VOL. 18, NO. 23, DECEMBER 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

SIMULATION OF STRONG VARIATIONS OF WELDING CURRENT AGAINST INCREASED TENSILE STRENGTH OF BOLT AND WELD JOINTS

Saripuddin M.[1], Ahmad Syarief[2], Ahmad Hanafie[3] and Suradi[3]
[1]Mechanical Engineering Study Program, Universitas Islam Makassar, Indonesia
[2]Civil Engineering Study Program, Universitas Halu Oleo Kendari, Indonesia
[3]Industrial Engineering Study Program, Universitas Islam Makassar, Indonesia
E-Mail: saripuddinmuddin@uim-makassar.ac.id

ABSTRACT

This study aims to analyze the simulation of welded current variations (100, 120, 140, and 160) Amperes at the combined combination of longitudinal, transverse, and combination (longitudinal-transverse) welds combined with the position of 4 square model bolts against an increase in plate tensile strength. The tensile testing process of welded and bolted combination joint specimens results in a ratio of tensile strength, loading, and elongation when the condition is proportional until the test specimen breaks. The results of tensile testing show that the simulation of variations in weld current given to the joint affects changes in loading, elongation, and tensile strength ratio. The position of the weld current of 140 Amperes at the combined welded direction (longitudinal-transverse) joint of the combination of 4 bolts of the square model has a maximum tensile strength of 347.222 MPa and a maximum strain of 58.758 % within 25.176 seconds. Results the combination join model is the best combination join of tensile test results. This research is expected to provide new insights into the use of current types and welding directions in welded and bolted combination connection systems in industries engaged in connection construction.

Keywords: simulation, welding current strong, tensile strength, weld-bolt combination joints.

Manuscript Received 2 June 2023; Revised 16 January 2024; Published 10 February 2024

1. INTRODUCTION

The strength of the combination of welded joints and bolts is an integral part of the construction, especially the use of joints in the shipping industry, bridges, building frames, and the automotive industry. [1] The mechanical behavior of the joint combination of bolts and welds causes an increase in strength compared to welded joints and bolts because it is influenced by the combination of bolts and welds and the final carrying capacity of welding with high-strength fastening of the bolts. [2] Stated that the experimental verification results of the combination behavior of high-strength bolts of 1400 MPa with the orientation of fillet welds used in the connection of the 570 MPa steel plate became a determining factor for safety in a joint construction design. [3] Based on the test results and the deformation relationship of the bolt analytical load with the estimated weld fracture, the new strength predicts the available test results more consistently. In bolt combination connection by longitudinal welding, the bolt contributes 80% of the final strength of the bolt joint, and when the transverse welding process occurs, 40% of the final strength of the bolt joint, while for the bolt-welded 3-sided combination joint, 90% of the final strength of each component as the nominal strength of the combination. This is a formula that can predict the overall test results. [4] Based on the investigation of the fatigue behavior of bolt joints occurs at the joints of the end plates with prestressed bolts, and for s welds joints occur in the weld area with full penetration of the area of tensile strength. [5] The results of the analysis show that to reduce joint fatigue in receiving loads, it is necessary to design the construction of joint joints of a combination of bolts and welds. The new shape of the bolt connection with the welded cover plate for modular steel constructions (MSC) through the results of joint testing of a hollow structural section (HSS) shows, that all specimens under monotonous load can develop the full plastic strength of the twin beams having an individual bending behavior. The application of seismic joint design shows the deformation capacity and ductility adopted to evaluate the characteristics of the stiffness joint that produced a "Semirigid" joint. [6] The research process showed that T-stubs are not stiffened with thin plates and large bolts, The distance from the T-stub rod to the bolt row affects the ductility and very high plastic capacity. The results of this study show that an increase in bolt diameter and weld thickness results in an increase in plastic capacity.

The connection usage is expressed by, [7] that bolted joints are widely used to connect safety critical parts in the shipping industry, aviation, building construction, bridges, and automotive construction that require proper structural assessment tools, particularly in the determination of bolted joint pressure. [8] The factors affecting the carrying capacity of the joint are the angle of the fitting and the lower plate of the rotating part so that an increase in the thickness of the lower corner upper plate on the rotating part is carried out. [9] An experimental study showed that within moderate limits, greater end plate thickness and stronger bolts can lead to better joint performance. The moment resistance capacity should be carried out further by surface treatment of stainless steel as a consideration to guarantee the friction grip of the joint so that it can be used in seismic design and can exploit the high degree of ductility and strain hardening of stainless steel. [10] This study specifically analyzes the redistribution of interface friction in sliding bolt steel joints, showing that the increase in temperature and bolt connection points affects the friction redistribution so that there is an increase in friction between faces at the bolt fracture joints. [11] The results of the analysis and experimental study of the LY315 steel moment bolt joint cover plate show that the larger load carrying capacity and initial rigidity have a stable energy dissipation capacity significantly increase the connection load carrying capacity, and effectively lower the shear deformation of the bolted joint cover plate areas. [12] This experimental study investigated the tensile behavior of T-stub joints on rigid bolts with different parameters, resulting in the distribution pattern of the yield line along the center of the bolt hole changing with the increase in the thickness of the rigid T-stub and the pitch of the longitudinal bolt affects the strength of the highest joint that is not monotonous. The simulation results show that an increase in the thickness ratio between the vertical plate and the horizontal plate can increase the final strength of the connection. [13] This study presents friction-type high-strength bolt T-stub joints focusing on structural behavior under shear and tensile forces. The test results show that the friction coefficient and shear-compression ratio have a great impact on the friction type high-strength bolt loading system.

