UDC 615
DOI: 10.15587/1729-4061.2024.295536

# OPTIMIZATION OF WELDING DIRECTION MODEL PARAMETERS TO ENHANCE THE TENSILE STRENGTH OF ST 42 STEEL JOINTS THROUGH VARIATION OF CURRENT STRENGTH SIMULATION

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***The welding process plays a central role in the welding industry, where the joint zone undergoing the welding process experiences structural and mechanical property changes. This research evaluates the comparison of current strength and parameters in the directional welding joint model, a critical aspect of addressing common weaknesses in welded joints. The research objects include four current levels (100, 120, 140, 160 A) and three types of welding directions (longitudinal, transversal, and combination). The aim of this study is to detect the optimal combination in welded joints that can produce a maximum tensile strength ratio. The research method involves tensile testing on various specimen models of joint types at specific current strength levels.***

***The research results indicate that at the current strength level of 120 A, the combined directional welding joint model (longitudinal+transverse) provides a maximum tensile strength reaching 335.370 MPa. This finding stands out significantly, surpassing the tensile strength values at other current levels and welding model types, such as at 100 A (331.574 MPa), 140 A (332.315 MPa), and 160 A (332.685 MPa). This discovery highlights that the combined joint model yields a substantial improvement in joint strength, making it an optimal solution for various current strength levels and joint models.***

***The key feature of this research involves specific recommendations for the welding industry, including guidelines on selecting optimal parameters to enhance the tensile strength of joints. The directional welding joint models can be a reference in designing welding procedure specifications to incorporate construction elements using ST 42 material. This research contributes both theoretically and practically, offering opportunities for improving efficiency and structural safety in the welding process, thus positively impacting the quality of joints in construction and manufacturing applications***

***Keywords: current strength simulation, welding direction joint model, tensile strength***

*Received date 19.01.2024*
*Accepted date 03.04.2024*
*Published date 30.04.2024*

***How to Cite:*** *Muddin, S., Ariyanto, Sriwati, Rahman, M. F. (2024). Optimization of welding direction model parameters to enhance the tensile strength of ST 42 steel joints through variation of current strength simulation. Eastern-European Journal of Enterprise Technologies, 2 (12 (128)), 23–31. https://doi.org/10.15587/1729-4061.2024.295536*

## 1. Introduction

Scientific research on optimizing the parameters of welding direction models to enhance the tensile strength of ST 42 steel joints holds significant importance in the context of modern industry. This is due to the evolving demands of the industry, the necessity for production efficiency, and the intense competition within industrial environments. The outcomes of these studies offer practical benefits such as improved product quality, enhanced production efficiency, and increased structural safety across various industrial applications. Consequently, these studies not only aids in enhancing production efficiency and product quality but also have a significant impact on structural safety, which is a crucial aspect of modern industry. The factors influencing the tensile strength of welded joints are crucial to adhere to the guidelines provided by the American Society for Testing and Materials Standards in achieving structural reliability in the industry [1]. Research on welding underscores the importance of maintaining electrical current stability to mitigate defects in the Heat-Affected Zone (HAZ). Effective welding process improvement relies heavily on managing key parameters such as peak power, pulse irradiation duration, and laser focus point. While precise control over these parameters can impact the quality of penetration and dimensions of the weld zone, ensuring consistency in parameter settings throughout the welding process and understanding the intricate interactions among these parameters present significant challenges. Thus, these studies provide a crucial foundation for understanding the complexities and challenges inherent in implementing these findings within real-world industrial settings [2]. The determination of optimal parameters in the spot welding process involves maintaining constant electrode shape, electrode material, and electrode force while varying current and welding time to achieve maximum joint strength [3]. The sampling resolution of 200 to 250 μm has been proven adequate for fatigue-loaded welded joints investigated in production, ensuring sustained quality assurance for welded structures [4].

The importance of these studies conducted in the modern era lies in the continuous development of technology and the increasing demand for structural reliability and safety, the structural integrity of steel columns reinforced by angle steel welding under high loads. To ensure quality welding results, attention needs to be focused on the influence of welding heat input [5]. Another researcher affirms that well-designed joint models, following industrial codes, exhibit excellent performance for all plate welding joints, especially when using a combination of low amplitude and high-frequency oscillation to enhance joint strength and ductility [6]. Similarly, another researcher emphasizes that the integration of Taguchi models highlights the importance of high voltage and current, low welding speed, and oscillation amplitude variation to achieve optimal joint strength. These findings serve as crucial guidelines in optimizing the welding process. Furthermore, this study explores welded steel plate connections under monotonic and cyclic loading conditions, providing important insights into mechanical parameters [7]. Practical guidelines for optimizing welding in steel structures are offered through the investigation of the Micro-Plasma Arc Welding (MPAW) process, emphasizing the importance of welding current strength, speed, and standoff distance to achieve optimal processes [8]. Other research also indicates that the tensile properties of welds increase with decreasing welding speed and increasing welding current and standoff distance. This aligns with the finding that welding speed is the most influential parameter in controlling weld strength [9]. Moreover, a study on the strength of welded joints with two current strength variations on SUS 304 stainless steel and SS 400 steel plates reveals that the highest tensile strength is obtained in specimens with a welding current of 100 A (25.59 kgf/mm$^2$), compared to a welding current of 80 A (16.17 kgf/mm$^2$), using GTAW and ER308L electrode types [10].

