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RESEARCH ARTICLE

OPTIMALIZATION OF COMBINED WELD AND BOLT CONNECTION TO INCREASE TENSILE STRENGTH OF PLATE

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ABSTRACT

The research objective to be achieved is to analyze the influence of strong currents (100, 120, 140, 160) Ampere, the model position number (2, 3, 4) bolt in the direction of the weld longitudinal and transverse as well as determine the best model of weld and bolt connection combination as an effort to increase tensile strength plate. The method used is to form specimens of welded connections (longitudinal and transverse) with various types of bolt position model. The manufacturing process produces a connection position 2 bolts model (Horizontal, Vertical, Slant A and Slant B), and the position of 3 bolts with the model (ΔA, ΔB, ΔC and ΔD) and position 4 bolts with the model (Square, rhombus, parallelogram A and parallelogram B). Welding treatment is done through a longitudinal direction, transverse direction and combinations (Longitudinal + transversal) with vary of strong currents. The testing process of tensile test produces output value of load, extension, tensile strain, maximum tensile and the time used. The phenomenon of the test results showedthe best the connection of weld and bolt combination. Results of tensile test results in improved strength through the addition of a (2, 3, 4) bolt from the various models and position 4 bolts models parallelogram Bhas the highest tensile strength of $\sigma_{U\_4Bolts\_\Im B} = 175{,}556\ MPa$ and weld connection combination direction (Longitudinal + transversal) with a strong current of 120 Amperes has highest tensile strength of $\sigma_{U\_Comb\_120A} = 335{,}370\ MPa$ and connection combinations of welding direction transversal to position of 3 bolts models triangleD in a strong current of 140 Ampere has the highest tensile strength values of $\sigma_{U\_Transv\_3Bolts\_\Delta D\_140A} = 379{,}259\ MPa$ compared to the 2 bolts models of slant A of $\sigma_{U\_Comb\_2Bolts\_MA\_100A} = 343{,}889\ MPa$ and position for 4 bolt model parallelogramB of $\sigma_{U\_Comb\_4Bolts\_120A} = 349{,}444\ MPa$ .Position 3 bolts models triangle D in weld connection combination direction transverse with a strong current of 140 Ampere showed the value of the highest maximum tensile strength as a results of tensile test and the best connection.

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INTRODUCTION

The strength of the connection is one of the determining factors in a construction, well construction shipbuilding, bridges, roof trusses and other construction uses metal material in the process of connecting. The amount of damage that occurred in the construction of the connection, whether through death or welding process connection or connection using bolts and nuts as a binder in use of construction of the connection. An increase in the tensile strength of the connection can be done through process of connection of weld combination and bolts to optimize the model and connection type, as well as variations in the use of electric current and vary the cooling medium after-treatment in welding process. Results of research and testing will be known the value of the ultimate tensile stress, strain value and the value reduction of the cross section through testing of the tensile test. The strength of the weld metal has the strength and tenacity were better or at least equal to the main metal and traction properties of welded connections blunt, essentially the same as the mains

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power as long as the selection of welding materials and welding in right way. Increased strength weld connection can be obtained through the variation of the electric current used in the welding process for steel materials. Saripuddin. M stated that the combination of weld and bolt connection has the highest tensile strength of, uσ = 0.312 kN / mm2 if compared to the tensile strength of welded connections, uσ = 0,293 kN / mm^2 and the tensile strength of the bolt connection, uσ = 0.271 kN / mm^2. Suhemi and Syamsuri stated that the effect or impact of the use of the welding current connection process will affect the region of HAZ, which can cause a decrease in strength and hardness of metal materials.