The technique of multi-pass welding is stated by, [14] About the investigation of the design results of welded joints subjected to longitudinal shrinkage and angular distortion by the effects of hot flux during the welding process, and tensile test results showed that the mechanical tensile strength of the welded joint was higher than that of the tensile strength of the parent metal. [15] The results showed that the process of welding V shape base metal grooves affects higher tensile strength compared to X-shape base metal groove welding using the Taguchi design method. [16] Other studies have shown that the thickness of the base metal has the most effect on increasing the tensile strength of joints undergoing the welding process. In this study, [17] Stating that the use of laser oscillation mode for ultra-high strength steel to obtain quality welded joints, the test results showed that the tensile strength of welded joints with circular, transverse, and longitudinal oscillation modes is higher compared to without oscillation mode. [18] Presenting an experimental investigation of the structural response of high-strength welded joints of S690 steel from various cyclic loading conditions, the results showed a significant decrease in strength in the parts of the joints that were not given the welding process, while the joints undergoing the welding process experienced an increase in the number of cycles, as well as the importance of conducting realistic cyclic tests to assess ductility.

Developed analytics model, [19] to evaluate the elastic interaction of bolt flange joints with multiple Pass Tightening strategies, showing that elasticity interactions have a significant effect on the joint strength of bolt stress variations by optimizing bolt joint tightening strategies. [20] Presenting the results of one- and two-bolt joint tests in investigating the behavior of the plates shows that the strength of the bolted joints on the plate is affected by the number of inner bolts installed. Results of experimental tests and analysis of finite elements [21] indicate that frictional force due to slip-critical joint pre-tightening force can have a significant effect on the capacity response and fracture behavior of gusset plates under tensile stress loading with shear block fractures. [22] Presents an experimental investigation into the cyclic behavior of block-to-column cold-formed steel (CFS) moment-resisting (MR) joints using a friction-slip mechanism in bolt web connection settings, indicates that all SC specimens meet the Special Moment Frames (SMF) requirements specified in the AISC Seismic Terms, while SRC specimens with a beam thickness of 2 mm undergo a sharp degradation of strength due to premature web local buckles. Experimental investigation of the carrying capacity of high-strength bolted joints with loose bolts by, [23] Showing that bolt fracture is the only failure mode for all joints tested under uniaxial tension and joints at different tightening conditions incites a similar trend under strain conditions around the bolt hole. It is also found that the yield load of high-strength bolt joints can be affected by the pretension force and slip coefficient, while the effect of the slip coefficient gradually decreases with an increasing number of loose bolts.

To find out which combination joints of welds and bolts are effective in use in steel joint construction, a strong simulation of welding currents at the combined joints is necessary for several reasons. One of them is that this study has never been tested by other researchers. Increased strength of the welded joint can be obtained through the variation of the welding current strength at the steel plate joint. One of the methods in combination joint research is to obtain a suitable current strength model in the best combination of welded joints and bolts according to the accepted load where the load requirements on existing bolted joints may change over time, so the joints may require repair. If the geometry does not allow the addition of more bolts, welding can be added to the joint to increase the capacity. In this case, the variations offered are (100, 120, 140, 160) amperes in increasing the tensile strength of the combination of joint variations in welding direction and 4 bolts of square models.

Therefore, this variation became the basis for research to experiment with new welding simulations using different current strengths in the combined joints of bolts and welds. This study aims to determine the influence of simulating current strength of 100, 120, 140, and 160 Amperes to determine the effect and change in tensile strength of the combination of welded joints and bolts. In addition, this study determined the formulation of a combination of bolt and weld joint system model with variations in the strength of the weld current to the strength of the plate joint. This research is expected to contribute to increasing knowledge about the steel industry, especially in joint construction, both joints, welds, bolts, and combinations of welds and bolts. This

ARPN Journal of Engineering and Applied Sciences

combination joint design can be used to build bridges, ships, and building structures.

2. METHOD

The method used in this study is experimental research and literature review of the influence of various models of welding current strong simulation (100; 120; 140; 160) Amperes with a combination of positions of 4 square model bolts in strengthening the strength system of the joint combination of bolts and welds. The research stage is carried out by making a test specimen for a square-shaped bolt joint position model, and the direction of the type of welding carried out is the longitudinal, transverse direction and the combination of welding directions (longitudinal-transverse) and then tensile testing is carried out. The design of the tensile strength test specimen uses steel plate material, the bolts used are M13 bolts with a tensile strength; of 932.398 MPa. The dimensions of each joint specimen are; 90 x 150 mm, and 60 x150 mm, the thickness of each joint specimen plate is 6 mm each, manual welding process with SMAW using ESAB 601 electrodes. Each joint specimen is welded with varying current strengths and combined with a square model 4-bolt joint which is further locked using 25 Nm of torque.

