a clamping system design tailored to the workpiece characteristics and process requirements can facilitate component positioning and maintain component placement during welding [7]. Other studies on the development of welding tables and support devices also indicate that integrating workpiece-holding facilities into the workstation can support process consistency and facilitate welding operations for specific joint configurations [8]. Thus, the presence of jigs and fixtures at the workstation relates not only to the positioning of the workpiece but also serves as a crucial factor in evaluating welding process characteristics, including the time required to complete the process.

Developing welding workstations that incorporate ergonomic considerations is one approach to improving the fit between the worker, the workpiece, and the work facilities. The development of an ergonomics-based welding table prototype, using the Quality Function Deployment (QFD) approach and a Pugh matrix, demonstrates that the needs of workers are a crucial aspect that must be integrated into the design process for workplace facilities [9]. In the context of welding operations, interventions regarding work facilities can also be implemented by adjusting workstation dimensions and configurations. The design of an adjustable workbench, supported by anthropometric data and digital human modeling, can reduce the level of risk associated with body posture during specific welding activities [10]. Ergonomics interventions at industrial workstations have also been reported to improve worker posture through modifications to tables, chairs, and other supporting facilities, particularly in welding tasks that require maintaining a specific body position for extended periods [4]. Beyond worker ergonomics, the design of welding facilities must also consider the mechanical function of securing the workpiece in position. Recent research on welding fixtures indicates that clamping designs can be used to maintain the position and stability of the workpiece during the process; consequently, the fixture plays a crucial role in integrating ergonomic requirements with the technical needs of the welding process [11].

Previous research has demonstrated the benefits of ergo-mechanical worktables in improving welding conditions; evaluations of work facilities must also take into account the characteristics of the process execution. In a manufacturing context, process development that incorporates ergonomic considerations can contribute not only to worker conditions but also to process performance and productivity; consequently, ergonomics evaluation can be expanded to include measurable operational parameters [12]. In the welding process, the use of jigs or fixtures has also been reported to help reduce processing time by controlling the position and standardizing the placement of the workpiece. Research on fixture-assisted TIG welding indicates that the use of welding jigs can facilitate a reduction in production time while maintaining the accuracy of the weld [13]. Another study on fixture design for welding-based assembly processes also indicates that the design of workpiece-holding facilities can serve as an approach to improve process time and reduce reliance on manual methods [14]. The findings indicate that processing time can serve as a parameter for evaluating the implementation of workstations for welding activities. However, further study is required to specifically evaluate actual SMAW welding times using ergo-mechanical worktables, while accounting for differences between 90° and 180° joint configurations.

Based on the foregoing, previous studies have demonstrated that welding fixtures and supporting workstations can improve workpiece positioning and contribute to reducing processing time [5,13,14]. Furthermore, Susana et al. [15] developed an ergo-mechanical worktable for small-scale SMAW welding by considering workers' anthropometric characteristics and mechanical requirements, including workpiece positioning for 90° and 180° joint configurations. However, comparative evidence regarding actual SMAW welding process time for these two joint configurations, under conditions with and without an ergo-mechanical worktable, remains limited in the literature reviewed. Unlike the previous study, which focused on worktable design and development, the present study uses the previously developed prototype to experimentally evaluate welding process time. Specifically, this study quantifies changes in average welding time, compares the magnitude of time reduction between 90° and 180° joint configurations, and examines variations in welding time using standard deviation and coefficient of variation (CV). Thus, the contribution of this study is to provide quantitative evidence of welding process time changes and their relative variability when using the previously developed ergo-mechanical worktable.

2 Method

This study is an experimental investigation that builds upon previous research regarding the design of an ergo-

mechanical, small-scale SMAW welding table [15]. In the earlier study, the workbench was developed by considering ergonomic and mechanical aspects and was equipped with jigs and fixtures to assist in positioning the workpiece for 90° and 180° joint configurations. The ergo-mechanical approach in this study is positioned as part of the development of a work system that considers the interaction between humans and system elements. Conceptually, ergonomics encompasses the application of data, principles, and methods to optimize human well-being and system performance [16].

