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EXPERIMENTAL AND FINITE ELEMENT ANALYSIS OF STRESS AND TEMPERATURE DISTRIBUTION ON WELDED STAINLESS STEEL PLATE

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Abstract— The present of work is aimed at the TIG process parameters selection and optimization with focus on weld sample output quality parameters namely temperature distribution, residual stresses, weld distortion. A 10 mm thick SS 316 plate of dimensions 300x150mm with TIG welding is selected as experimental investigation and four specimens with thicknesses 20, 15, 10, and 5 mm are taken for FEM analysis using ANSYS software to predict the temperature variation and thermal stresses. Also 4 different materials are included in this study to figure out the thermal stresses post welding in the specimens using simulation. For calculating the thermal stresses coupled field analysis is used, firstly transient thermal analysis is performed and the results are taken as inputs for the structural analysis.

Keywords— TIG welding, ansys, fem, thermal stress.

I. INTRODUCTION

The Stainless steel 316 (SS 316) bowl of dimension 300 mm X 150 mm X 10 mm has been used as a work piece materials for present experiment study. And ER 316L weld rods are utilized as filler components for the weld signing up for procedure. A model was produced in ANSYS (An over-all purpose FEA software program) using SOLID BRICK 8 NODE 70 (3D solid component with temperature dof) and PLANE 55 (A 2D Solid Element with 4 nodes), according to the measurements of the plate used for the experimentation. A refined mesh is manufactured predicated on the convergency requirements and the evaluation is conducted to estimate the temperature distribution. First of all a transient thermal evaluation was carried out giving high temperature flux as enough time varying insight to estimate the heat range variation. The nonlinear materials properties are fed for heat transfer solution. After that coupled field evaluation is carried out to have the residual stresses and distortion by coupling thermal evaluation to static evaluation. The variation of the heat range with time, the rest of the stresses and distortion are attained. The variation of the are talked about and reported. In adition to experimentation with ss 316, in simulation three more components are added, they are ss304, ss410, ss430. These materials are selected as these are widely used in the construction fields all the details are discussed in the further chapters.

II. LITERATURE SURVEY

In recent years, with the development of powerful computing facilities, Finite Element (FE) analysis methods have been applied to the simulation of TIG welding using commercial FE software packages.

A. About TIG welding simulation

Your research activity in welding ruse started a long time ago. Rosenthal [1], (1946) was among the first research to develop a great analytical treatment of heat move during welded based on location heat copy for guessing the shape within the weld pool area for two and three-dimensional weldings. Using the Fourier partial differential box equation (PDE) of heat location, he announced the going coordinate program to develop alternatives for the and limit heat options and utilized this efficiently to address a variety of welding concerns. His analytic solutions within the heat move made possible the first time the examination of the method from an option of the welded parameters particularly the current, power, welding quickness, and welds geometry.

Comprehension of the theory of warmth flow is vital in order to analyze the welded process analytically, numerically or perhaps experimentally. Considering that the pioneering job of Rosenthal, considerable affinity for the arctic aspects of welded was listed by many study workers such as Kamala and Goldak [2], (1993), Nguyen et approach. [3], (1999), and Komanduri and Hou [4], (2000).The most critical input data required for welding thermal analysis are the parameters necessary to describe the heat input to the weldment. Goldak et al. (1984) derived a mathematical model for welding heat sources based on a Gaussian distribution of power density. They proposed a doubled ellipsoidal distribution in order to capture the size and shape of the heat source of shallow and deeper penetrations. Some researchers have also developed the thermal finite element simulation to investigate the temperature distribution of a metal such as Kraus (1986), Tekriwal and Muzumder (1988), Yeung, and Thorthon (1999), and Bonifaz (2000).

In the last couple of years, limited element strategies have already been utilized extensively so that they can predict contortion and left over stresses because of welding functions like the tests by Friedman [5], (1975), Song and brown [6], (1992), Mechaleris and Debiccari (1997), Scott and frewin [7], (1999), and The singer et approach. (1999). Generally, the limited component technique was already proved to be an effective device to duplicate the complicated welding procedure as performed by Friedman (1975). His 2-D finite component analysis work was utilized by Taylor et al then. [8], (1999) to verify their particular 3-D computational modeling of welding phenomena. The full total results of finite element analysis completed by Taylor et al. (1999) were in fair contract with the effect obtained simply by Friedman (1975). The Freidman's work in addition has been found in this thesis as a confirmation finite component model.