From the tensile test results, each specimen is compared and analyzed based on research preparation to find the best combination and connection configuration.

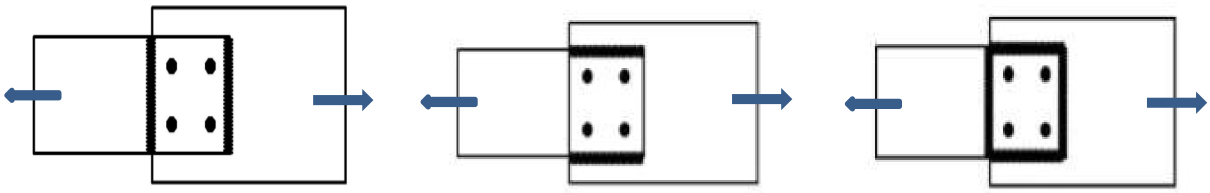


Figure-1. Connection; A). Transverse - bolt, B). Longitudinal - Bolt, C). Combination of welds - odors.

The joint tensile strength testing process shows several conditions for each test specimen, ranging from proportional, yielding, ultimate, and breaking conditions, and produces tensile strength, strain, elongation, time, and load values from the tests performed. From the results of this test, the influence of the relationship between the simulation of current strength variation and welding direction was analyzed with the position of the connection of 4 bolts of the square model. This tensile strength test is to produce the best combination joint model and become a reference for industries engaged in joint construction.

The quality of the welding results is influenced by thermal energy, which means that it is influenced by three parameters, namely welding current (I), voltage (R), and welding speed (V). The relationship between the three parameters produces welding energy, often called heat input. The welding current in the connection system will affect the HAZ area. Therefore, it can lead to a decrease in the strength and hardness of the base metal. Decreased strength and hardness can damage the steel frame connection area (HAZ). This may occur when the welded joint is incompatible with the metal material. Heat input is the relationship between three parameters that produce welding energy. The variety of heat input used in the welding process can also increase the strength of the connection. To calculate the heat input using the formula:

$$\text{HI(Heat Input)} = \frac{\text{Welding Stress (E) x Welding curren (I)}}{\text{welding speed (V)}} \quad \text{............... (1)}$$

The tensile test specimen of the welded and bolted combination joint, will gradually undergo tensile loading (F), the change in the length (ΔL) of the joint plate increases, with the initial cross-sectional area (Ao), then the stress (σ) and strain (ε) can be calculated using the following equation;

$$\sigma = \frac{F}{Ao} \quad \text{............. (2)}$$

$$\varepsilon = \frac{\Delta L}{Lo} \, x \; 100 \,\% \quad \text{............... (3)}$$

Note that it could be considered that the elastic limit and the proportionality limit are not different. In the static testing process where the load acting on the test rod is continued until it is outside the elastic limit there will be a sudden permanent extension of a test rod, this is called the Yield point, where the strain increases even if there is no increase in voltage At this point the working load is F_y, so that there is an increase in voltage by:

$$\sigma_y = \frac{F_y}{A_0} \quad \text{.................................. (4)}$$

With:

σ_y = Yield power (N/mm^2)
F_y = Melting load (N)
A_0 = Cross-sectional area (mm^2)

The maximum nominal voltage held by the test rod before breaking is called the maximum tensile stress which is the ratio between the maximum load and the first cross section. Pada titik ini tegangan yang terjadi besar.

$$\sigma_u = \frac{F_u}{A_0} \quad \text{............................(5)}$$

With:

σ_u = Maximum tensile strength (N/mm^2)

ARPN Journal of Engineering and Applied Sciences

F_u = Maximum load (N)
A_0 = Cross-sectional area (mm^2)

Welded joints are fixed joints, which can produce large joint strength. As for the calculation of weld strength can be obtained through:

The weldability strength of the transverse joint consists of:

Single fillet:

$$F = \frac{t\ x\ L}{\sqrt{2}} x\ \bar{\sigma}_t = 0{,}707\ x\ t\ x\ L\ x\ \bar{\sigma}_t \quad \ldots\ldots\ldots\ldots (6)$$

Double fillet;

$$F = 2\ \frac{t\ x\ L\prime}{\sqrt{2}} x\ \bar{\sigma}_t = 1{,}414\ x\ t\ x\ L\ x\ \bar{\sigma}_t \quad \ldots\ldots\ldots (7)$$

Where:
t = Weld thickness (mm)
L = Weld length (mm)
F = Pulling force (N)
$\bar{\sigma}_t$ = Tensile stress of the weld (N/mm^2)

The weldability of parallel (Longitudinal) joints consists of:
Maximum shear force of single parallel fillet:

$$F_s = \frac{t\ x\ L}{\sqrt{2}} x\ \bar{\tau} = 0{,}707\ x\ t\ x\ L\ x\ \bar{\tau} \quad \ldots\ldots\ldots\ldots (8)$$

Maximum shear force double parallel fillet:

$$F_s = 2\ \frac{t\ x\ L}{\sqrt{2}} x\ \bar{\tau} = 1{,}414\ x\ t\ x\ L\ x \quad \ldots\ldots\ldots\ldots (9)$$

Where:
F_s = Maximum Shear Force (N)
$\bar{\tau}$ = Shear stress of the weld (N/mm^2)

The optimal strength of the welded joint is largely determined by the direction of welding and the use of the appropriate current. The strength of the bolt joint is determined by the bolt position model given in the connection process. This combination joint can be compared with the strength of bolted or welded joints alone using tensile strength testing. Bolts and welds can be combined in situations where metal joints can be subjected to simultaneously shear and tensile loads. The difference in mechanical properties between bolts and welded joints allows for a combination of bolts and welds in metal joints, of course, with designs that consider shear stress. The bearing capacity of the bolt also needs to be considered to determine the strength of the bolt joint.