Therefore, studies in this scientific and practical field are crucial for enhancing understanding of the effects of varying current intensity and welding direction models on the tensile strength of joints.

## 2. Literature review and problem statement

According to [1], the importance of optimizing the parameters of welding direction models to enhance the tensile strength of ST 42 steel joints is emphasized due to the evolving demands in the industry, production efficiency, and intense competition. In line with [2], the significance of electrical current stability to reduce defects in the Heat-Affected Zone (HAZ) is highlighted, providing a crucial foundation for understanding the complexities and challenges of implementing findings in real industrial settings. To achieve maximum strength, step [3] focuses solely on determining parameters in the welding process by emphasizing consistent material form and electrode style. Findings from [4] and [5] affirm that adequate sample resolution in fatigue-loaded welded joints ensures sustained quality assurance for welded structures and reinforces the structural integrity of steel column connections reinforced by angle steel welding, aligning with structural reliability and safety in modern industry. Well-designed plate joint models by [6] demonstrate optimal performance, particularly with low amplitude and high-frequency oscillation combinations. Conversely, [7] concentrates on the importance of various parameters to achieve optimal joint strength through plate steel connections under monotonic and cyclic loading. Practical guidelines for optimizing welding in steel structures are provided through Micro-Plasma Arc Welding (MPAW) process investigations according to [8], while weld strength depends on welding speed, as revealed by [9]. [10] asserts that weld joint strength is obtained from variations in the current strength of steel plate welding, benefiting industrial applications. However, several research findings by other researchers have yet to focus on the combined parameters of welding direction with various current strength variations.

This study aims to assess the performance of rotatable inter-module connections with simplified structures through tensile and shear testing, as well as parametric analysis. Findings from the study [11] indicate that key components in the tensile connection are the corner fittings and the bottom plate, both of which are rotatable. It was found that increasing the thickness of the bottom plate has a positive impact on its load-bearing capacity. Meanwhile, in the shear performance context, the top plate of the bottom corner fitting emerges as a significant innovative focus in enhancing the overall load-bearing capacity of the connection. Additionally, the study notes the absence of emphasis on the use of welding direction model parameters with varying current strength to further explore connection performance. An additional exploratory goal is to enhance structural reliability and efficiency in inter-module connection innovation and design. Another study investigates the impact of multi-layer welding processes on lap joints of layered stainless steel plates. The main focus is to understand the factors affecting temperature distribution along the longitudinal, transverse, and thickness directions in all stages of the welding process without altering the welding direction. Observations focus on accurately varying temperatures using strategically placed thermocouple arrays on the plates. The analysis of collected temperature data, with particular emphasis on two aspects, longitudinal contraction and angular distortion resulting from heat flow effects during cooling processes. The measurement results show an angular distortion of 9.1° and a longitudinal contraction of 8 mm. The significance of this distortion lies in the residual stresses formed during the welding process, especially around the weld centerline. These findings provide insights into the complexity of deformation and residual stresses involved in the lap joints of layered stainless steel plates during multi-layer welding processes. Furthermore, according to [12], the technical challenges associated with these welding processes significantly contribute to the general understanding of the welding effects on layered stainless steel materials in the context of multi-layer welding. These insights have not fully examined the comparison of current strength usage and combined welding direction model parameters, but they can assist designers and industry practitioners in developing more effective welding strategies while minimizing adverse effects on structural and material performance.

This study demonstrates that the thickness of the base metal significantly affects the tensile strength of welded joints during the welding process. Thicker materials exhibit a stronger influence on tensile strength due to variations in heat dissipation, cooling rates, and grain structure changes during solidification. This emphasizes the crucial role of considering the thickness of the base metal in optimizing tensile strength during welding processes, offering valuable insights for welding practitioners and engineers in welding and structural design. This study explores various welding processes between austenitic stainless steel (AISI316) and low carbon steel (AISI1018) using $CO_2$ laser technology. The main focus of this study is on AISI316/AISI1018 joints, with welding speed identified as a critical parameter. Experiments were conducted with variations in laser power (2600 W) and welding speed (1.5 m/minute). The results show that a combination of high laser power and low welding speed produces superior mechanical properties, including full penetration in the welded joints. These findings significantly contribute to the understanding of laser welding processes in different material configurations, opening opportunities to enhance joint quality in austenitic stainless steel and low-carbon steel.