Unlike previous research that focused on the design and ergonomics evaluation of the workstation, this study focuses on the implementation of the workstation and the process time characteristics of SMAW welding. Consequently, the workstation from the previous study was used as the work facility for the experiment without undergoing redesign. This study employed a comparative experimental approach involving two experimental factors: workstation condition (without and with the ergo-mechanical worktable) and joint configuration (90° and 180°). These factors resulted in four experimental conditions. Ten workers from small-scale welding workshops participated in the experiments, with each participant performing three repetitions under each condition. The welding process time was analyzed descriptively using the mean, standard deviation, coefficient of variation (CV), and percentage reduction in welding time. These parameters were used to characterize differences in average welding time and its variability across the four experimental conditions. The analysis focused on describing and comparing the observed welding process time characteristics rather than statistically testing the main effects or interaction between the experimental factors. A factorial design enables the evaluation of the effects of each individual factor as well as the interaction between them [17]. The worktable used in this study is an SMAW welding table that was developed in previous research using an ergo-mechanical approach [15]. The previous design took into account the workers' anthropometric characteristics and the mechanical aspects of the table's construction. The workbench is equipped with jigs and fixtures to help maintain the workpiece's position during the welding process. These features support welding operations for 90° and 180° joint configurations. In this study, the workstation was neither modified nor redesigned but was instead used as a work intervention to evaluate welding process times. Thus, this research shifts the focus from the ergonomic aspects addressed in previous studies toward an evaluation of process time characteristics.

As shown in Figure 1, the ergo-mechanical welding workbench consists of several components designed to facilitate workpiece positioning, ensure structural stability, and provide mobility. Workpiece positioning guides (1) and clamps/gripping tools (2) assist in aligning and securing workpieces during the welding process. A curved angle guide (3) serves as a reference for workpiece placement, while the support frame for the tabletop (4) maintains the stability of the work surface. The base frame and its supporting mechanisms (5) provide structural support, and caster wheels (6) facilitate the mobility of the workbench

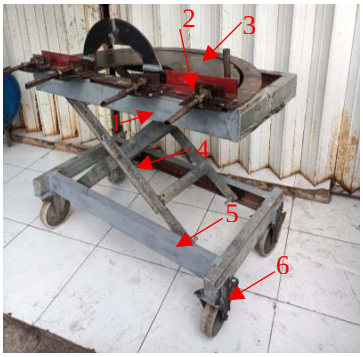


Fig. 1. Ergo-mechanical worktable used in the study [15]

The research subjects consisted of 10 workers performing the welding process. The research subjects consisted of 10 workers from small-scale welding workshops who routinely performed SMAW welding activities. The participants were not classified as professionally certified welders, as they did not hold formal welding competency certificates. Their welding skills were primarily acquired through practical work experience in small-scale workshop environments rather than formal professional training and certification programs. All participants had experience performing manual welding activities and were involved in all experimental conditions. Each worker performed welding on 90° and 180° joint configurations, both without and with the ergo-mechanical worktable, with three repetitions for each condition. This approach allowed the evaluation of welding process time under different workstation conditions among workers with practical welding experience in small-scale workshop settings.

Each worker performed all combinations of experimental conditions, so that each worker was subjected to four test conditions. The design included a within-subject/repeated-measures design, meaning that the experimental conditions were administered to the same subjects, so that measurements between conditions were not considered independent observations. A repeated-measures design is appropriate when multiple measurements are conducted on the same subjects under different conditions [18]. Each worker performed three repetitions of each condition. The total time measurements obtained were calculated using Equation 1.

$$N=n\times A\times B\times r \quad (1)$$

N is the number of measurements, n is the number of workers, A is the number of desk usage conditions, B is the number of joint angle conditions, and r is the number of repetitions. With 10 worker subjects, 2 desk usage conditions, 2 joint angle conditions (90° and 180°), and 3 repetitions, the total number of measurements is 120.