3. RESULT AND DISCUSSIONS

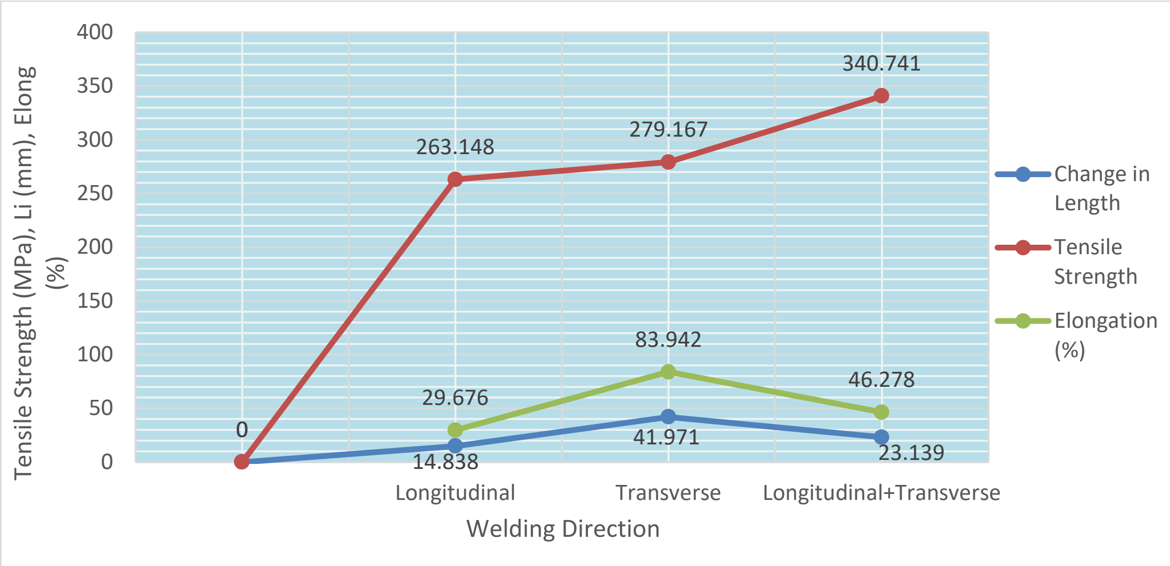
The tensile strength test results of the combination of welded joint systems and bolts with 4 bolts installed at current strength variations of 100, 120, 140, and 160 Amperes are described in the table below;

Table-1. Tensile Test Result.

Welding current	Welding direction	Time (t)	Load(kN)	Change in Length (mm)	Tensile Strength (MPa)	Elongation (%)
100 A	Longitudinal	44.836	142.100	14.838	263.149	29.676
	Transverse	126.256	150.750	41.971	279.167	83.942
	Long+Transverse	69.812	184.000	23.139	340.741	46.278
120 A	Longitudinal	25.755	151.850	14.766	281.204	29.532
	Transverse	39.142	182.300	22.706	337.593	45.412
	Long+Transverse	47.933	162.600	23.998	301.111	47.996
140 A	Longitudinal	35.345	150.900	20.420	279.444	40.840
	Transversal	43.536	166.800	25.176	308.889	50.352
	Long+Transverse	58.623	187.500	29.379	347.222	58.758
160 A	Longitudinal	34.746	134.750	20.043	249.537	40.086
	Transverse	44.337	167.550	25.746	310.278	51.492
	Long+Transverse	52.629	171.550	26.331	317.685	52.662

