Numerical Analysis of Resistance Spot Welded Joints Under Static Load

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Abstract:- The resistance spot welding (RSW) is the methods which are including with thermal, involves, metallurgical, electrical and mechanical fields. In this process, the contact interaction related thermal, electrical and mechanical connection where thermal and electrical conduction over faying interface created intense affected by using mechanical connection pressure and temperature at this interface surface conditions and material composition. However, the portrayal of the contact associations frequently disentangled with no or constrained thought of a blend of impacts as referenced above in state-of-the-art models of numerical reproduction because of negligible accessibility of electrical and thermal contact obstruction information at different pressures and temperatures. From the previously conducted experiment, the Tensile-Shear test performed on the resistance spot weld joint yield that the maximum tensile capacity spot weld joint is in average 7.33KN. As a result, the shear stress of the welded joint is 145 MPa. In the simulation of the resistance spot joint, the Shear stress of the welded joint is 77.33 MPa. The reason behind the difference of experimented data and simulated data are atmosphere temperature, the hardness of the weld mass.

Keywords:- *Resistance Spot welded (RSW), Static Load, Shear stress, Resistance spot joint.*

I. INTRODUCTION

Resistance welding has various types of methods; spot welding is one of them. It is joining the two or more than two-sheet material together without utilizing any filler material by using weight and warmth to the territory to be welded. This technique used for joining sheet materials and utilizations framed copper metal terminals to apply pressure and pass on the electrical flow through the workpieces. All in the RSW, the parts are regionally heated. The material among the wires produces and regularly pressed then melts, harming the interface between the components. The stream turned off, and the "piece" of hot materials takes shape framing the joint[1]. Resistance welding high costly technique that is particularly appropriate for programmed creation lines and large-scale manufacturing. Resistance welding likewise fitting for little group creation due to utilizing strategy is movable, gear basic and the welding procedure simple to control. Moreover, using sort wedding have noteworthy preferred position strategy. It used for joining a high number of metallic materials. Resistance welding fit for the welding of the fundamental metal covered steel sheets.[2].

In the modern industry, now using resistance spot wedding oldest electric welding methods. The automotive industry used this method frequently because of high performance manufacturing thin metal sheets. When the Welding process running it contacting metal surface joined by the heat obtained from resistance to electric current. It requires the coordinated application of electrical flow and mechanical stress of correct dimensions and form. The electrodes implement the pressure and to ensure sufficient connection between surfaces. As the current from the electrode travels through the metal sheets, the resistance of the plate metal to electrical current flow because localized heat in the mutual, and the weld has made[3]. Figure 1 shows that the Resistance spot welding basic block diagram.

Welding is the metallurgical technique, all highlights of a welding strategy can be, pretty much, connected to metallurgy if the materials engaged with welding, either the base metal or the cathodes. After spot welding, massive changes happen in the mechanical and metallurgical properties of the spot-welded zones and warmth influenced zones [4] . The examination of these progressions is impressive for the wellbeing quality of the welded joints. Among such investigations, the mechanical properties of the joint under static stacking is generally imperative.

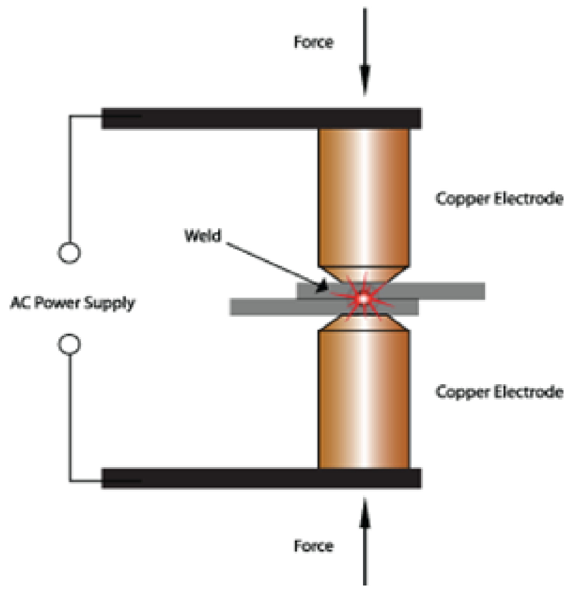

Fig 1:- Resistance Spot Welding

ISSN No:-2456-2165

The tractable shear and the hardness trial of the joint uncovers different mechanical properties advancing quality, crashworthiness, strength, and so forth.