Materials and equipment include an ergo-mechanical workstation, an SMAW welding machine, welding workpieces/specimens, SMAW electrodes, workpiece holding jigs/fixtures, an angle measuring tool, a stopwatch/timer, and personal protective

equipment. Specific electrode parameters and SMAW electrical settings such as current and voltage were not used as research variables. The welding process was carried out using the Shielded Metal Arc Welding (SMAW) method. The same welding machine, electrode type, and electrode diameter were used throughout all experimental conditions to maintain consistency in the welding setup. Welding current and voltage were not treated as independent research variables because this study focused on evaluating the effect of the ergo-mechanical worktable on welding process time. The welding settings were maintained at the same nominal operating conditions during testing, while the welding process was performed using the same general working procedure. Arc length was maintained by the operators through manual control during welding. Although minor variations in arc length and electrical parameters could not be completely eliminated, the use of consistent equipment, electrode specifications, and nominal welding settings was intended to minimize their influence on the comparison between experimental conditions. Workplace safety was prioritized throughout the testing. The welding process presents potential hazards, including welding fumes, ultraviolet radiation, burns, eye damage, electric shock, and mechanical risks, therefore, the use of safe work practices and personal protective equipment is required during the welding process [19].

The welding process was carried out using the Shielded Metal Arc Welding (SMAW) method. The same electrode was used for all testing conditions. Testing was conducted under two table-use conditions without a table and with an ergo-mechanical worktable. For each condition, welding was performed on 90° and 180° joints. In the setup involving a work table, the workpiece is positioned and held in place using a jig or fixture mounted on the table. In the setup without a work table, the process is carried out without using such a table. Welding time is defined as the actual duration of the welding process, specifically, the interval between the start and completion of the welding. Measurement begins when the welding process commences and stops when it concludes. The time is recorded in seconds and calculated using Equation 2.

$$t = t_{end} - t_{start} \quad (2)$$

t is the welding time (s), t_{start} is the welding start time, and t_{end} is the welding completion time. Pre-welding preparation time and post-welding activities are not included in the measurement. This definition of time was applied consistently across all workers and experimental conditions.

Thus, the study evaluated the actual duration of the welding process rather than the total time of the work activity. Figure 2 shows the SMAW welding process without a worktable, and Figure 3 shows the SMAW welding process using an ergo-mechanical worktable.



Fig. 2. SMAW welding process conditions without a worktable



Fig. 3. The SMAW welding process utilizes an ergo-mechanical worktable

For each worker under each condition, three trials were conducted to obtain the average welding time. This average value was then used to represent the worker's time for the respective condition. Descriptive statistics were used to characterize the welding times for each experimental condition. Descriptive statistics were used to compare temporal trends and the degree of process variation across the four experimental conditions. The parameters employed included the mean, standard deviation (SD), minimum, maximum, and coefficient of variation (CV). Average value ($\bar{t}$) calculated using Equation 3.

$$\bar{t} = \frac{\sum_{i=1}^{n} t_i}{n} \quad (3)$$

The coefficient of variation (CV) is calculated using Equation 4.

$$CV = \frac{SD}{\bar{t}} \; x \; 100\% \quad (4)$$

The change in process duration, representing the magnitude of the time change following the use of the workstation, is calculated as a percentage reduction in time based on Equation 5.

$$R_t = \frac{t_{without} - t_{with}}{t_{without}} \; x \; 100\% \quad (5)$$

R_t represents the percentage reduction in time (%), while $t_{without}$ is the average time without the worktable (s), and t_{with} is the average time with the worktable (s). The percentage reduction in welding time was calculated separately for 90° and 180° joint configurations to

determine the change in welding duration following the implementation of the ergo-mechanical worktable. The analysis results are interpreted specifically in terms of changes in welding time and are not used as a measure of overall productivity or energy efficiency.