Another researcher conducted an analysis focusing on resistance spot welding (RSW) parameters involving weld geometry, mechanical properties, and SEM-EDS observations on two different materials, namely soft steel and stainless steel. Findings [13] revealed that the nugget diameter reached the highest value at 6.65 mm, while the highest shear tensile strength achieved was 7.66 kN. The most significant parameter affecting welding results is the current, contributing to 75.08 %. The importance of these findings is evident from an applicative standpoint, where optimizing RSW welding parameters can enhance the quality of welded joints between soft steel and stainless steel. These insights provide information in the form of welding procedures that enable welding engineers to produce more effective and high-quality welded joints, especially when dealing with various materials, as demonstrated in this study. Additionally, this study also explores the influence of welding current variations and welding direction models on the tensile strength of welded joints. By examining various combinations of welding current intensities and welding direction parameters, the results of this study serve as a comparative factor for the research object, providing insights into optimal settings to achieve maximum tensile strength in welded joints. Through experimental analysis, it is observed that some combinations of welding current intensities and welding direction models lead to an increase in tensile strength in welded joints, especially in joints with thicker base metals. This investigation emphasizes the importance of considering welding parameters comprehensively to improve the overall performance and reliability of welded joints.

Research on current variations and welding joint models by researchers [14] highlights methods and ways to improve the quality of welded joints. The results of tensile testing conducted showed that increasing current strength affects elongation percentage, with brittle cracking behavior at low currents and ductile cracking at high currents. Welding different metals between AISI 316 L and AISI 310S using tungsten gas processes affects mechanical properties and microstructure. A fracture during testing occurred on the AISI 316 L side due to alloy differences. Variations in current also affect dendrite size and unmixed zone, with XRD analysis confirming austenite as the dominant phase in welded joints. Another study examined how temperature variations induced by welding currents affect TIG welded joints in thin 304L austenitic stainless steel sheets. Mechanical properties vary with welding current, affecting temperature distribution and influencing the mechanical properties of the joints. Morphological analysis during tensile testing visually represents the impact of temperature variations on the failure of welded joints. An experimental study conducted by the researcher [15] investigated spot welding in Ti6Al4V titanium alloy sheets under varying parameters. Analysis of Variance obtained explores the parameter's impact on welding results, with the identification of significant parameters affecting joint strength. The highest strength is achieved under static and dynamic conditions in the control group.

Further research investigates the influence of welding parameters on welding quality, especially testing welding current, voltage, and welding speed [16]. Understanding parameter variations provides insight into optimizing welding conditions for desired results [17]. Similarly, another study focuses on the impact of welding current, voltage, and welding speed on the Heat Affected Zone during welding, aiming to improve joint quality [18]. Decreases in the strength and hardness of the base metal, especially in the Heat-Affected Zone, pose risks to steel frame joints [19]. Therefore, proper management of mechanical property changes is crucial to reduce the risk of damage [20]. Incompatibility between welded joints and base metals, along with imbalances in welding parameters, can further reduce strength and hardness [21]. Careful parameter control is required to maintain structural integrity. Increased input heat correlates positively with load-bearing capacity due to the formation of larger nuggets, increasing joint strength. According to researchers [22], the use of welding current and welding time variations has shown a proportional increase in nugget size and load-bearing capacity, emphasizing precise heat input control for optimized joint performance. These findings focus on tensile strength evaluation for practical applications in construction planning and material selection, ensuring structural integrity and reliability in real-world scenarios.

The previous research has outlined the utilization of welding current intensity and welding parameters; however, it has yet to explore simulations and combinations to enhance the tensile strength of joints. In this context, this study stands out by delving into simulations of varying welding current intensity (100, 120, 140, 160 A) and parameters of longitudinal, transverse, and combined (longitudinal+transverse) welding direction models on the tensile strength of welded steel plate joints. This marks a significant breakthrough that adds value by focusing on combinations of parameters not comprehensively explored previously. By offering fresh insights into the influence of these parameters on weld quality, this research serves as a strong foundation for optimizing the welding process more efficiently.

## 3. The aim and objectives of the study

This study aims to critically identify the parameters of the model type that influence the optimal and high-quality tensile strength of welded joints, aiming to enhance the effectiveness and reliability of the welding process in practical applications.

To achieve this aim, the following objectives are accomplished:

– to identify the influence of welding current strength variations on the tensile strength of welded joints for determining the optimal current strength;

– to identify the influence of parameters on various types of welding direction connections towards the optimal model of tensile strength in ST 42 steel;

– to identify the influence of welding connection parameters with variation in current strength on the material strength of ST 42 steel plates.