II. RELATED WORK

D. Afshari [5] investigated the mechanical properties of resistance spot welds in lightweight applications. The results showed that the neural network models produced in this research could accurately predict the nugget size and the residual stresses generated in resistance spot weld. By using a combination of these two developed models, the nugget size and the residual stresses can predict in terms of spot weld parameters with high speed and accuracy. MD Ibrahim [6] studied the effect of Weld time on the spot weld joint strength of mild steel sheets. The study revealed an optimum welding time of 4 sec under 4KA of constant current and 6KN of electrode pressure. M. Pouran vari [7] studied the fracture mode of galvanized low steel resistance spot welds. This study showed that increasing welding current alters failure mode from interfacial to pullout failure mode. M. Pouranvari [8] also studied the impact of welding tide on the mechanical rejoinder of resistance spot welds of irregular thickness steel sheets in tensile-shear priming conditions. Results explained that in opposition to spot welding of sheets with comparable thickness, a Pear-like shape of the welded nugget was formed due to heat unbalance resulted from the difference in bulk resistively of the layers.

Omar [9] investigated deformation caused by spot welding by simulation. In the investigation, tests have conducted, and it has found that the geometric deviation of the extension does not depend on the heat form the spot welding. Matsushita et al. [10] studied the development of next-generation resistance spot welding technologies contributing to auto bodyweight reduction. From their study, they concluded that varying the force and welding current.

Intelligent spot welding made it possible to achieve easier three sheet lap welding more generally performed with increased application of high strength steels. Hirsch et al. [11] studied the resistance spot weldability of galvanized interstitial free steel sheets. Which also have austenitic stainless-steel sheets. In microhardness measurements, the maximum hardness values were in the middle of the weld nugget. Darwish et al. [12] have developed a mathematical pattern that rule of spot-welding parameters (welding time, welding flow, sheet diameter, and electrode force) on the power of spot-welded stainless sheets with popular virtue. Maxwell et al. [13] studied to describe the effect of nugget width on the exhaustion force of resistance spot fused joints of plated iron and austenitic stainless steel welded as lap joints. Bouyousfi et al. [14] have studied the effect of spot-welding method parameters (are welding duration, intensity, and applied pressure) on the mechanical properties and characteristics of the spot joints between two stainless steel sheets having the same thickness. Microhardness and tensile test results have shown that the weld resistance is essential and extremely correlated to the utility of the method parameters, especially the applied pressure. The applied load appears to be the control factor of the mechanical properties of the weld joint associated with the welding span and the current strength. Yorozu et al. [15] have contributed their research on the selection of optimal welding situations and formed new standard steels for automotive purposes. The study is based on influence tensile testing to spot welding sheets. Seeger et al. 18 investigated spot weld behavior using detailed modeling. The found that the experimental investigation of pressure speed outcomes at higher rapidity's of joints are quite Sophisticated due to dynamic effects of the test arrangement; oscillations often overlay the magnitudes. Yorozu et al. [15] conducted an experimental study on the strength of the spot-welded joint. This study result shows that the optimum parameter for tensile shear-type is at 6 K.A. current and 4 second welds time (3847N), and the highest strength for coach peel type is at 6 KA current and 5 second Welds time (889.5N). Finally, the comparison result shows the higher concentration of orientation using the spot-welding machine is a tensile shear type. Chandler and Giesecke [16] focused his study on the development of a universal spot weld model for automotive finite element method (FEM) crash simulation. It concluded that to assess the Crashworthiness of automotive structures, they require to be interpreted correctly in realistic simulations, which require the expansion of spot-welded joint models to be included in crash analysis. M.R.H et al. [6] based their research on the predictive accuracy of resistance spot welding simulation. They presented that the predictive accuracy of the FEM has obtained by linear covariance propagation, where the statistics of nugget size and surface indentation derived from the covariance matrix of the PC metrics. By this method the productive accuracy of future simulation can be assessed using past analysis and test experience. Considering all this research, very few types of research have done on numerical analysis of resistance spot welded joints under static load.

III. METHODOLOGY

A. Geomertry model

Our 2D steel sheet model show in the figure 2.