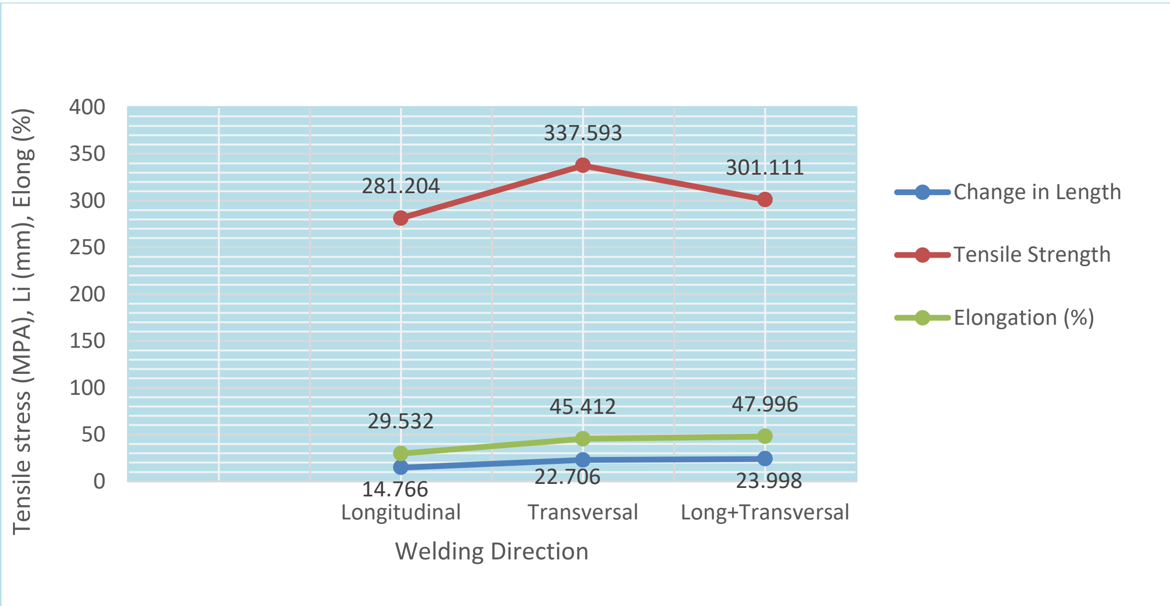
The above data is the strength of the connection of 4 square model-shaped bolts of longitudinal, transverse, and combined welding direction types (Longitudinal + Transverse) at a given welding current strength of 100 Ampere. The test results showed that the combined connection system has a maximum tensile strength of 340.741 MPa compared to the longitudinal and transverse directional connection systems. The combined joint test also produced a maximum load of 184.000 kN, with an elongation of 23.139 mm in time, 69.812 seconds, and resulted in a maximum strain of 46.278%. The test result data is shown in the following graphic figure:

ARPN Journal of Engineering and Applied Sciences



Graph-1. Welding direction combination connection graph with the position of four bolts of square shape with strong current Welding 100 Amperes

Graph-1 shows that elongation and stretching increase starting from the shape of the longitudinal, transverse welding direction and decreasing again at the condition of the combination of directions (longitudinal + transverse) joint. This test shows the maximum tensile strength under Longitudinal direction joint conditions of 263.148 MPa, Transverse of; 279.167 MPa, and under directional combination connection conditions (Longitudinal + Transverse) has a maximum tensile strength value of; 340.741 MPa which is the best connection type for strong current 100 Amperes. Testing of the maximum tensile strength of the joint followed by a current strength of 120 Amperes showed that the combination of transverse directional joints had the highest maximum tensile strength value of; 337,593 MPa, at loads of; 182,300 kN and a maximum strain of; 45.412 % with a extension occurring of; 22.706 mm, compared to longitudinal directional joint and directional combination (transverse + longitudinal). The test results can be shown in the following graph:



Graph-2. Welding direction combination joint graph with the position of four bolts of square shape with strong current Welding 120 Amperes.

The graph shows that the increase in elongation and stretching starts from the shape of the directions Longitudinal, transverse, and a combination of directions (longitudinal + Transverse). Tensile strength testing shows an increase in the maximum strength value of the longitudinal direction of; 281.204 MPa to form a

ARPN Journal of Engineering and Applied Sciences

transverse direction system of; 337.593 MPa and the combined form of directional welding (longitudinal + transverse) decreased with a maximum strength value of n of; 301.111 MPa.

Furthermore, tests were carried out on 4-bolt combination joints of square models with various types of welding directions at a current strength of 140 Amperes, showing that the combination joints of welding directions (Longitudinal + Transversal) showed the highest maximum tensile strength with values of; 347.222 MPa, at stretch with a value of; 58.758 % and an elongation of; 29.379 mm at a load of; 187.500 kN in 58.623 seconds. This can be compared with the test results on strong weld currents (100 and 120) Amperes, which have the highest maximum strength lower than the welding current strength of 140 Amperes. The test results are shown in the following graph:

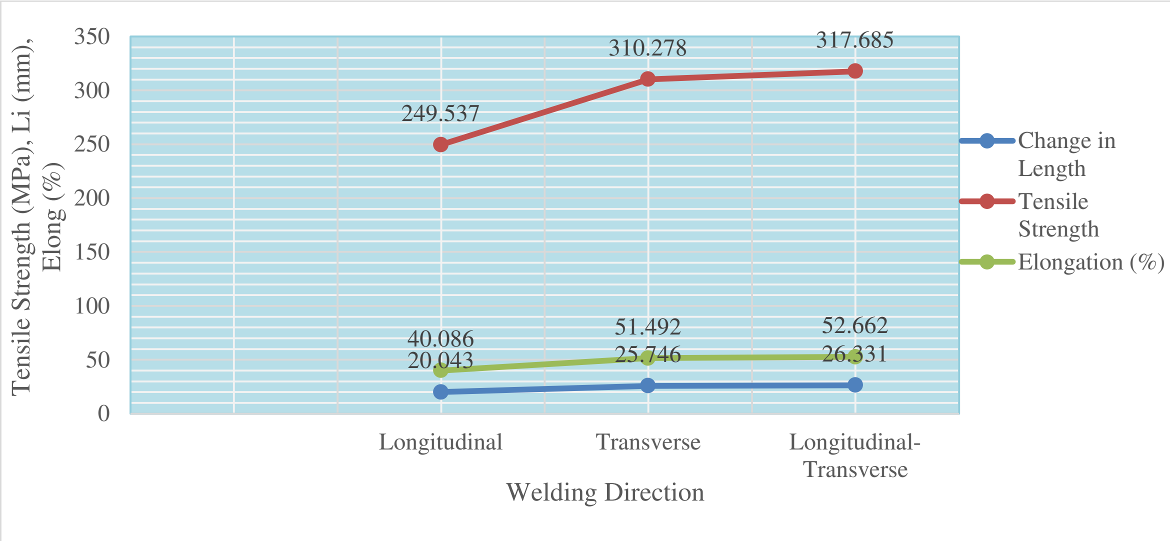
Graph-3. Welding direction combination connection graph with the position of four bolts of square shape with strong current Welding 140 Amperes.