3 Results and Discussion

Welding time is one of the parameters that can be used to characterize the execution of a work process. In a welding workstation, Iriondo Pascual et al. evaluated productivity based on the cycle time of the welding activity sequence [20]. In the study, cycle time encompasses both value-added activity times, such as welding time, and other supporting activities. Therefore, this study utilizes welding time as a more specific process parameter, defined as the duration measured from the start of welding until the welding process is completed. Measurements were conducted on 10 workers, with three repetitions for each test condition, covering 90° and 180° connections under conditions both without and with an ergo-mechanical workbench. Descriptive statistics of the measurement results are presented in Table 1.

Table 1. Welding time characteristics for each condition

Test conditions	90°	180°
Without a table, Mean ± SD (s)	57,90 ± 6,43	47,03 ± 6,91
With a table, Mean ± SD (s)	41,33 ± 8,18	35,13 ± 7,75
Without a table, Min–Maks (s)	45–75	32–60
With a table, Min–Maks (s)	28–56	19–49

Based on Table 1, welding times differed between conditions without and with the use of the ergo-mechanical worktable for both joint configurations. For the 90° joint, the average welding time decreased from 57.90 ± 6.43 seconds without the worktable to 41.33 ± 8.18 seconds with the worktable, representing a reduction of 16.57 seconds (28.62%). Similarly, for the 180° joint, the average welding time decreased from 47.03 ± 6.91 seconds to 35.13 ± 7.75 seconds, corresponding to a reduction of 11.90 seconds (25.30%). These results descriptively indicate that the use of the worktable was accompanied by shorter welding times for both joint configurations. However, the standard deviation increased under both conditions. For the 90° joint, it increased from 6.43 to 8.18 seconds, while for the 180° joint, it increased from 6.91 to 7.75 seconds. This indicates greater dispersion in welding times among the observations when the worktable was used. The increased variation may be associated with differences in workers' practical welding experience, individual adaptation to workpiece positioning on the worktable, and manual control of electrode movement during welding. Since the participants were workers from small-scale welding workshops and did not hold formal welding competency certificates, differences in individual welding skills may also have contributed to the observed variation. These factors are possible explanations, as individual adaptation and welding skills were not directly measured in this study. Overall, although the use of the ergo-mechanical worktable was accompanied by a reduction in average welding time for both joint configurations, the increase in standard deviation indicates that the reduction was not equally consistent across all observations.

Individual worker patterns related to welding time are presented in Figures 4 and 5. For the 90° joint shown in Figure 4, the average welding time with the worktable was lower than without it across all 10 workers. Figure 4 shows variations in welding time among individual workers under different working conditions. In the condition without the workbench, Worker No. 5 exhibited a substantial decrease in welding time, whereas Workers No. 6–10 showed a relatively increasing trend. These differences may reflect variations in individual welding skills, manual electrode control, and consistency in performing the welding process. Since the participants had different practical work experiences and were not formally certified welders, their individual performance may have varied during the experiments. A different pattern was observed in the condition using the workbench. Worker No. 2 showed a decrease in welding time, while Worker No. 7 experienced a considerable increase. This variation may be related to differences in individual adaptation to the workbench, particularly in positioning the workpiece and adjusting hand movements during welding. Although the workbench was intended to facilitate workpiece positioning, its use may not have provided the same level of benefit to every worker. Differences in individual working techniques and familiarity with the worktable may have influenced the observed welding times. These findings indicate that the implementation of the ergo-mechanical worktable did not produce an identical response among all participants. Individual differences in practical welding experience, working techniques, and adaptation to the workstation may have contributed to the variations observed in Figure 4. However, these factors should be considered possible explanations rather than confirmed causes, as they were not directly measured in this study.