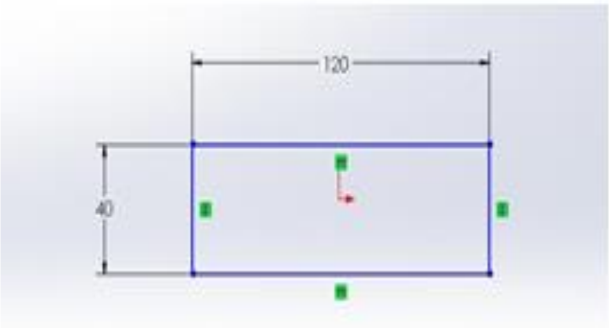

Fig 2:- 2d model of the steel sheet. (all parameter is in millimeter)

In the figure 3 and 4 shows that 3D model of the steel sheet is given below-

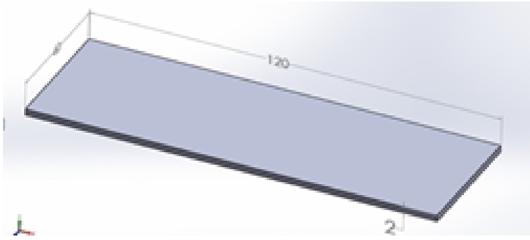

Fig 3:- 3d model of the steel sheet. (all parameter is in millimeters)

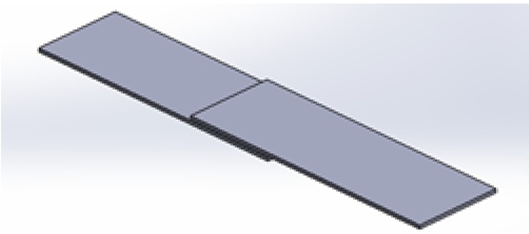

Fig 4:- 3d view of welded parts

B. Mesh Generation

Mesh view of base plate: The mesh generation of the steel plates has created on the mesh windows on ANSYS mechanical structure. There are mainly two types of mesh generation. One is the meshed generation for the base plate, and the other is mesh generation for the total welded plates.

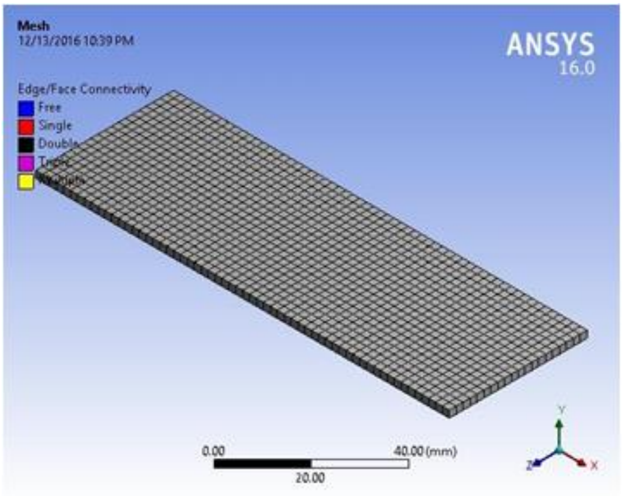

Fig 5:- shows that fine mesh view for the base material.

After the final grid refinement, we found the total number of 8803 nodes and 1200 elements. Based on the skewers, smoothness, and aspect ratio, the suitability of the grid can decide. For a quality grid, the aspect ratio near one appreciate. On the network of the current study, 560 elements out of 1200 items found having aspect ratio 1. Cross-sectional view of a welded part shows in the figure 6.

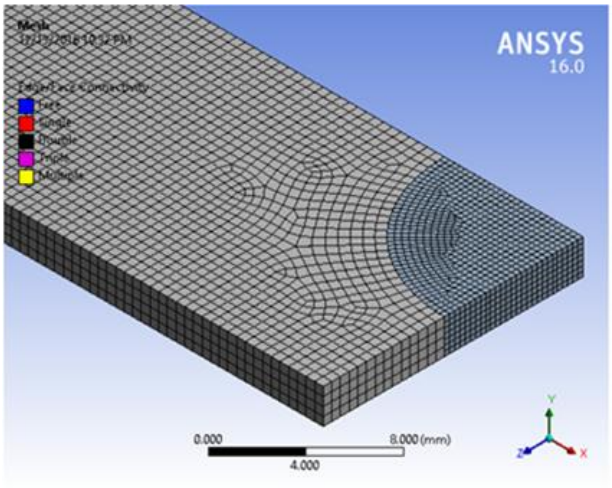

Fig 6:- cross-sectional view of a welded part.

Mesh View of Welded parts: In the mesh generation of welded components, it's better to show mesh generation in symmetric cross-section view. Enlarged mesh of welded part show in the figure 7.