Decreased strength and hardness can cause damage to the local connection (HAZ) in use on the bridge structure, building, steel frame before the end of the lifespan, this may happen if the use of welded connections was not known yet of types of flow weld that matches the metal materials used, (research has not been done in the laboratory). The scope of the use of combination connection of bolts and welds in the construction field is very broad, covering the shipping industry, building, bridge structures, steel structures, pressure vessels, rail vehicles and so on. In addition to the manufacturing, welding process can also be used for repairs, filling the holes on the results of castings, making a hard coating on the tools and utensils, strengthen the parts that have been worn and various types of other improvements, (Wiryosunarto, Harsono).The results of previous research on tensile testing of welded connections of steel ST 42 was 464.50 N / mm2, with an increase of 0.15% strength, (Faith Pujo *et al.*) and the results of tensile testing of welded connections in robust welding current 110 A has a tensile strength values at 507, 33 N / mm^2 tensile strength with an increase of 0.65%, (Fenoria Princess). While the results of testing a single bolt connection Curling result in behavior which causes the pivot mechanism does not work perfectly, (WiryantoDewobroto).

The strength of welded connections in building construction are sometimes not able to accept the expenses incurred. Example: tensile load, stress or shear loads that occur suddenly which was never considered before. This will cause damage to the welded connections, which in turn will damage the structure of a building or bridge, because the loss of such construction elements. One of the methods to be able to add value to the tensile strength of the connection without changing the size and shape of the connection by combining a variation model of the position of the bolts into the weld connections direction of the longitudinal, transverse and combinations so if the welded connection damaged, the connection between the elements of the construction of the connection is not immediately broken or loose. To determine the increase of the metal material tensile strength in the utilization of the construction field, it is necessary to research into the use of configuration bolt position model connection in combination to obtain the best bolt position.

Formulation of the problems

Based on the explanation of the background outlined above, it can be formulated as follows:

- How does the effect of position of connection models (2, 3, 4) bolts in increasing the tensile strength when compared to the tensile strength of the welding connection variation direction?
- How big is the influence of welding strong current (100, 120, 140, 160) Ampere in the longitudinal direction of the weld connection treatment, and the combination of transverse direction (longitudinal + transverse)?
- How is the relationship between weld connections combination model and bolt with providing variation of welding strong current and the number of bolts in an effort to obtain the best connection models?

Objective of Study

- Based on the formulation of the problem, this study has the following objectives: To analyze the effect of variation connection models (2, 3, 4) bolts in order to increase the tensile strength when compared to the tensile strength of the connection strength with the variation of the direction of welding;
- Analyzing the powerful influence of welding current (100, 120, 140, 160) Ampere in the longitudinal direction of the weld joint treatment, and the combination of transverse direction (longitudinal + transverse);
- Determine the best connection models of weld and bolt combination by a strong variation of welding current and number of bolts;

Benefits of research

Results of this research has the following benefits:

- For basic usage models connection bolt position and condition of the combination of the direction of welding for the industry engaged in the construction of ships, buildings and bridges or in the field of construction industry related to the use of the connection.
- The study results of the effect of bolt position model and condition of the connection combination of welding direction can be used as the base material for researchers who want to develop further innovations connection models and types of alloys in use for the development of the construction industry.
- Guidelines for the construction of learning for technical implementing connections in implementing the appropriate and correct the use of current.
- It can extend the lifespan for use in various connection in building construction, bridge structures or other construction related to welded connections and bolts.

Basis Theory

Bolts and Nuts

Bolts and nuts are a very important tool fastener and a connection or a tool that can be removed at any time can be opened again. Bolts are classified according to the head, the hexagon and square head. Bolts and nuts can be divided into: bolt clamp, bolt for the special use, machine screws, settler screw, stopper screw and nuts. Connection with transverse loading occurs when two plates in connection with the use of bolts while the plates work gravity laterally bolt parts that receive the greatest tensile is the place where the two plates coincident. In this place as if in a pair of scissors by the second plate. Then the forces acting on the bolt was based upon the shift indicated at the Figure 1below.