The graphic figure shows that both lengthening, stretching, and maximum strength have increased respectively starting from the shape of the welding direction longitudinal, transverse, combination of directions (Longitudinal + Transverse), namely (20.42; 25.176; 29.379) mm, the stretch value is also equal to (40.84; 50.352; 58.758) %. The test also showed an increase in the maximum strength value starting from the longitudinal direction of; 279,444 MPa to form a transverse direction system of; 308.889 MPa and a combination of directional welding forms (transverse + longitudinal) with a maximum strength value of; 347.222 MPa, which is the highest maximum tensile strength of the test result.

The results of the welding direction combination test with a 4-bolt square model against a current strength of 160 Amperes show that the combination welding direction joint (longitudinal + transverse) shows the highest maximum strength with a value of; 317.685 MPa, with a stretch of value of; 52.662 % and an extension of; 26.331 mm at 171.550 kN load in 52.629 seconds. It can be compared with the results of joint testing on longitudinal and Transversal direction welding, which has a lower maximum strength than the form of the combined welding direction system (Longitudinal + Transverse). In detail, the test results are shown in the following graph:

VOL. 18, NO. 23, DECEMBER 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

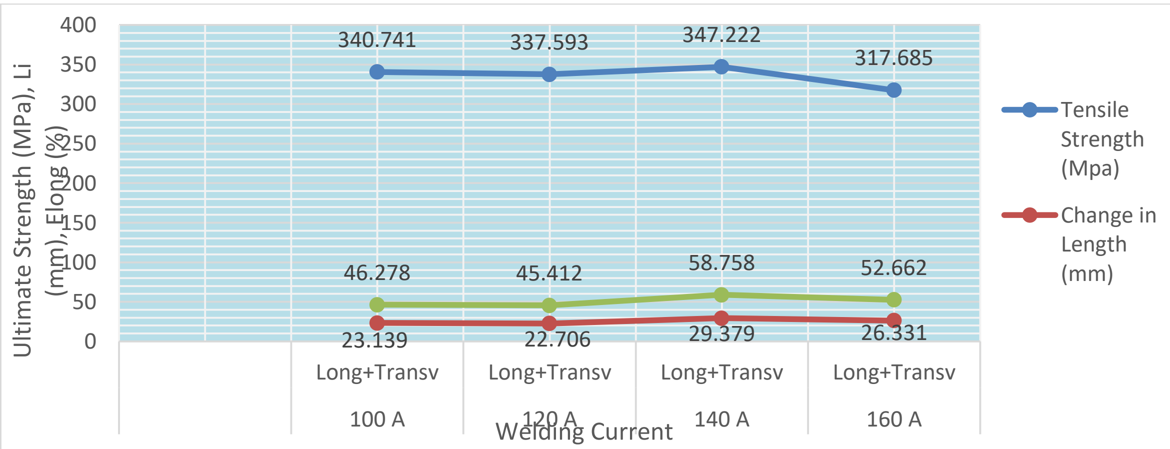
www.arpnjournals.com



Graph-4. Welding direction combination connection graph with the position of four bolts of square shape with strong current Welding 160 Amperes.

The graphic image shows that in both elongations, stretching, and maximum strength, each of them has increased, ranging from the shape of the welding direction Longitudinal, transverse, combination (longitudinal + transverse), namely (20.043; 25.746; 26.331) mm. The stretching conditions are also the same with values (40.086; 51,492; 52.662) % as well as the highest increase in maximum strength values at longitudinal directional joints of; 249.537 MPa to form a Transverse directional system of; 310.278 MPa and form a combination welding directional (longitudinal + transverse) with a maximum tensile strength value of; 317.685 MPa. In the welding direction process with a current strength of 160 Amperes, there is a decrease in the maximum tensile strength value compared to the current strength of 140 Amperes.

Hasil pengujian kekuatan tarik maksimum pada simulasi variasi kuat arus las terhadap kekuatan sambungan kombinasi las dengan 4 baut model persegi pada tabel 1, menunjukkan bahwa kekuatan sambungan kombinasi maksimun tertinggi pada kuat arus las 140 Ampere dengan arah las (Longitudinal + Transversal) menghasilkan nilai kekuatan maksimum tertinggi sebesar; 347.222 Mpa. Hal ini dapat dibandingkan dengan simulasi kuat arus las 100 Ampere, 120 Ampere, dan 160 Ampere. Secara rinci, hasil pengujian setiap arus pengelasan terhadap sambungan kombinasi las dengan 4 baut ditunjukkan pada grafik berikut:



Graph-5. Welding direction combination connection graph with the position of 4 square shape bolts against the variation in welding current strength (100; 120; 140;160) Amperes.