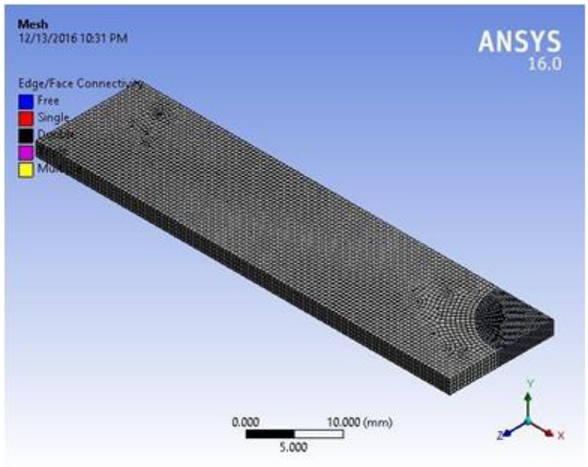

Fig 7:- enlarged mesh of the welded part.

After the final grid refinement, a total number of 86929 nodes and 17933 elements found.

C. Data Collection

The study had carried out through several steps. The spot-welded joint designed on the design modular, creating parts on the geometry. The pieces intentionally created for better accuracy of the grid creation. The smoothness of the grid was better because of the production of different parts and applying different methods in each section. Finally, 3144 nodes and 1414 elements found. We are setting various parameters; the numerical analysis carried out. The outcome parameter values of this analysis noted down from the Mechanical APDL- post window.

- **Data collection methods:** The geometry design on the Design Modular and the grid generation was done successfully on the grid window. We were setting different parameters; the simulation conducted on the setup window — every element of the grid takes into consideration for the calculation. And there were 3144

ISSN No:-2456-2165

nodes as well as 1414 items on the grid surface. The mechanical simulation software ANSYS conducted the analysis and provided the final result based on the equations of the model selected for the current study. After finishing the numerical analysis, the data of the current

- **Base Material methods for normal stress :** An average pressure is a stress that occurs when an axial force loads a member. The value of the reasonable power for any prismatic section is simply the force divided by the cross-sectional area. Typical stress will occur when a member place in tension or compression. In the base plate, a fixed support place at one end and axial load give on the other side of the plate. Figure 8 shows that the normal stress of the base material. Figure 9 shows that enlarged normal stress of the base material.

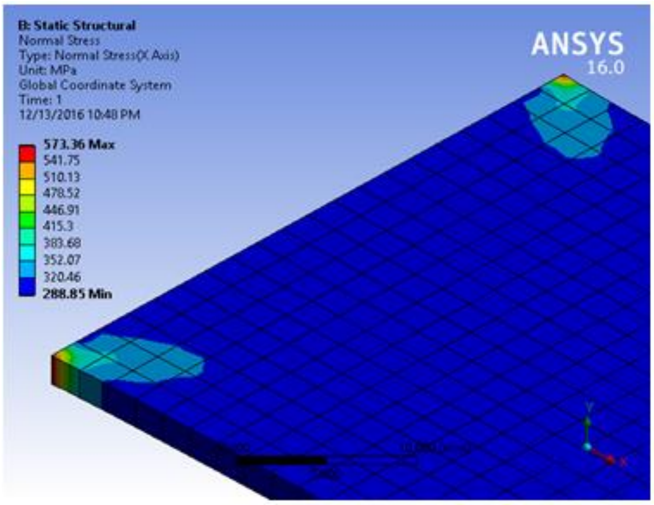

Fig 8:- Enlarged Normal Stress of the base material.

- **The normal stress for the welded joint:** An average pressure is a stress that occurs when an axial force loads a member. Normal pressure will happen when a member place in tension or compression. In this case, Tensile axial strength applies, and figure 10 shows the normal stress of the welded joint gives below-

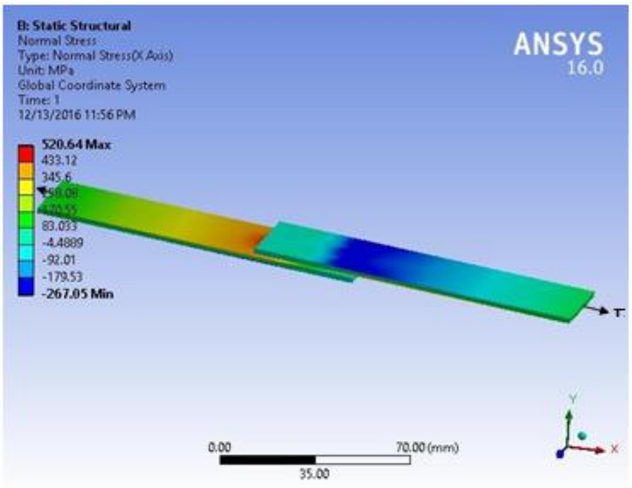

Fig 9:- Normal Stress of the welded joint.