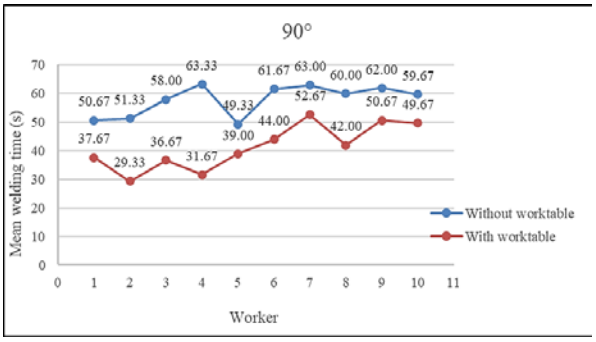


Fig. 4. Comparison of mean welding time between without and with worktable conditions for a 90° joint

A similar pattern was observed for the 180° joint shown in Figure 5, where every worker demonstrated a shorter welding time after using the workbench. Thus, the reduction in the average values presented in Table 1 was not driven by changes in only a few specific workers but was consistently observed across all tested workers.

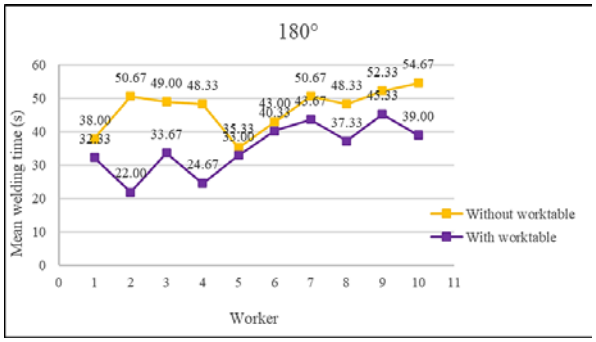


Fig. 5. Comparison of mean welding time between without and with worktable conditions for a 180° joint

Figure 5 illustrates variations in welding time among individual workers under different working conditions. In the condition without the workbench, Worker No. 5 exhibited a substantial decrease in welding time, whereas Workers No. 6–10 showed a relatively increasing trend. These differences may be associated with individual variations in practical welding experience, manual electrode control, and consistency in performing the welding process. Since the participants were workers from small-scale welding workshops without formal welding competency certificates, differences in individual working skills may have contributed to the observed variations. In the condition using the workbench, Worker No. 2 showed a decrease in welding time, whereas Worker No. 9 experienced a considerable increase. This contrasting response may indicate differences in individual adaptation to the workbench, particularly in workpiece positioning and the adjustment of hand movements during welding. Although the workbench was designed to facilitate workpiece positioning, its implementation may not have resulted in the same time-saving effect for every worker. Individual working techniques and familiarity with the worktable may have influenced the observed results. Figure 5 indicates that the changes in welding time varied among participants under both working conditions. The worktable was associated with shorter average welding times, as shown in the overall results; however, individual responses were not uniform. Differences in practical experience, welding techniques, and adaptation to the workstation are possible contributing factors, although these factors were not directly measured in this study.

The magnitude of the time reduction varied among workers. For 90° joints, the average time without the workbench ranged from 49.33 to 63.33 seconds, whereas with the worktable, it ranged from 29.33 to 52.67 seconds. For 180° joints, the average time without the worktable ranged from 35.33 to 54.67 seconds, while with the worktable, it ranged from 22.00 to 45.33 seconds. These variations indicate that workers' responses to workstation conditions were not uniform. The implementation of the ergo-mechanical worktable in this study resulted in reduced welding times for both joint configurations, demonstrating that changes to the work setup impact not only ergonomics aspects but also process time characteristics. These findings align conceptually with Muthohar and Yohanes, who demonstrated that the implementation of a rotating jig during the welding process can improve ergonomics conditions while simultaneously increasing productivity [21]. Thus, the results of this study indicate that an ergo-mechanical approach can be examined through the relationship between changes in work facilities and welding time as a process indicator. The use of an ergo-mechanical workstation resulted in reduced welding times for 90° and 180° joints across all workers. Although the magnitude of the reduction varied among individuals, the pattern demonstrated a consistent trend for both joint configurations. These findings serve as the basis for further analysis of the magnitude of time reduction and the significance of the differences between welding conditions.