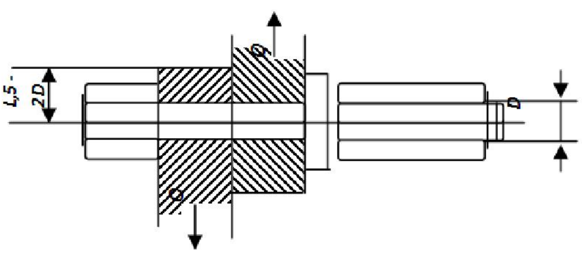

Figure 1. Image bolts with transverse loading

General shape in transverse loading is:

$$D = \sqrt{\frac{4p}{\pi . n . \tau_d}} \qquad \text{.....................(2)}$$

By: P = Imposition in Kg
n = Number of bolts mounted
D = out side diameter of the bolts in mm
τd = shear stress in Kg / cm2
τ_t = tensile stress (N / mm2)

Hypothesis of Wiryanto Dewobroto, 2008, that the pivot mechanism can be developed on this thin plate connection system. Reasoning for generating innovation starts with understanding the behavior of the key of pivot mechanism. As it is known that the width of the plate, there is a critical part in the contact plate - bolts, and its performance is determined by the diameter of the bolt and plate thickness. In the mounting bolt, bolt hole diameter should larger, the yield gap condition. The new connection system with a special washer is based on a new mechanism, depending on the diameter of the groove and thick plate. Contacts are between the plates when the new channel is formed due to pretentioning at the washer men chant. Because the contact area can be formed without the role of the bolt, then during the transfer of forces on the plates, the bolt does not undergo shear stress.

Therefore, the bolt does not determine the strength of the connection but it only plays a role in the formation of the new channel (if possible) and a tool to maintain the shape of the grooves in the plates continued, which serves as the contact area of the new with a size larger than the contact area abutting the previous (normal washer).An increase in the strength of the connection of new system to the old system is determined by the ratio of groove diameter than the diameter of the bolt. If the ratio of the diameter can be made not differ significantly then remain acquired increased performance because it can eliminate the slip factor that generally exist on pivot-type connection system. No need for slip phenomenon when the external load work on the connection causing the structure that uses the connection system becomes rigid, in which the connection system as it is more resistant to risk.

Welding process

Welding of the most popular in Indonesia, namely arc welding with electric flame (SMAW), in some areas of the construction industry that use advanced technology, has been using this type of TIG welding, MIG and electrical resistance welding (ERW). As well as submerged arc welding (SMAW). Length of the rod electrode is usually about 230 to 460 mm and a diameter of 2.5 to 9.5 mm. Filler metal is used as the electrode rod must be in accordance with the metal to be welded, the composition is usually very close to the composition of which is owned by the base metal. Wrapping layer consists of cellulose powder mixed with oxides, carbonates, and other elements that are then combined with the silicate binder. Metal powder is sometimes also used as a compound to increase the filler metal and adding elements of alloy. During the welding process flux material used to encapsulate the electrode, as a result of electric arc heat, melt to form a slag of molten metal which is then covered in a pooled connection and works as an oxidation barrier. Displacement of the metal electrode occurs when tip electrode melts to form grains carried by currents electric arc occurred. Electric current is used about 30 to 300 A at a voltage of 15 to 45 V. Selection of power used depends on the metal to be welded, type and length of the wire electrode, and the desired weld penetration.

Welding Parameters

In the welding process there are lots of welding parameters, where each parameter has a different influence on the welding results. Some of these parameters among other things:

- Strong current; Direct effect on the penetration of the weld metal, bead shape, width of HAZ and dilution. The greater the welding currents can deepen the penetration of the weld metal and HAZ widen, and vice versa. Strong magnitude of electric current on the welding process depends on the type of man metal, dimensions and electrode diameter.
- Welding speed; The higher welding speeds are usually influenced by the high welding currents. To melt the tip electrode / wire welding enough heat energy required. If the heat energy given more than enough for example to provide higher currents, then the process of melting of the electrode tip (feeding rate) is rapid. Electrode melting rate is not matched by the welding speed will cause liquid accumulation of weld metal on the surface of the main metal.
- Long Welding; is a function of the time of the welding process. The longer the welding is done then the longer time required for welding the same speed. Because of the time required when the welding process is done for longer, then the heat absorbed by the main metal is also much more so it is likely the greater of the distortion occurred.
- Heat Input; Disbursement of main metal and filler metal requires considerable energy. The energy generated in welding operations resulting from wide - range of sources depending on the welding process. In the electric arc welding, the source of energy comes from electricity that is converted into heat energy. This heat energy is actually the result of a collaboration of the welding current, welding voltage and welding speed.