## 4. Materials and methods

The object of the study is the welding process.

The study hypothesis suggests the possibility to detect the optimal combination in welded joints that can produce a maximum tensile strength ratio.

The design of the tensile test specimens utilizes ST 42 steel plate material. The dimensions of each joint specimen are 90×120 mm and 60×120 mm, with a thickness of 6 mm for each plate of the joint specimens. The welding process is conducted manually using Shielded Metal Arc Welding (SMAW) with ESAB 601 electrodes. The tensile strength values of the joints under various current strengths and welding directions are obtained through digital testing using a Universal Testing Machine Controller.

The form and design of the longitudinal, transverse, and combined direction (longitudinal+transversal) connection system models are shown in Fig. 1.

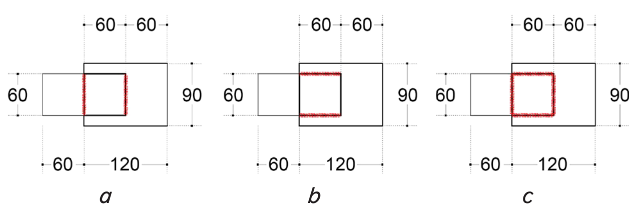


Fig. 1. Connection: *a* – transverse; *b* – longitudinal; *c* – combination (transverse+longitudinal)

In the utilization of connection systems in construction work, it is stated that the quality of welding will be influenced by the welding current strength and the parameters of the welding direction model. There are no significant external factors affecting the test results, such as temperature changes or other environmental conditions. Simplification is applied to the variations in welding current strength and welding direction models tested, with dimensions and thicknesses of the joint specimens ensuring consistency in testing and result analysis. The use of manual welding methods with ESAB 601 electrodes is employed to facilitate the implementation and consistency of the welding process. The tensile strength testing process will yield various conditions for each test specimen, ranging from proportional, fatigue, peak, to failure conditions, and will produce values of tensile strength, strain, elongation, time, and load from the conducted tensile strength tests. From these test results, the relationship between simulated variations in welding current strength and the parameters of welding direction types will be analyzed.

The increase in the tensile strength of welded joints can be achieved through variations in the welding current strength on steel plates. In this research, one of the methods used is the simulation of current variations (100, 120, 140, 160 A) with various types of welding directions to obtain the highest tensile strength from the appropriate model of current corresponding to the best welding direction parameter.

## 5. Results of tensile strength test results with variations in current strength from various parameters of welding direction joint models

### 5. 1. The influence of welding current strength variations on the tensile strength of welded joints for determining the optimal current strength

The tensile test results of the welded joint system with a current strength of 100 A show that the parameters of the welding direction type combination system (longitudinal+transverse) are joints that have a maximum tensile strength of 331.574 MPa compared with transverse direction type parameters of 311.852 MPa and longitudinal amount 169.444 MPa. Likewise, the results of tensile strength testing show that the stretch value with the ultimate combination connection of the welding direction type (longitudinal+transverse) is 44.642 % compared to the longitudinal direction of 24.334 % and transverse direction of 38.642 %. The phenomenon of the parameter system of directional type combination welded joints (longitudinal+transverse) is shown in the following graphic Fig. 2.

Based on the tensile strength test, a relationship between stress and strain in the welded joint was observed under a current strength of 100 A. In Fig. 2, the graph depicts the directed combined welding joint system (longitudinal+transverse), illustrating that under initial loading conditions, both stress and strain are zero. Subsequently, there is an increase in the strength resistance of the system along with a concurrent increase in strain towards the proportional limit to the ultimate point. Beyond the ultimate point, a phenomenon occurs where the system's strength drastically decreases with a slight increase in strain. Gradually, the strain conditions reach a maximum until reaching the break point, with a time duration of 41.140 seconds.

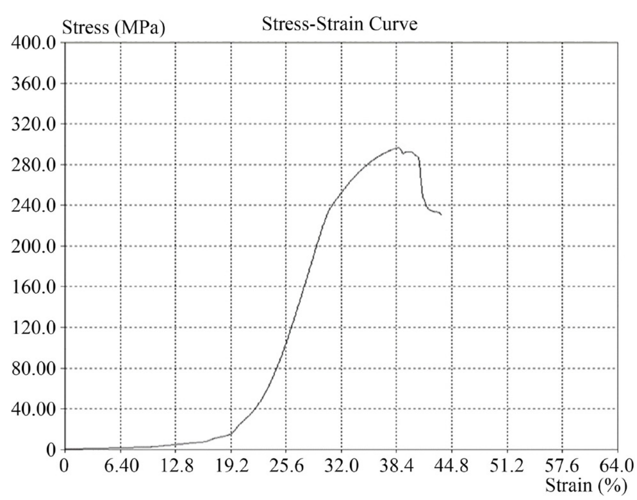


Fig. 2. Graph of the relationship between tensile strength and strain of combined directional welded joints (longitudinal+transverse) with a current strength of 100 A