Most of the welding study previously was likely conducted to investigate the dispersion of surplus tension and as well, distortion together with welded metallic. The task sang the national anthem by Mandal and Sundar (1997) for instance, estimates the most important welding shrinking in a welded butt part through the use of one specific mathematical edition strategy. Debiccari and michaleris, and Okumoto [9], (1997, 1998) conducted thermo-elasto- plastic material specific element evaluation for welded simulation to allow them to predict the most important welding daub. They have claimed that their approaches have already been proven consistent to empirical and experimental data. Utilize, Puchaicela (1998) in his content reviewed and as well, analyzed many formulas and as well, figures so that they can provide a real guidebook on the dominance and reduced amount of distortion.

Not only the welding residual stress and distortion have been studied by welding researchers, but the effects of welding variable, welding order, welding on the geometry, and root opening has also been investigated by several researchers previously. Harwig de plus al. (1999) for instance, calculated the effect relating to welding details and electrode classification inside the diffusible hydrogen content material relating to gas protected flux cored arc weldings. In 1999, Tsai et 's. studied the effect of welding sequence on buckling and warping behavior of a thin-plate panel structure. Tsai et way. (2001) have also investigated the effects of welding parameters and so joint geometry on the specifications and daily monetary service of surplus stresses concerned with thick-section behind joints. The effect of the basis opening on the topic of mechanical properties and assets, deformation and so residual stress offers been quite reported by Jang et way. (2001)

Experimentation

B. Experiment Details

The TIG welding process parameters towards the development of welded joints are fabricated developed and analysed for the weld quality parameters temperature distribution, residual stresses and weld distortions.

The TIG welding machine specification machine used in this process is shown below in table 4.

Table 4 Specification of machine

Parameter	*Specification*
Supply Voltage	*30-450Volts*
Frequency	*50*
Phase	*3Phase*
Max Input Amps(Current)	*40-80Amp*
KVA	*30*
Range of hand amps(Current)	*40-450Amps*
Shielding Gases	*Argon*
Tungsten Electrode	*2% Thoriated tungsten*
Polarity	*DC-DCEN*
Work Piece	*300x150x10mm*

C. *Experimental Results*

The experimental work is carried out on the SS316 plates of 0.3x0.15x0.01m dimensions by following the sequence of operations by varying the parameters as shown in the table 4.1

Table 4.1 Process parameters

S.NO	*PARAMETER*	*UNIT*	*LEVEL-1*	*LEVEL-2*
1	*Welding Current*	*AMP*	*70*	*80*
2	*Welding Voltage*	*VOLT*	*14*	*15*
3	*Thickness of the Plate*	*Meter*	*0.01*	*0.02*
4	*Welding Speed*	*mm/sec*	*1.5*	*2.5*

Fig 4.8 Experiment Plates

D. *Weld Experiment Data*

Table 4.2 Experimental Data

S No	*Current (Amp)*	*Voltage (Volt)*	*Area (mm2)*	*Welding Speed (mm/sec)*	*Heat Flux (W/m2)*
1	*70*	*15*	*1350*	*1.5*	*0.46E6*
2	*80*	*15*	*1350*	*2.5*	*0.53E6*

Table 4.3 Experimental results

Voltage (Volt)	*Current (Amp)*	*Area (mm2)*	*Welding Speed (mm/sec)*	*Efficiency (%)*	*Distortion (deg)*
15	*80*	*1350*	*2.5*	*0.6*	*1.3*
15	*70*	*1350*	*1.5*	*0.6*	*1*

III. SIMULATION

A. *Problem Definition*

A good Finite Element (FE) simulation of the welding process yielding the welding-induced residual stresses in a butt-welded plate is presented. In fusion welding, a weldment is locally heated by the welding heat source. Because of the non-uniform heat distribution during the thermal cycle, incompatible strains result in thermal stresses. These kinds of incompatible strains because of dimensional changes associated with solidification from the weld metal (WM), metallurgical transformations, and plastic deformation, are the sources of residual stresses and distortion. Welding-induced residual stresses and distortion can play a very important role in the reliable design of welded joints and welded structures.

Another, a radical component feinte of the welded procedure glorious the heat range distribution, welding-induced residual attaque and the disfigurement in a butt-welded plate are actually presented.