The quality of welds are influenced by thermal energy which means influenced by three parameters: welding current, welding voltage and welding speed. The relationship between the three parameters that produce energy welding is often called heat input. The equation of heat input results from the merging of the three parameters can be written as follows:

$$HI(Heat\ Input) = \frac{Welding\ tension\ (E)\ x\ Welding\ current\ (I)}{Welding\ speed\ (V)} \quad \text{........(2)}$$

From the equation it can be explained some understanding among others, if we want a high heat input the parameters that can be measured ie welding currents can be enlarged or welding speed is slowed. The size of the welding current can be measured directly on the welding machine. Welding tension generally can not be set directly on the welding machine, but their influence on heat input remains. To obtain the actual heat input from a welding process, the similarity of one multiplied by the welding process efficiency (η) so that the equation becomes:

$$HI(Heat\ Input) = \eta\ x\ \frac{Welding\ tension\ (E)\ x\ welding\ current\ (I)}{Welding\ speed\ (V)} \quad \text{......(3)}$$

The process of connecting steel buildings we recognize two types of welding, namely:

- Weld Carbide (OTOGEN welding); welding using a propellant of oxygen gas (acid) and acetylene gas (acetylene). In welded steel construction is only for light work or secondary construction, such as; iron fence, trellis, and so on.
- Weld Electricity (melted welding); Welding using electric energy. Required for welding, is needed the welding plane is equipped with two cables, one cable is connected to clamp the work piece and the other one is connected with a cable clamp pliers welding rod / welding electrodes. If the welding electrodes are brought closer to the work piece, the contact that generate heat that can melt steel and electrodes (welding rod) is also fused ends as well as a gap filler in the weld joint. For steel construction that is structurally (shoulder the burden of construction), the welding connection is not permitted to use Otogen welding, but it must be done with electric welding and must be done by a skilled professional workforce..

Testing the strength of welded connections can be done by two methods, namely:

- Test without damaging materials (NDT-Non Destructive Test): This test is performed using X-rays or Gamma to examine the state of the inner weld joint.
- Testing by damaging materials (DT-Destructive Test): This test is done with material damage by way of: Tensile test, hardness test, and test arch.

Welding connection is a fixed connection, which can produce great connection strength. The calculation of the weld strength can be obtained through:
Weld strength transversal connections consist of:

1) Single fillet: $F = \frac{t\ x\ L}{\sqrt{2}}\ x\ \bar{\sigma}_t = 0{,}707\ x\ t\ x\ L\ x\ \bar{\sigma}_t$ ....(4)

2) Double fillet; $F = 2\,\frac{t\ x\ L}{\sqrt{2}}\ x\ \bar{\sigma}_t = 1{,}414\ x\ t\ x\ L\ x\ \bar{\sigma}_t$ ....(5)

By: A= Are aminimum of welding $\frac{t\ x\ L}{\sqrt{2}} = 0{,}707\, t\ x\ L$

t =welding thickness (mm)
L=length of the welding(mm)
F=Tensile(N)
Weld strength parallel connections(longitudinal) consisting of:

1) The maximum shear force parallel single fillet; $F_s = \frac{t\ x\ L}{\sqrt{2}}\ x\ \bar{\tau} = 0{,}707\ x\ t\ x\ L\ x\ \bar{\tau}$ ....(6)

2) The maximum shear force parallel double fillet; $F_s = 2\,\frac{t\ x\ L}{\sqrt{2}}\ x\ \bar{\tau} = 1{,}414\ x\ t\ x\ L\ x\ \bar{\tau}$ ....(7)

By; Fs = the maximum shear force (N)
$\bar{\tau}$ = Tensile stress welding $\left(\frac{N}{mm^2}\right)$