The next test result, namely the welded joint system with a current strength of 120 A, shows that the parameters of the welding direction type combination system (longitudinal+transverse) are also joints that have a maximum tensile strength of 335.370 MPa, compared to transverse direction parameters of 302.037 MPa and longitudinal amounting 208.981 MPa. Likewise, the results of the joint tensile strength test show that the ultimate stretch value of the welding direction type combination joint (longitudinal+transverse) is 42.044 % compared to the longitudinal direction of 22.666 % and transverse direction of 30.510 %. The phenomenon of the parameter system of directional type combination welded joints (longitudinal+transverse) is shown in the following graphic Fig. 3.

Based on the tensile strength testing parameter system, a relationship between stress and strain in the welding direction joint at a current strength of 120 A is illustrated (Fig. 3), the graph depicts the combined directional welded joint system (longitudinal+transverse). Under initial conditions, both loading and stretching are zero. Subsequently, there is a gradual increase in the system's strength resistance offset by an augmented stretching towards the point proportional to the endpoint. Beyond the ultimate point, the strength condition of the system gently decreases with increasing stretching, eventually reaching the maximum stretching condition until it reaches the breaking point, with a time elapsed of 39.841 seconds.

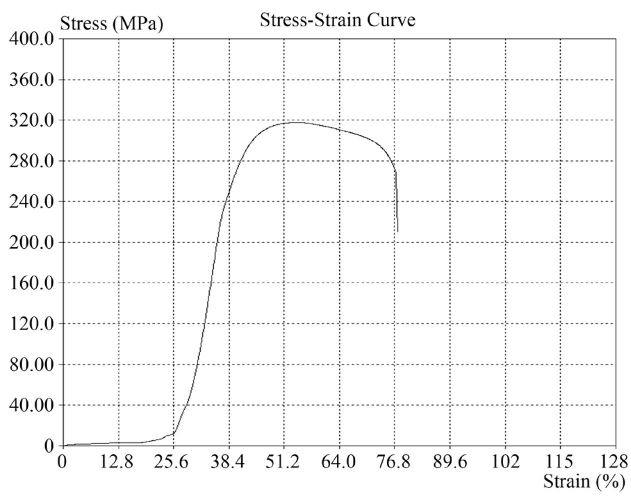


Fig. 3. Graph of the relationship between tensile strength and strain of the combined welded joint (longitudinal+transverse) with a current strength of 120 A

The next test result, namely the welded joint system with a current strength of 140 A, shows that the parameters of the welding direction type combination system (longitudinal+transverse) are also joints that have a maximum tensile strength of 332.315 MPa, compared to transverse direction type parameters of 280.741 MPa and longitudinal amount 246.111 MPa. Likewise, the results of tensile strength testing show that the maximum stretch value occurs in the combined connection of the welding direction type (longitudinal+transverse) of 40.038 % compared to the longitudinal direction of 28.264 % and transverse direction of 32.580 %. The phenomenon of the system of joint parameters of combination types of welding direction (longitudinal+transverse) is shown in the following graphic Fig. 4.

Based on the results of tensile strength testing, a relationship between stress and strain in the welding direction joint at a current strength of 140 A can be observed. This monitoring is illustrated in Fig. 4, which displays a system graph of a welding direction combination joint model (longitudinal+transverse). In the initial conditions, where there is no loading and stretching, there is a significant increase in the strength resistance of the system. This increase is offset by an increase in stretching towards a point proportional to the endpoint. After surpassing the endpoint, the strength state of the system drops dramatically with minimal increase in stretching. This process continues until it reaches the state of maximum stretching, causing it to reach the breaking point. The time taken to reach the breaking point was recorded at 42.639 seconds.

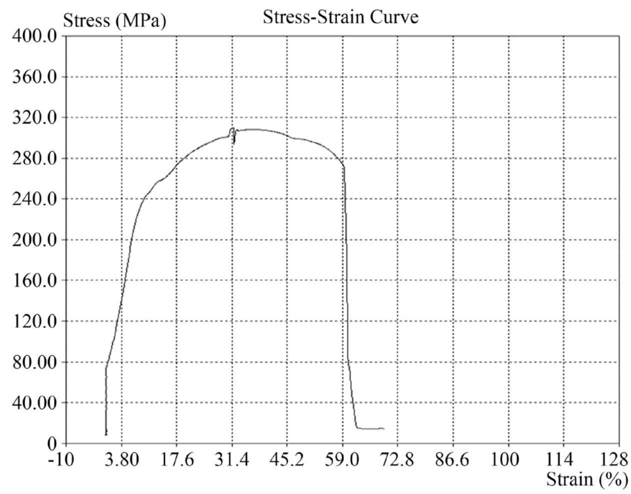


Fig. 4. Graph of the relationship between tensile strength and strain of combined directional welded joints (longitudinal+transverse) with a current strength of 140 A