To complement the welding time characteristics presented in Table 1, relative variation was analyzed using the Coefficient of Variation (CV), defined as the ratio of the standard deviation to the mean value, expressed as a percentage. The CV was calculated based on 30 observations for each condition (10 workers × 3 repetitions) to compare welding time variations for 90° and 180° joints, both without and with the ergo-mechanical worktable, as shown in Table 2.

Table 2. Coefficient of variation of welding time

Welding condition	Mean (s)	SD (s)	CV (%)
90° – Without worktable	57.9	6.43	11.1
90° – With worktable	41.33	8.18	19.8
180° – Without worktable	47.03	6.91	14.69
180° – With worktable	35.13	7.75	22.07

Based on Table 2, the coefficient of variation (CV) values under the condition without a workbench were 11.10% for the 90° joint and 14.69% for the 180° joint. Following the implementation of the ergo-mechanical worktable, the CV values increased to 19.80% and 22.07%, respectively. This indicates that the dispersion of welding times relative to their mean values was greater under the worktable condition. This increase in relative variation should be interpreted in conjunction with the changes in mean welding time and standard deviation. For the 90° joint, the mean welding time decreased from 57.90 to 41.33 seconds, while the standard deviation increased from 6.43 to 8.18 seconds. Similarly, for the 180° joint, the mean decreased from 47.03 to 35.13 seconds, while the standard deviation increased from 6.91 to 7.75 seconds. The increase in standard deviation indicates that the observed welding times became more widely dispersed around their respective mean values after the worktable was introduced. In other words, although the average welding time decreased, the differences in welding time among observations became greater. The increase in standard deviation may be associated with variations in individual workers' responses to the worktable. Differences in practical welding experience, familiarity with the worktable, workpiece positioning, hand movements, and manual electrode control may have contributed to the observed dispersion. Since the participants were workers from small-scale welding workshops who did not hold formal welding competency certificates, differences in their practical skills and working techniques may also have influenced the results. However, these factors should be considered possible explanations rather than confirmed causes because individual skill levels and adaptation to the worktable were not directly measured in this study. The increase in CV does not indicate an increase in welding time. Rather, it indicates that the relative dispersion of welding times became greater following the implementation of the worktable. This is consistent with the nature of CV as a measure of relative variability, which is determined by the relationship between the standard deviation and the mean value [22]. Therefore, the higher CV values reflect both the increase in standard deviation and the decrease in mean welding time. The differences in CV also suggest that the time-saving response was not entirely uniform across workers and repetitions. From an ergonomic perspective, these findings provide additional information about individual task execution characteristics when using the worktable. The CV should therefore be interpreted as a complementary measure of process time variability rather than as a direct indicator of workstation effectiveness. Overall, the implementation of the ergo-mechanical worktable was accompanied by lower average welding times for both joint configurations, although the increased standard deviation and CV indicate greater variation in individual welding time responses.

The percentage reduction in welding time was calculated to quantify the change in process time following the implementation of the ergo-mechanical workstation, as presented in Table 3. This value was determined by comparing the welding time under the condition without the workstation with that under the condition with the workstation. The results indicate a reduction in the average welding process time for both 90° and 180° joint configurations. This reduction represents an improvement in process-time performance, indicating that the welding task could be completed in a shorter duration when using the workstation. A process-time measurement approach can be used to evaluate performance changes following an intervention at a welding workstation, while ergonomic aspects may also be considered when evaluating changes in working conditions [12]. However, the reduction in welding time observed in this study should not be interpreted as an overall improvement in welding efficiency or productivity, since weld quality was not assessed. Therefore, the findings are limited to the evaluation of welding process time and do not establish whether the shorter welding duration was accompanied by equivalent or improved weld quality.