A material can be changed with the forces acting on it and will get resistance force in a material that tends to resist external forces. Results of the two styles of interaction is the tendency of a material to return to forms reversed when external forces eliminated the so-called flexibility (elasticity) of materials. Elastic deformation occurs when a piece of metal loaded style and if attempted pull objects will get longer, otherwise if the burden of the compressive force resulting in objects being short. Elastic strain is the result of the extension of the unit cell in the tensile stress direction or in the direction of pressure. If there is only elastic deformation, strain will be proportional to the tension. Comparison between tension and strain is called the modulus of elasticity. The greater the tensile force between the metal atoms, the higher the modulus of elasticity. When the test rod receiving the tensile force of F, with the first sectional area Ao, then the length of the rod will increase of ΔL, then causing tension force of

$$\sigma = \frac{F}{Ao} \quad \text{..........................(8)}$$

WithF=Load(N)
Ao=initial cross-sectional area(mm^2)
Comparison between the length($\Delta l = l_1 - lo$) with original length(lo) is called strain.

$$\varepsilon = \frac{Li - Lo}{Lo} \quad \text{....................(9)}$$

With ε= Strain
L_1= length after a given load (mm)
Lo = initial length (mm)

Comparison between stress and strain is called the elastic modulus of elasticity (Young's modulus), the formulation as follows:

$$E = \frac{\sigma}{\varepsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

By: E = Young's modulus (N / mm^2)
σ = Stress (N / mm^2)
ε= Strain (%)

In the tensile test, specimen loaded gradually, which grew little by little. Loading due to this, it changes the length of the magnitude to the load by tensile machine causing the relationship diagram(σ- ε). Up to a peak point called the proportional limit, when a tension proportional to the strain, then the graph will show a straight line. When it comes to the elastic limit, the voltage is no longer proportional to strain. If the load is removed, the length of the rod will be returned to its original state. For the record that could be considered the elastic limit and the limit of proportionality is no different. If the load acting on the test rod passed up beyond the elastic limit will happen suddenly extension permanently from a test rod, is called Yield point (limit melted), where the strain increases even if there is no increase in voltage (only occurs in soft steel), At this point the work load is equal to F_y, resulting in a tension of $\sigma_y = F_y / A_o$.

MATERIALS AND METHODS

Research Design

The method used in this research is experimental research and literature review on the optimization of weld and bolt connections combination as efforts to increase the tensile strength of the plate. Stages of research conducted through the manufacture of test specimens for model of position number (2, 3, 4) bolts, welding process toward the longitudinal, transverse and weld combination direction by using a variation of electric current (100, 120, 140, 160) Ampere, further testing the tensile strength the tensile test machine. From the results of testing the tensile strength of the connection is done every kind of model analysis of the influence of the position of the bolt, weld joint conditions direction longitudinal, transverse and combination (transverse + longitudinal) with strong variations in flow. Analysis results found the types of bolts position model and the best model of weld connection combination direction.

The analysis technique used

Analysis of each kind of the position model (2, 3, 4) bolts on the condition of the weld connection direction (transverse, longitudinal and combinations) from the welding process with the use of a strong current of 120 amperes, the process of tightening the bolt (torque remains). The process of connection tensile test generating a direct values of tensile strength, loading, stretching, and an extension of time ranging from proportionate conditions, ultimate and fracture condition (Break). From the test results known the effect of each model of bolt position, good direction condition, against an increase in tensile strength connection steel plates. The forms of the equations used are; $\sigma = \frac{F}{A}$ and $\varepsilon = \frac{\Delta l}{lo} \times 100\ \%$

RESULTS AND DISCUSSION

Results of testing the maximum tensile strength of 2 bolts position connection with model of horizontal, vertical, slant A and slant B showed that the model of vertical connections have the highest maximum tensile strength values of $\sigma_{U\_2Bolts\_V} = 96{,}019\ MPa$ compared to other models. The highest tensile strength for connections of 3 bolts positions with a triangle A, B, C and D model showed that the bolt position of triangle model D had the highest tensile strength values of $\sigma_{U\_3Bolts\_\Delta D} = 135{,}278\ MPa$. While the connection 4 bolts with square models, rhombus, parallelogram A and B also showed that connection of parallelogram A had the highest tensile strength values of $\sigma_{U\_4Bolts\_\Im A} = 175{,}556\ MPa$.