In the graph of the connection of the combination of welding directions with the position of 4 bolts of the square model to the strength of the welding current of 140 Amperes, shows that the highest maximum value of extension that occurs in the strength test of the combination of joints in the welding direction (Longitudinal + Transverse) is the best connection with a maximum tensile strength value of; 347.222 MPa, with a maximum extension of; 29.379 mm and the maximum stretch value is; 58.758 %. Based on the graph of the relationship between the variation of welding current with load, stress, strain, and elongation at the 4-bolt joint as shown in the graph, it shows that the gradual addition of welding current strength, from 100 Ampere to 160 Amperes in welding longitudinal direction, transverse and combination of direction (Longitudinal + transverse) resulting in varying maximum tensile strength values.

The highest maximum tensile strength is shown at the 4-bolt combination joint with directional welding (Longitudinal + Transverse) at a current of 140 Ampere and combination directional welding (Longitudinal + transverse) and is the best combination joint simulation model of the test results. The current strength and welding direction of the joint combination affects the load, strain, and length values of the connection system. The greatest increase in load and elongation is achieved at a current strength of 140 Ampere with a combination of directional welding (Longitudinal + transverse) of; 187.500 kN and maximum elongation achieved of; 29.379 mm.

Graph of the relationship of the combination of welding directions with the joints of 4 bolts of square models with strong variations of welding currents (100, 120, 140, 160) Amperes, showing that at a current strength of 140 Amperes with a combination of directional welds (Longitudinal + Transverse produces the highest maximum tensile strength value of; 347.222 MPa, with an ultimate current extension of; 29.379 mm and a maximum strain value of; 58.758%. Based on the graph of the relationship between the variation of weld current to load (P), tensile stress (σ), strain (ε), and length increase (Li) shows that the process of adding weld current strength from (100; 120; 140; 160) Amperes results in a maximum tensile strength value that varies in the welded and bolted combination connection system.

The simulation of strong variations of welding current applied to longitudinally welded directional joints, transverse welds, and directional weld combinations (longitudinal + Transverse) to square model 4-bolt position joints, also affects the loading, strain, and elongation systems of weld and bolt combination joint systems.

The results of the study [24] say that bolt-weld combination joints are used in metal construction practices to increase the load-bearing capacity of bolted and welded joints in operational structures. The results showed that the strength of the bolt joints increased which was strengthened by the combined treatment of the welding process. While According to [25] states that when the strength of one bolt joint or welded joint is significantly greater than the strength of the other, the joint with the lower strength fails first, allowing its carrying capacity to be fully used while the carrying capacity of the connection with higher strength cannot. Since the strength ratio of bolts and welds affects the bearing capacity, the impact of the strength ratio of bolts and welds must be overcome when establishing a combination connection.

4. CONCLUSIONS

In low carbon steel plate connection research, investigating the simulation of strong variations of current strength and welding direction (Longitudinal + Transverse) with combined 4 bolts of the square model used in combination joints as well as for the development of mechanical properties in connection systems. Tensile strength testing is carried out to determine the impact of variations in current strength and direction of combined welding of bolt-weld combination joints on the tensile strength of joints resulting in the following conclusions:

a) The connection capability of low carbon steel plate material increases significantly, with an increase in the amount of strong current from 100 to 400 Amperes in the connection system, and also the strength of welded joints increases by developing the number of types of welding directions (longitudinal-Transverse).
b) The combination of a combined 4-bolt welded direction (Longitudinal-Transverse) joint with a current strength of 140 Amperes has a maximum tensile strength of; 347.222 MPa, when compared to the tensile strength of a joint with a current strength of 100; 120; and 160 Amperes.
c) The simulation produces a current strength of 140 Ampere given to a combination connection of 4 bolts square model combined directional welding (Longitudinal-Transverse) is the best combination joint model test results of tensile strength system.

REFERENCES

[1] T. Lan. 2019. Analysis of Ultimate Load-Carrying Capacity of Combined Connection with Bolts and Welds. Mechanics, 25(6): 426-433, doi: 10.5755/j01.mech.25.6.24791.

[2] H. Y. Chang and C. Y. Yeh. 2019. A study on the behavior of steel joints that combine high-strength bolts and fillet welds. Steel Compos. Struct., 31(4): 361-372, doi: 10.12989/scs.2019.31.4.361.

[3] D. K. Kim and C. H. Lee. 2020. Experimental and analytical study of combined bolted-welded lap joints including high-strength steel. J. Constr. Steel Res., 168: 105995, doi: 10.1016/j.jcsr.2020.105995.

[4] H. Bartsch, B. Hoffmeister and M. Feldmann. 2020. Fatigue analysis of welds and bolts in end plate connections of I-girders. Int. J. Fatigue, 138(April): 105674, doi: 10.1016/j.ijfatigue.2020.105674.