- **Shear Stress of the welded joint:** A shear pressure characterizes as the segment of force coplanar with a material cross-area. Shear pressure emerges from the power vector part corresponding to the cross-segment. Substantial pressure, then again, results from the power vector segment opposite to the material cross-segment on which it acts. In figure 11 shows the sheer worry of the welded joint.

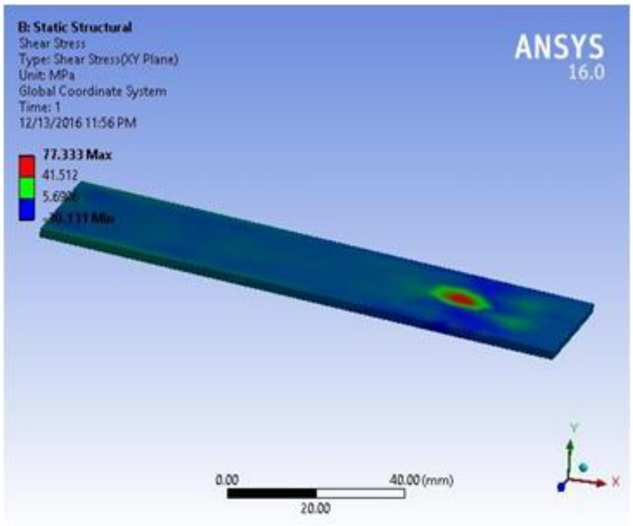

Fig 10:- Shear Stress of the welded joint.

- **Stress Intensity of the welded joint:** The stress intensity is used in fracture mechanics to predict the stress state near the tip of a crack caused by a remote load or residual stresses. In the resistance spot-welded joints, the Stress intensity is more significant in the welded region. Figure 12 shows the stress intensity of the welded joint.

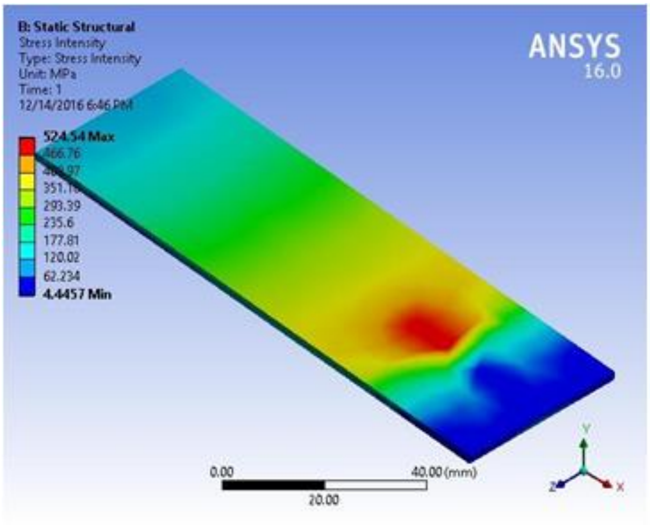

Fig 11:- Stress Intensity of the welded joint

- **Normal Elastic Strain of the welded joint**: Interior strain inside metal is either versatile or plastic. On account of flexible disfigurement, this sees as a mutilation of the gem cross-section on account of plastic deformation, this follows by the nearness of separations

– the relocation of part of the precious stone grid. Such strain impacts can bring about undesirable breaking of the material shows in figure 13, just like the case with remaining plastic strain. In different occurrences, the intentional presentation of plastic distortion brings about a reinforcing of the substance and other execution improving practices.