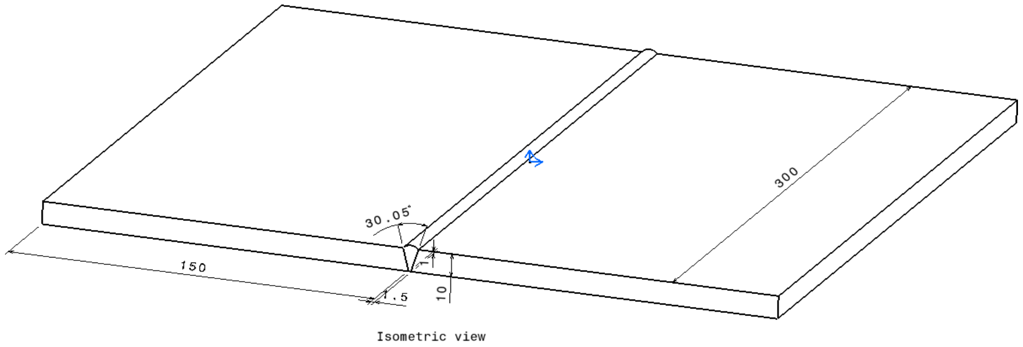


Fig Schematic diagram of welding test plate

B. Material Used

SS316 material can be used. Grade 316 may be the habitual molybdenum-bearing grade, second on importance if you want to 304 amongst the austenitic stainless steels. One of the molybdenum gives 316 better overall corrosion resistant properties come up with Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics. It is readily brake as well as roll formed into a variety of parts meant for applications inside the industrial, architectural, and vehicles fields. Grade 316 also has outstanding welding characteristics. Post-weld annealing is not required when ever welding skinny sections

To produce 316L, the reduced carbon is rather of 316 and is defense from sensitization (grain bounds carbide precipitation). Thus it really is extensively found large appraise welded elements (over in 6mm). To produce 316H, using its higher susceptible to articles is bound to have program might elevated temperature ranges, as does stable quality 316Ti. The austenitic framework gives these grades exceptional toughness also, down to cryogenic temperature ranges even. Excellent welded capability just all regular fusion strategies, both offering and without filler metals. FOR 1554. to enjoy pre-qualifies welded of 316 with Quality 316 as well as , 316L offering Quality 316L rods akan electrodes (or their full silicon equivalents). Large welded sections near Quality 316 need post-weld annealing for the optimum decay, rust, calcium, lime level of resistance. This is simply not required for 316L. Quality 316Ti may also be used instead of 316 for large section welding.

Grade 410 metal steels are general purpose martensitic stainless steels containing 14. 5% chromium, which provide good decay resistance property. However , the corrosion level of resistance of quality 410 steels could be enhanced by some processes such as for example hardening further, tempering and simply polishing. Tempering and quenching may harden quality 410 steels. They are utilized for applications involving gentle corrosion generally, warm air level of resistance and simply high power. Martensitic s / s steels are actually fabricated by using methods that demand final heat therapy. These position are much less resistant to corrode in comparison with which austenitic position. Their operating temperature ranges are affected by their loss of power at high temperatures frequently, due to over reduction and tempering of ductility at subzero temperatures.

Stainless steel grade 430 is definitely your own non-hardenable alloy containing right chromium, and so is one of the ferritic group of steels. This steel is known for its good corrosion resistance and formability, put together with practical mechanized properties. It can be used in likely chemical job applications due to its resistance to nitric acid. Grade 430F steel is usually equipped in bodega type so that it will be utilized by automatic bolt devices. May help you 434 would have identical belongings as may help you 430, though it is usually the new molybdenum shouldering edition. My molybdenum content material enhances the dog's corrosion resistant.

C. Material Properties

Several different material have been used in structures where welding is involved, with low carbon steel being the most common. The weldment material properties employed in this work were of SS316.

Environment dependent material properties were definitily needed inside analyses. These modulus pertaining to elasticity is definitely a measure of the rigidity of a material. A higher modulus material is going to be more likely into resist contortion. The amount of expansion or inquiétude of a metallic will endure during a heating system or an air conditioning cycle depends on the ratio of high temperature expansion. High temperature conductivity gives a measure of a new ease of power circulation by using a material.

The selected material properties are Young's Modulus, Poisson's ratio, thermal conductivity, specific heat, thermal expansion coefficient and density The table 6.1 below gives the t material properties of all materials used in this study.