The next test result, namely the welded joint system with a current strength of 160 A, shows that the parameters of the welding direction type combination system (longitudinal+transverse) are also joints that have a maximum tensile strength of the same 332.593 MPa, compared to transverse direction parameters of 210.000 MPa and longitudinal amount 220.926 MPa. Likewise, the results of the tensile strength test of the welded joint show that the maximum stretch value also occurs in the combined joint type of welding direction (longitudinal+transverse) of 43.280 % compared to the longitudinal direction of 23.100 % and transverse direction of 22.282 %. The phenomenon of the parameter system of directional type combination welded joints (longitudinal+transverse) is shown in the following graphic Fig. 5.

Based on the results of tensile tests with a current strength of 160 A, a clear relationship between stress and strain in the welding direction joint is illustrated. Fig. 5 analysis presents a graph of the connection system using a combined model of welding direction types (longitudinal+transverse). In the initial conditions without loads and strains, there is a significant increase in the system's strength resistance as strain gradually increases. This phenomenon persists until reaching both the proportional and endpoint. Beyond the endpoint, the system strength experiences a drastic decrease with minimal strain increment. Concurrently, the strain condition slowly approaches its maximum value, culminating in reaching the breaking point within a span of 30.950 seconds.

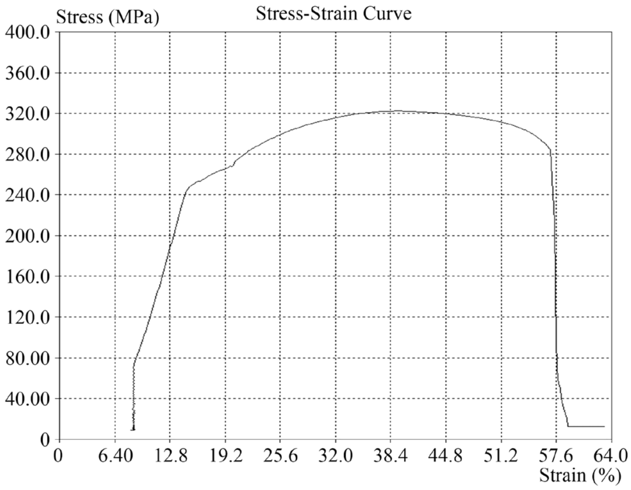


Fig. 5. Graph of the relationship between tensile strength and strain of combined welded joints (longitudinal+transverse) with current strength of 160 A

The results of strength current simulation tests across various models of welding direction connections suggest that a current strength of 120 A is the optimal choice for connections in different welding direction models on ST 42 steel material. This conclusion is reinforced by an analysis of the welding current variation graphs, revealing the consistency and compatibility of 120 A with the best performance across all tested conditions of welding direction connection models.

**5. 2. Analysis of the influence of parameters on various types of welding direction connections towards the optimal model of tensile strength in ST 42 steel**

In this study, various combinations of welding direction connections were assessed through a series of tests. The research findings indicate that the welding direction combination, particularly (longitudinal+transverse), yields satisfactory performance based on welding current strength simulations. Specifically, the maximum tensile strength values for the welding direction combination (longitudinal+transverse) were tested with simulated variations in welding current strengths of 100, 120, 140, and 160 A. Detailed values of the maximum tensile strength can be found in Table 1 below.

Based on the testing outcomes across various parameters of the combined welding direction connection model (longitudinal+transverse), it can be conclusively asserted that this model demonstrates superior performance among the diverse simulations of current strength variations.

Table 1

Test results of tensile strength of combination weld type joints (longitudinal+transverse)

| Current strength | Model | Time (t) | Load (kN) | Elongation (mm) | Stress (MPa) | Strain % |
|---|---|---|---|---|---|---|
| 100 A | Combination | 38.442 | 179.050 | 22.3210 | 331.574 | 44.642 |
| 120 A | Combination | 36.245 | 181.100 | 21.0220 | 335.370 | 42.044 |
| 140 A | Combination | 34.546 | 179.450 | 20.0190 | 332.315 | 40.038 |
| 160 A | Combination | 25.255 | 179.650 | 21.6400 | 332.685 | 43.280 |

The comprehensive series of simulations involving varied welding current strengths on ST 42 steel plate material unequivocally affirms that alterations in the parameters of the combined welding direction connection significantly impact the attainment of maximum tensile strength in this particular material. Therefore, the combined welding direction connection model (longitudinal+transverse) stands out as the optimal combination model, substantiated by the meticulous and trustworthy results derived from the simulation tests.