Results of tensile testing of weld connections towards longitudinal, transverse and combination direction (longitudinal + transverse) with the use of variations of electric current (100, 120, 140, 160) Ampere showed that the use of the current strength of 120 Amperes in weld connection combination direction (longitudinal + transverse) had the highest tensile strength values of $\sigma_{U\_Comb\_120A} = 335{,}370\ MPa$. This can be compared with the use of a powerful 100 amperes with a maximum tensile strength of $\sigma_{U\_Comb\_100A} = 331{,}574\ MPa$, and to 140 Amperes with maximum tensile strength of $\sigma_{U\_Comb\_120A} = 332{,}315\ MPa$,as will to 160 Amperes with maximum tensile strength of $\sigma_{U\_Komb\_160A} = 332{,}685\ MPa$.

Results of testing the tensile strength of maximum weld and bolt connections combination by using variations of strong currents (100, 120, 140, 160) Ampere showed that the connection combination of 3 bolts position of triangle model D towards the welding direction transverse with the strong current of 140 Ampere had the highest tensile strength of $\sigma_{U\_Transv\_3Bolts\_\Delta D} = 379{,}259\ MPa$, This can be compared to the 2 position of the bolt connection models slant A towards the direction of welding combinations (longitudinal + transverse) with strong currents 100 Ampere only had a maximum value of tensile strength of $\sigma_{U\_Comb\_2Bolts\_slant\_A} = 343{,}889\ MPa$. So is the 4-position bolt connection model of parallelogram B towards weld combination direction (longitudinal + transverse) with a strong current of 120 amperes showed maximum values of tensile strength of $\sigma_{U\_Comb\_4Bolts\_\Im B} = 349{,}444\ MPa$ .Results of testing the tensile strength of the model positions (2, 3, 4) bolts in the weld connection direction transverse, longitudinal and combination (transverse + longitudinal) showed that the position of 3 bolts triangle model D on weld directions transverse with current of 140 amperes was the best connection type compared model positions 2 and 3 bolts of various types of weld connection. Detailed, value of maximum tensile strength of each position of the bolt in the direction of the weld connection variations are shown in the following table.

Table 1. Values Tensile Strength maximum connection Weld against Combination Model Position Number of Bolts

Bolt Numbers	Stron Currents (a)	Model	Kondition	Time (t)	Load (kn)	Extension (mm)	Stress(mpa)	Strain%
2 BOLTS	100	Slant A	COMB	56.224	185.700	28.144	343.889	56.288
	120	Slant A	TRANSV	38.941	183.900	22.546	340.556	45.092
	140	Slant B	COMB	77.804	177.400	25.810	328.519	51.620
	160	Horizontal	COMB	44.637	172.100	25.834	318.704	51.668
3 BOLTS	100	Triangle C	TRANSV	40.839	182.200	23.620	337.407	47.240
	120	TriangleA	TRANSV	35.145	182.900	20.356	338.704	40.712
	140	TriangleD	TRANSV	43.637	204.800	25.393	379.259	50.786
	160	TriangleC	TRANSV	29.152	181.550	16.763	336.204	33.526
4 BOLTS	100	Square	COMB	69.812	184.000	23.139	340.741	46.278
	120	Parallelogram B	COMB	41.24	188.700	23.829	349.444	47.658
	140	Square	COMB	58.623	187.500	29.379	347.222	58.758
	160	Parallelogram B	TRANSV	45.336	183.300	22.602	339.444	45.204