Table 6.1 material properties

T (K)	*E (GPa)*	*Density*	*□ 0 (10-6/0C)*	*K (W/m 0K)*	*C (KJ/Kg 0K)*
Ss 304	*193.*	*8000*	*15.2*	*16.20*	*500.0*
Ss 316	*193*	*8000*	*15.9*	*16.3*	*500.0*
Ss 410	*200*	*7800*	*9.9*	*24.9*	*460.0*
Ss 430	*200*	*7750*	*10.4*	*26.1*	*460.0*

Based on the results from the simulation and analysis, the simplified modeling process for simulating welding-induced residual stresses and distortion using a general-purpose FE package described here is reliable and instructive.

IV. RESULTS AND DISCUSSIONS

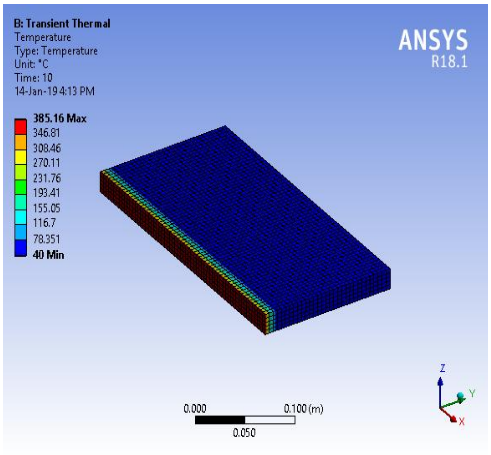
1. Use symmetrical feature of the model to reduce the program running time and space required

2. Simulating the 3-D effect of that arc traveling by applying your ramped temperature input celebration. Adopting uncoupled thermal and stress analyses, the heat history results are read from the thermal analysis as loading to the stress analysis. That thermal analysis should be transient to trace that rapid modification of heat with time while a static analysis can be adopted to get the stress evaluation. However, a significant number of time period points, at which the heat results are to generally be read into the stress evaluation, should be identified to capture that heat gradient and give exact residual anxiety results applying the load procedures option.

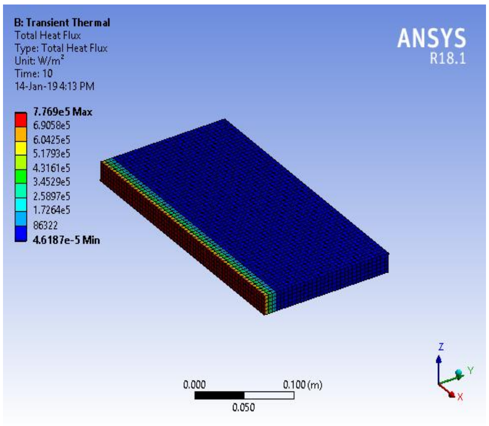
3. Radiation and latent heat from phase transformation can be ignored to simplify the modelling procedure.

A. Thermal Results

Transient thermal analysis of 20 mm plate made with ss304 material



Temperature distribution



Total heat flux

B. Tables

- Table representing the simulation results for SS 304 material at different plate thicknesses

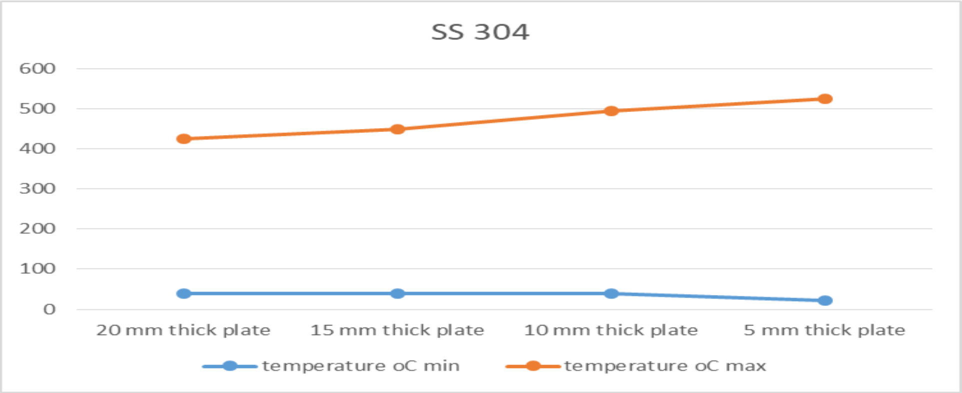
SS 304	temperature oC		heat flux W/m2		total deformation (m)		equivalent elastic strain(m/m)		equivalent stress (Pa)	
	min	max	min	max	min	max	min	max	min	max
20 mm thick plate	40	385.16	4.62E-05	7.77E+05	0	0.000105	3.71E-08	0.014562	7164.7	2.81E+09
15 mm thick plate	39.826	408.43	4.99E-05	8.30E+05	0	0.000106	7.28E-08	0.015099	14045	2.91E+09
10 mm thick plate	39.785	455	0.000285	9.36E+05	0	0.000111	9.10E-08	0.016125	17562	3.11E+09
5 mm thick plate	22	503.63	8.79E-05	6.37E+06	0	3.82E-04	1.66E-08	0.019092	2292.1	3.75E+09