**5. 3. The influence of welding connection parameters with variation in current strength on the material strength of ST 42 steel plates**

Efforts to increase the strength of the welded joint system from various parameters of the type of connection model to simulate variations in the strength of the current given to affect the tensile strength value of the connection system. Results of tensile strength testing of welded joints against simulations of variations in the strength of a given current (100, 120, 140, 160 A). The results of the tensile strength test in Table 2 show that the addition of the current strength of each welded joint increases tensile strength, in both types of transverse direction, longitudinal direction, and combination (longitudinal+transverse) connections. The highest tensile strength of welded joints at each current strength is a combination of types of welding directions (longitudinal+transverse), namely current strength of 100 A with a maximum tensile strength value of 331.574 MPa, 120 A with 335.370 MPa, 140 A with 332.222 MPa and 160 A with 332.593 MPa.

Table 2

Tensile strength test results of welded joint current strength variations

| Current strength | Model | Time (t) | Load (kN) | Elongation (mm) | Stress (MPa) | Strain % |
|---|---|---|---|---|---|---|
| 100 A | Longitudinal | 21.059 | 91.500 | 12.1670 | 169.444 | 24.334 |
| | Transverse | 33.248 | 168.400 | 19.3210 | 311.852 | 38.642 |
| | Combination | 38.442 | 179.050 | 22.3210 | 331.574 | 44.642 |
| 120 A | Longitudinal | 22.159 | 112.850 | 12.8330 | 208.981 | 25.666 |
| | Transverse | 26.354 | 163.100 | 15.2550 | 302.037 | 30.510 |
| | Combination | 36.245 | 181.100 | 21.0220 | 335.370 | 42.044 |
| 140 A | Longitudinal | 24.456 | 132.900 | 14.1320 | 246.111 | 28.264 |
| | Transverse | 28.152 | 151.600 | 16.2900 | 280.741 | 32.580 |
| | Combination | 34.546 | 179.450 | 20.0190 | 332.315 | 40.038 |
| 160 A | Longitudinal | 20.06 | 119.300 | 11.5500 | 220.926 | 23.100 |
| | Transverse | 19.361 | 113.400 | 11.1410 | 210.000 | 22.282 |
| | Combination | 25.255 | 179.650 | 21.6400 | 332.685 | 43.280 |

When evaluating the values in Table 2, it is evident that there is an intriguing pattern regarding the influence of welding current intensity on the tensile strength and deformation of weld joints. There is a consistent increase in tensile strength with the escalation of welding current intensity from 100 to 160 A. Tensile testing results also demonstrate a comparison among the longitudinal, transversal, and combined welding direction model configurations. The combined welding direction model (longitudinal+transverse) generally yields the highest tensile strength across all tested welding current intensities and represents superior joint strength compared to welding with a single direction. Although tensile strength increases with the rise in welding current intensity, deformation also tends to increase. This suggests that the augmentation of welding current intensity can escalate deformation in weld joints, which necessitates consideration in practical applications.

The research findings indicate that an increase in current strength, coupled with directional welding variations, significantly affects the changes in tensile strength, strain, elongation, and time. Specifically, in the joint parameter displaying a combination of longitudinal and transverse directions at a current strength of 100 A, the maximum tensile strength reaches 331.574 MPa with a strain of 44.642 % and an elongation of 22.3210 mm within 12.1670 seconds. At a current strength of 120 A, the maximum tensile strength reaches 335.370 MPa with a strain of 42.044 % and an elongation of 21.0220 mm within 36.245 seconds. For a current strength of 140 A, the maximum tensile strength reaches 332.315 MPa with a strain of 40.856 % and an elongation of 20.0190 mm within 34.546 seconds, while at a current strength of 160 A, the maximum tensile strength reaches 332.685 MPa with a strain of 43.970 % and an elongation of 21.6400 mm within 25.255 seconds. These findings provide a comprehensive overview of the impact of current strength variations and welding directions on the mechanical properties of joints, revealing the values of maximum tensile strength and strain. Meanwhile, a previous study, reported that the mechanical properties, especially the maximum tensile strength, reached 43.802 MPa with a fracture strain of 4.833 %. This information originated from simulations involving variations in current strength (65, 70, 75, 80 A) in a joint system using welding processes with ST 42 steel, contributing to a deeper understanding of mechanical characteristics in a similar experimental context.