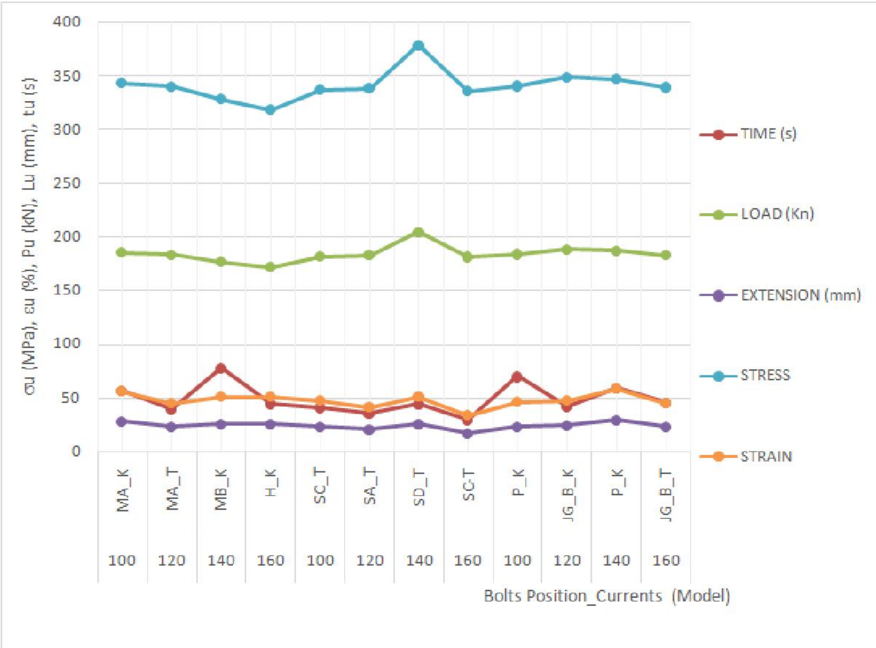

Figure 2. Graphic Relationship Between Tensile Strength, Strain, Load, Position Against Time Extension and Model Bolt, strong currents

Effect of position models (2, 3, 4) bolts and strong currents (100, 120, 140, 160) Ampere is a contributing factor in the increase in tensile strength of weld connections, whether longitudinal direction, transverse or combination (transverse + longitudinal). A phenomenon that occurs from the welding process direction of transverse direction with strong current of 140 amperes is the best connection on the position of supporting 3 bolts model of triangle D while the welding process direction combination (transverse + longitudinal) with a strong current of 100 amperes is the best connection type to support positions 2 bolts models of slant A and the use of 120 Amperes for position 4 bolts models parallelogram B. Value of tensile strength, strain, load, extension, and the time when the maximum (ultimate) each bolt position against the direction of the longitudinal welded joints, the transverse and combination (transverse + longitudinal) is shown in the following graphic:
Maximum tensile strength of the weld and bolt connections combination was influenced by the model positions (2, 3, 4) bolts and strong variations in current (100, 120, 140, 160) Ampere in an effort to get the types of maximum tensile strength of the connection plate.

The phenomenon of the maximum tensile strength resulting from the testing of the weld and bolt connection combination found models of bolt position, direction and welding direction and strong current appropriate and the best connection type.

Conclusion

1) Addition number (2, 3, 4) bolts of various models of the bolts position has a configuration of an increase in the tensile strength of the connection plate occurs at position 4 bolts models of parallelogram A with the highest tensile strength of $(\sigma_{U\_4Bolts_{3A}} = 175{,}556\ MPa)$ than the tensile strength of the highest maximum at position 3 bolt triangle model D $(\sigma_{U\_3Bolts_{\Delta D}} = 135{,}278\ MPa)$ and The highest maximum tensile strength at position 2 bolts vertical model $(\sigma_{U\_2Bolts\_V} = 96{,}019\ MPa)$.
2) The strength of the weld connection direction of longitudinal, transverse, and the combination had an

increasing trend towards maximum tensile strength towards with the addition of strong currents (100, 120, 140, 160) Ampere and occurs in combination weld connection direction (longitudinal + transverse) in strong currents 120 Ampere as the highest maximum tensile strength $(\sigma_{U\_Comb_{120\,A}} = 335{,}370\ MPa)$; compared to the strong currents (100, 140, 160) Ampere for welding longitudinal or transverse direction only.

3) The relationship model of weld and bolt connections combination with using strong current variations (100, 120, 140, 160) Ampere occur in connection of 3 bolt position model of triangle D in the weld connection direction of transverse at the strong current of 140 Ampere has the highest maximum tensile of $\sigma_{U\_Transv\_3Bolts\_\Delta_{D140\,A}} = 379{,}259\ MPa$ which is the best connection than model types of 2 and 3 bolts positions.

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