- Table representing the simulation results for SS 316 material at different plate thicknesses

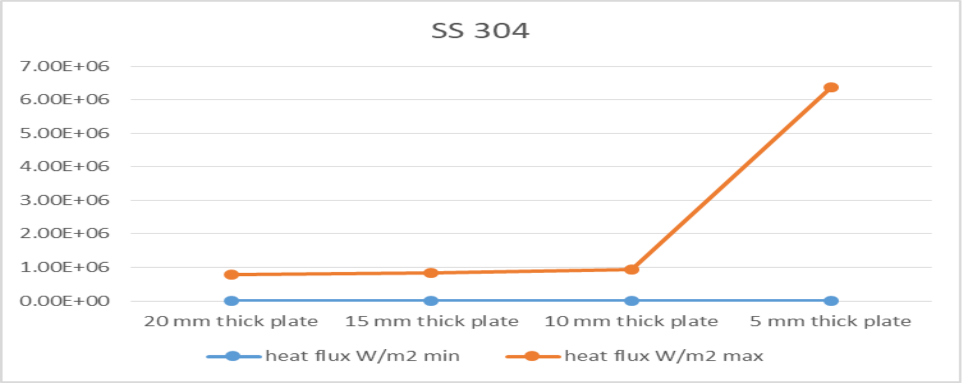
SS 316	temperature oC		heat flux W/m2		total deformation (m)		equivalent elastic strain(m/m)		equivalent stress (Pa)	
	min	max	min	max	min	max	min	max	min	max
20 mm thick plate	39.838	384.05	9.85E-05	7.77E+05	0	9.66E-05	5.84E-08	0.013429	11279	2.59E+09
15 mm thick plate	39.826	408.43	4.99E-05	8.30E+05	0	0.000106	7.28E-08	0.015099	14045	2.91E+09
10 mm thick plate	39.78	453.72	0.000164	9.36E+05	0	0.000103	8.37E-08	0.014877	16154	2.87E+09
5 mm thick plate	39.626	592.4	0.000752	1.25E+06	0	0.000117	7.16E-08	0.017508	13812	3.38E+09

C. Graphs

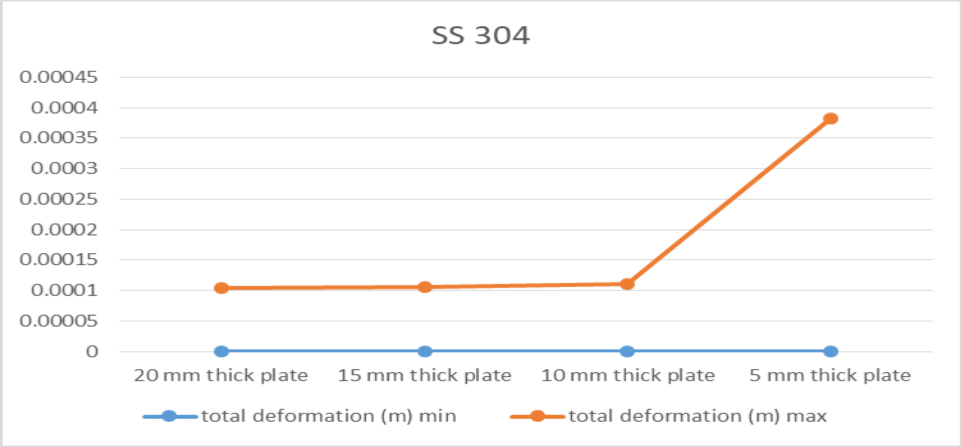
- Graph representing the simulation results for SS 304 material at different plate thicknesses