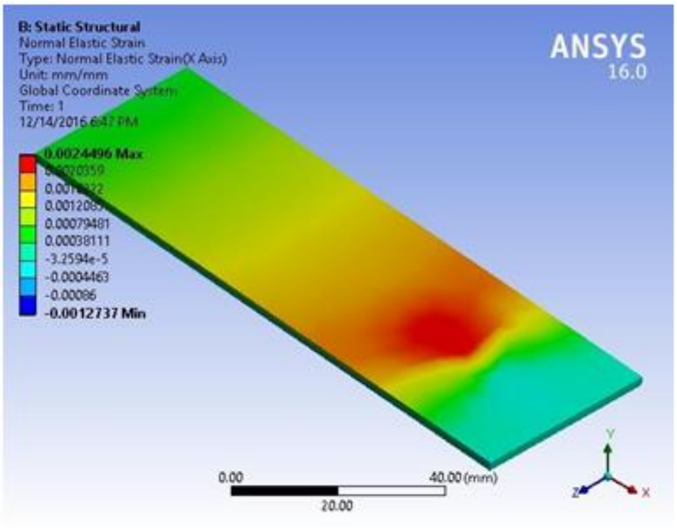

Fig 12:- Normal Elastic Strain of the welded joint

➢ **Failure Analysis:** Interface failures can be caused by excessive cracking or porosity in the nugget, particularly with thick steel, if insufficient force or extreme splash occurs. More extended time/pulsed conditions and sufficient hold time may help to minimize such imperfections. The Experimental result of the welded joint is, as shown in Figure 14. The simulation of failure of the spot-welded joint is as shown as in Figure 15.

Fig 13:- Joint Failure Mode: Interfacial & Joint Failure Mode: Tear at One Edge

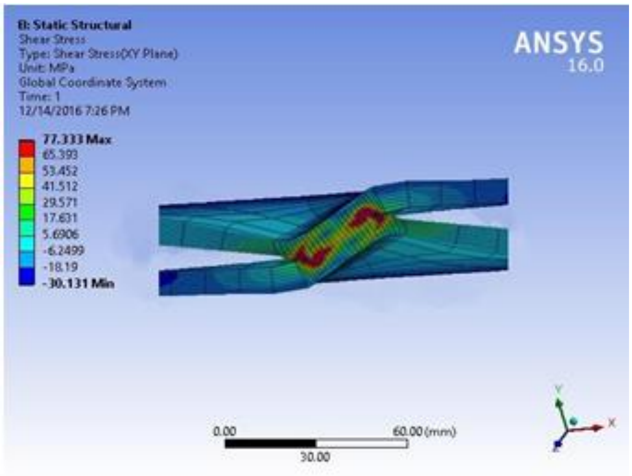

Fig 14:- Joint Failure Mode.

IV. RESULT ANALYSIS

After completing all the steps i.e., designing the welded geometry, making a proper grid, and finally setting up all the boundary conditions, the analysis carried out until the solution gets converged. Then from the post-analysis window, the output values of different parameters are noted down and based on the results of the analysis.

A. Summary Result

In the previously conducted experiment, the Tensile-Shear test performed on the resistance spot weld joint yield that the maximum tensile load of the spot weld joint is, on average, 7.33KN. That means the shear stress of the welded joint is 145MPa. In the simulation of the resistance spot joint, the Shear stress of the welded joint is 77.33 MPa shows in the Table 1,2 and 3.

Serial No.	Test Specimen	Max. Tensile Load before Fracture	Shear Stress	Average Shear Stress
1	Test Specimen 1	7 KN	139 MPa	
2	Test Specimen 2	7.5 KN	149 MPa	145 MPa
3	Test Specimen 3	7.5 KN	149 MPa	

Table 1:- Tensile -Shear Test Data

Parameter	Unit	Maximum	Minimum
Normal Stress	MPa	573.38	288.85

Table 2:- Numerical Analysis Result of Base Plate.

ISSN No:-2456-2165

Parameter	Unit	Maximum	Minimum
Normal Stress	MPa	520.64	-267.05
Shear Stress	MPa	77.333	-30.131
Stress Intensity	MPa	524.54	4.4457
Normal Elastic Strain	mm/mm	0.0024496	40.0012717

Table 3:- Numerical Analysis Result of Different Parameter of the Spot Welded Joint.

V. CONCLUSION

The resistance spot welding is the fastest and cleanest welding process. It has a wide range of applications. It is more popular with the lightweight application as it does not require a filler material. This particular study focused on the numerical analysis of the spot weld joint under static load conditions, among which tensile shear explores the strength and crashworthiness of the joint. From this particular study, it found that normal stress, shear stress, stress intensity, and typical elastic strain region in the spot welded joint. The specific analysis shows where normal stress, shear stress, stress intensity, and normal elastic strain will occur for the predetermined load. By this simulation, the spot-welded joint is strictly observed, and the post result data collected form the ANSYS report section. There is an enormous scope of studies in this field, such as studying the effect of current and cycle time on joint hardness, toughness, etc. as resistance spot weld is becoming more popular day by day, so further study on such subject should be encouraged.

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