[5] E. F. Deng, L. Zong, Y. Ding, X. M. Dai, N. Lou and Y. Chen. 2018. Monotonic and cyclic response of bolted connections with welded cover plate for

modular steel construction. Eng. Struct., 167(April): 407-419, doi: 10.1016/j.engstruct.2018.04.028.

[6] Y. O. Özkılıç. 2021. The capacities of unstiffened T-stubs with thin plates and large bolts. J. Constr. Steel Res., 186(May), doi: 10.1016/j.jcsr.2021.106908.

[7] M. Nguyen-Hoang and W. Becker. 2020. Tension failure analysis for bolted joints using a closed-form stress solution. Compos. Struct., 238(January): 111931, doi: 10.1016/j.compstruct.2020.111931.

[8] Z. Chen, J. Wang, J. Liu and Z. Cong. 2020. Tensile and shear performance of rotary inter-module connection for modular steel buildings. J. Constr. Steel Res., 175: 106367, doi: 10.1016/j.jcsr.2020.106367.

[9] Y. Bu, Y. Wang and Y. Zhao. 2019. Study of stainless steel bolted extended end-plate joints under seismic loading. Thin-Walled Struct., 144(March): 106255, doi: 10.1016/j.tws.2019.106255.

[10] G. Wang and Y. Ding. 2020. The effects of uniform temperature and bolts fracture on the behaviour of high strength bolted frictional steel connection in Dashegnguan Railway Bridge. J. Eng. Res., 8(1): 107-127, doi: 10.36909/jer.v8i1.6500.

[11] L. Yang, M. Wang, Y. Sun, Z. Li and Y. Li. 2021. Experimental and numerical study of LY315 steel moment connection with bolted cover plates. Thin-Walled Struct. 159(May 2020): 107277, doi: 10.1016/j.tws.2020.107277.

[12] Y. Zhang, S. Gao, L. Guo, F. Fu and S. Wang. 2022. Ultimate tensile behavior of bolted stiffened T-stub connections in progressive collapse resistance. J. Constr. Steel Res., 189(August 2021): 107111, doi: 10.1016/j.jcsr.2021.107111.

[13] G. Xu, Y. Wang, Y. Du, W. Zhao and L. Wang. 2020. Static strength of friction-type high-strength bolted T-stub connections under shear and compression. Appl. Sci., 10(10), doi: 10.3390/app10103600.

[14] R. Ghorbel, A. Ktari and N. Haddar. 2021. Experimental analysis of temperature field and distortions in multi-pass welding of stainless cladded steel. Int. J. Adv. Manuf. Technol., 113(11-12): 3525-3542, doi: 10.1007/s00170-021-06788-y.

[15] S. S. S. Elfallah. 2022. Study on the influence of groove shape on the tensile strength of commercial steel. J. Eng. Res., pp. 1-15, doi: 10.36909/jer.18695.

[16] S. Elfallah. 2022. Effect of Gtaw on the Tensile Strength and Hardness of Mild Steel. Ann. Dunarea Jos Univ. Galati, Fascicle XII, Weld. Equip. Technol., 33: 95-100, doi: 10.35219/awet.2022.08.

[17] C. Chen, H. Zhou, C. Wang, L. Liu, Y. Zhang and K. Zhang. 2021. Laser welding of ultra-high strength steel with different oscillating modes. J. Manuf. Process., 68(PA): 761-769, doi: 10.1016/j.jmapro.2021.06.004.

[18] H. C. Ho et al. 2021. Structural response of high strength S690 welded sections under cyclic loading conditions. J. Constr. Steel Res., vol. 182, doi: 10.1016/j.jcsr.2021.106696.

[19] Analytical evaluation of elastic interaction in bolted flange joints.pdf.

[20] P. Može. 2018. Bearing strength at bolt holes in connections with large end distance and bolt pitch. J. Constr. Steel Res., 147: 132-144, doi: 10.1016/j.jcsr.2018.04.006.

[21] Y. Zeynali, M. J. Samimi, A. Mazroei, J. A. Marnani and M. S. Rohanimanesh. 2017. Experimental and numerical study of frictional effects on block shear fracture of steel gusset plates with bolted connections. Thin-Walled Structures, 121: 8-24, doi: 10.1016/j.tws.2017.09.012.

[22] M. F. Shahini, A. Bagheri Sabbagh, P. Davidson, R. Mirghaderi and S. Torabian. 2022. Experiments on cold-formed steel moment-resisting connections with bolting friction-slip mechanism. J. Constr. Steel Res., 196(May): 107368, doi: 10.1016/j.jcsr.2022.107368.

[23] X. Xue, S. Lin, Z. Guo, Y. Zhao, Q. Lin and Y. Chen. 2021. Mechanical behavior of loose high-strength bolted connections with thin sheet steels. Thin-Walled Struct. 168(November 2020): 108281, doi: 10.1016/j.tws.2021.108281.

[24] S. Vasil, Lecture Notes in Civil Engineering Innovations and Technologies in Construction. 2020.

[25] B. Huang and Z. C. Hong. 2020. Local Buckling Behavior of High Strength Steel Welded Circular Tubes Under Axial Compression. J. Fail. Anal. Prev., 20(4): 1364-1375, doi: 10.1007/s11668-020-00942-6.