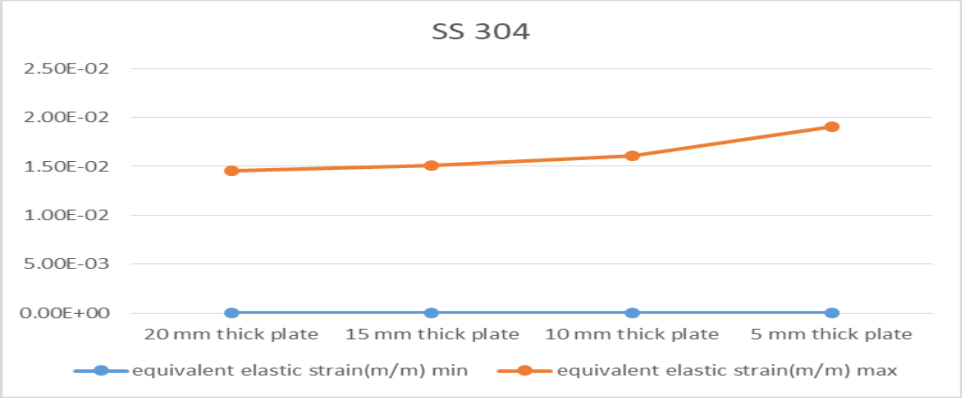
Graph representing temperatures



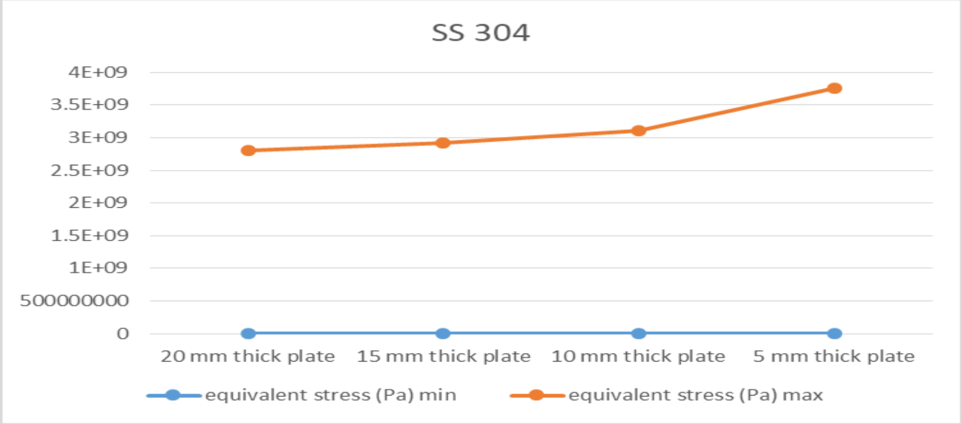
Graph representing heat fluxes



Graph representing deformations



Graph representing strain



Graph representing stress

V. CONCLUSIONS

VI. Development of a 3-dimensional coupled thermo-mechanical finite element model of a TIG welding process was described in this work.

1. By conducting experiments with weld parameters the heat flux is calculated and is used as input for the finite element analysis in butt-welding of plates.
2. Analysis of this weld joint gives useful information for the modeling of the process under different process conditions without carrying out real experiments on the machine, this saves money, time and resources.
3. The results obtained from the welding process simulation explain about the temperature and stress distributions from the weld region to the other regions.
4. Maximum temperature of 503°C was observed by applying the heat flux value of 0.84x106 W/m2
5. Variation of temperature by varying welding voltage, joint efficiency and thickness of the weld plate is observed.

6. The temperature is gradually increasing from 294 to 370 o C as the voltage is varied from 12 to 15V
7. The temperature is gradually increasing from 320 to 501 o C as the joint efficiency is varied from 0.6 to 0.9
8. The temperature is gradually decreasing from 372 to 271 o C as the thickness of the plate is varied from 10 to 25mm
9. Coupled field analysis is carried out to estimate the residual stresses. The maximum induced stress observed due to the temperature distribution of 503 o C is 136 MPa.
10. Temperature is accumulating more and more as the thickness is decreased
11. Stress are gradually increasing with decrement in thickness, this could be a result of temperature accumulation.
12. As the thickness is reducing the net volume is also reducing, as specific heat doesn’t change higher temperatures are recorded in the plates with low thickness
13. In the similar passion stress are also increasing because of higher thermal gradient
14. Here we are not comparing the materials because we are studying the thermal stress behavior of the materials by varying the plate thicknesses.
15. To reduce thermal stress in thin plates, some assistance must be provided for better removal and quick removal of heat from the works piece.
16. The resultant distortion observed in the weld plate is 0.043mm

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