The phenomenon that occurs in tensile strength testing for welded joint systems with longitudinal direction, transverse type parameters, and a combination of direction type parameters (longitudinal+transverse) shows that for longitudinal directional welded joints there is damage to the welding joint area and for transverse direction connection types and directional type combinations (longitudinal+transverse), deformation of the parent plate until it reaches the breaking point. Based on the findings of this study, it is concluded that simulating a welding current strength of 120 A with a combination of longitudinal and transverse welding directions produces the most optimal welding quality for ST 42 steel plates. Tensile test results indicate that this welding current strength significantly influences the mechanical performance of the joints, enhancing structural aspects and making it the best option for achieving maximum welding quality in the specified welding direction model.

## 6. Discussion on the effect of welding current variations and connection direction models on the tensile strength of ST 42 steel joints

The experimental results encompass the impact of current variations on the tensile strength of the joint, a comparative analysis of various welding direction joint models, as well as a significant contribution to the tensile strength of ST 42 steel joints, with practical implications in the field of joint design. Variations in welding current and the comparison of welding direction joint models have a substantial effect on tensile strength. In detail, Table 2 presents experimental results indicating that the combination of models of various welding direction joints, with variations in current strength, produces the highest tensile strength compared to one-way models alone. The test results reveal that the parameters of the directional combination connection model (longitudinal+transverse) with a current strength of 120 A yield a maximum tensile strength of 335.370 MPa, making it the best connection model.

According to the researchers [10], experiments involving two types of current strength variations (80, 100 A), with GTAW and ER308L electrode types on SUS 304 stainless plate and SS 400 steel plate materials, showed that the highest joint tensile strength was achieved in specimens with a welding current of 100 A (25.59 kgf/mm$^2$), compared to a welding current of 80 A (16.17 kgf/mm$^2$).

As illustrated in Fig. 2, the highest tensile strength is achieved due to the model system incorporating a combination of the welding direction joint type and adjustments of various current strengths. Welding parameters that affect the speed of tensile welded joints are current, time, and electrical determination. This phenomenon aligns with the results of previous studies [14], concluding that variations in welding current strength have an effect on changes in tensile fracture behavior, resulting in increased joint strength. Increased tensile strength and elongation are observed with increased current strength. Additionally, findings from [15] state that the application of experimental design techniques, combining static and dynamic loading conditions through parameter optimization using spot welding with key control factors, leads to the highest combination of weld joint strengths.

Structural failure of welding joints occurs due to the low tensile strength of the joints in response to loads, mainly because the connection process involves only a single welding direction model. To achieve the study's objective of determining the best and satisfactory type of welding direction joint model, the formulation of the welding direction joint combination model was executed, as depicted in Fig. 1, *c* and detailed in Table 1, highlighting the highest joint tensile strength.

One limitation of this study is the absence of an analysis of the influence of heat on the joint material undergoing the welding process through metallographic tests, and the limited combination connection models performed. Acknowledging these limitations and shortcomings makes the research more transparent, enabling readers to assess the applicability of findings in a broader context. The authors recommend that future research should address these limitations and strive to increase the complexity of connection simulation models.

This research also necessitates further development to deepen understanding and relevance by emphasizing aspects such as material variability, simulation models, microstructure analysis, mechanical properties, and the influence of operator skills, along with a more comprehensive exploration of environmental factors. Progress in these aspects will enhance the accuracy, validity, and relevance of research results, contributing more to practical and theoretical understanding in the context of forces, models, and welding currents.

## 7. Conclusions

1. The research findings demonstrate a significant positive correlation between welding current intensity and tensile strength of weld joints. Although an increase in welding current intensity tends to enhance the tensile strength, this relationship

is not linear. For instance, in the combined welding direction model parameter, there is an increase in tensile strength from 331.574 MPa at 100 A to 335.370 MPa at 120 A. However, the tensile strength slightly decreases at 140 A (332.315 MPa), before increasing again at 160 A (332.685 MPa).

2. Comparison of the welding direction model parameters indicates that the combination of longitudinal and transverse welding directions tends to yield the highest tensile strength compared to either transverse or longitudinal welding directions individually. For example, at a current intensity of 120 A, the tensile strength for the combined welding direction reaches 335.370 MPa, whereas for longitudinal welding direction, it only reaches 208.981 MPa, and for transverse welding direction, it reaches 302.037 MPa.

3. Overall, this research recommends the use of a combined welding direction model (longitudinal+transverse) with a welding current intensity of 120 A for welding joints. These findings provide deep insights into the factors influencing the mechanical properties of weld joints, particularly welding current intensity and welding direction. This analysis holds significant relevance in the context of construction applications and the development of welding techniques to enhance the quality of weld joints and overall structural integrity.

**Conflict of interest**

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

**Financing**

The study was performed without financial support.

**Data availability**

The manuscript has data included as electronic supplementary material.

**Use of artificial intelligence**

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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