Table 3. Percentage reduction in welding time

Joint angle	Without worktable (s)	With worktable (s)	Time reduction (s)	Reduction (%)
90°	57.9	41.33	16.57	28.62
180°	47.03	35.13	11.9	25.3

Based on Table 3, the use of the ergo-mechanical worktable was associated with a reduction in welding time for both joint configurations. For the 90° joint, the average welding time decreased from 57.90 to 41.33 seconds, representing a reduction of 16.57 seconds or 28.62%. For the 180° joint, the average welding time decreased from 47.03 to 35.13 seconds, corresponding to a reduction of 11.90 seconds or 25.30%. Thus, the relative time reduction for the 90° joint was greater than that for the 180° joint, with a difference of 3.32 percentage points. The difference in time reduction may be related to the distinct geometric characteristics and workpiece positioning requirements of the two joint configurations. The ergo-mechanical worktable may have provided a greater time-saving advantage for the 90° joint by facilitating workpiece positioning during welding. In contrast, the relative reduction for the 180° joint was slightly lower, possibly because its initial average welding time without the worktable was already lower than that of the 90° joint. Differences in individual working techniques and adaptation to the worktable may also have contributed to the observed results. However, these factors should be considered possible explanations because the effects of joint geometry, positioning requirements, and individual adaptation were not independently measured in this study. These results indicate that changes in workstation configuration are associated with changes in welding process time. This finding is consistent with the research by Komarudin and Towip, who developed an ergonomic welding table by considering worker posture through the Rapid Entire

Body Assessment (REBA) method [23]. Their study emphasized the importance of designing welding facilities that better accommodate workers' postural requirements. Similarly, Abushgair et al. (2025) demonstrated that the ergonomic redesign of a welding workstation can influence task execution time and productivity [24]. These studies support the relevance of evaluating welding workstation modifications in terms of both ergonomic considerations and process performance. In the present study, process performance was specifically evaluated based on welding time, defined as the duration from the start to the completion of the welding process. Therefore, the reductions of 28.62% for the 90° joint and 25.30% for the 180° joint represent empirical findings under the experimental conditions. The difference between these values indicates that the magnitude of time reduction varied according to joint configuration. Overall, the implementation of the ergo-mechanical worktable was accompanied by shorter average welding times for both configurations, although the magnitude of the reduction was not identical. These findings highlight the importance of considering joint characteristics when evaluating the effects of workstation modifications on welding process time.

4 Conclusion

Based on the experimental results, the implementation of the ergo-mechanical worktable was associated with a reduction in average SMAW welding process time for both 90° and 180° joint configurations. The average welding time decreased by 28.62% for the 90° joint and 25.30% for the 180° joint. These findings demonstrate the potential of the worktable to improve welding process-time performance under the experimental conditions. However, since the analysis was based on descriptive statistics, the observed reductions cannot be interpreted as statistically significant effects. Despite the reduction in average welding time, the standard deviation and coefficient of variation (CV) increased under the worktable condition, indicating greater dispersion and relative variability in welding time among workers and repetitions. This suggests that the time-saving response was not uniform across participants. Differences in practical welding experience, individual working techniques, manual electrode control, and adaptation to the worktable may have contributed to this variation. However, these factors were not directly measured and should therefore be considered possible explanations rather than confirmed causes. The main scientific contribution of this study is the experimental evaluation of a previously developed ergo-mechanical worktable in terms of SMAW welding process time and its variability for two joint configurations. Unlike the previous study, which focused on worktable design and development, the present study provides quantitative evidence of changes in welding process time under conditions with and without the worktable. The findings highlight the importance of considering not only average process time but also variations in individual performance when evaluating workstation modifications. This study is limited to the evaluation of welding process time and does not establish improvements in weld quality or direct ergonomic benefits, since weld quality, working posture, musculoskeletal load, and physical workload were not assessed. Future studies should investigate weld quality through the assessment of weld defects, weld bead characteristics, and mechanical properties of welded joints. Direct ergonomic evaluations should also be conducted by assessing workers' postures, musculoskeletal loads, and physical workload. Furthermore, anthropometric measurements should be incorporated to evaluate the suitability of worktable dimensions for workers with different body dimensions. Finally, welding parameters, particularly welding current and voltage, should be systematically controlled and recorded to examine their influence on welding process time and weld quality. These investigations would provide a more comprehensive evaluation of the worktable in terms of process-time performance, weld quality, and ergonomic suitability.

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