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Thermal And Structural Analysis Of Friction-Welded Dissimilar Materials

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Abstract

Continuous direct drive friction welding is one of the methods in solid-state metal joining techniques, which finds a variety of applications in various industries. In this work, the relation between the response (Tensile Strength) and the input parameters were studied for the weld between low and medium carbon steel. Temperature distribution plays a vital role in determining the integrity of the weld joint. To evaluate the joint properties, the interface temperature was measured during the course of welding process. Thermal and structural analyses were performed and suitable comparisons were made using QuickField analysis program. It was observed that maximum strength value was obtained during optimum input parameter setting of high friction and upset pressure, low burn-off length and medium rotational speed. The dependence of tensile strength over heat flux was also analyzed.

Keywords— Friction pressure, Friction welding, Heat flux, Structural analysis, Temperature, Tensile strength, Thermal analysis.

I. Introduction

Conventional welding process is not feasible for dissimilar metals due to wide differences in melting point, thermal properties mismatch etc. In order to overcome these disadvantages, a solid-state metal joining technique was developed. Continuous direct-drive friction welding is a technique in which one of the workpieces is held stationary and the other is held in a rotating chuck with a specified rotational speed. The intimate contact between the two workpieces creates frictional heat for a certain period of time. On application of axial pressure (upset pressure) through the stationary workpiece, plastic deformation of the materials creates a permanent weld of the two materials. This type of joining technique is being used in different industries because of lesser material wastage, low production time and the possibility to weld dissimilar metals or alloys [1]. The most interesting parameters in friction welding are friction time, friction pressure, upset time, upset pressure and rotation speed [2]. Manideep et. al studied the austenitic and ferritic stainless steel combination using different process parameters [3]. The deformation is confined to ferritic stainless steel. Amit Handa et. al studied the mechanical characteristics of dissimilar metals AISI 304 and AISI 1021. The experimental research revealed that axial pressure has significant effect on mechanical properties of the joint [4]. Anantha Padbanaban et.al reported the experimental studies on effects of friction welding parameters on Mild steel and stainless steel joints [5]. Mumim studied that hardness variation and microstructure at the interface of the steel joints [6]. Mumin Sahin simulated the friction welding of similar metals AISI 1040 by developing a computer program [7]. Ahmet CAN et. al thermically evaluated and modeled the friction-welded joints of AISI 1040 using QuickField [8].

From the literature it is understood that the published works were concerned with the mechanical and metallurgical studies. Very less systematic study has been carried out to correlate the temperature and the joint properties of dissimilar friction welded joints. Hence, in this present investigation, friction welding was performed on dissimilar metals and simulations of thermal and mechanical stresses were performed using QuickField.

II. Experimental Procedure

A. Material and Methods

The base materials, AISI316L and EN 08 steel, used in this study, were cylindrical rods of 22 mm in diameter 22mm and 75mm in length. Prior to welding, the faces of the specimens were cleaned with acetone to remove rust and foreign particles, which would otherwise adversely affect the joint properties [9]. The chemical composition, mechanical and thermal properties are presented in Table 1 and Table 2 respectively.

Material	C (%)	Si (%)	Mn (%)	Ni (%)	Cr (%)	Mo (%)	S (%)	P (%)
EN 08	0.38	0.15	0.7	-	-	-	0.06	0.06
AISI 316L	0.03	0.75	2	12	16	-	0.030	0.045

Table 1. Chemical composition of base materials

Grade	Tensile Strength (MPa)	Yield Stress 0.2% Proof (MPa)	Poisson's Ratio	Young's Modulus (GPa)	Thermal Conductivity (W/mK)
SS316L	485	170	0.305	193	17
EN 08	550	280	0.303	205	52

Table 2. Mechanical and thermal properties of base materials

The continuous direct drive friction welding machine which was used during this process had a stroke length of 300mm, maximum set up force of 200KN, spindle motor of 20HP and operating speed up to 2500rpm was used to weld the workpieces. The process parameters were selected based on previous literatures and trials. To minimize the number of trials Taguchi array was used. The weld joints were machined as per the guidelines of American Society for Testing and Materials (ASTM) before tensile testing.

III. Results And Discussions

To analyze the joint properties, tensile strength is one of the main responses. In order to evaluate the joint properties, temperature distribution and heat flux across weld zone, heat affected zone and parent zone are important. Temperatures at the interface were measured directly using an infrared thermometer during the course of the experiment. Table 3 gives the parameters of the friction welding process and interface temperature of samples having low, medium and high tensile strength.

S.NO	Friction Pressure (MPa)	Upset Pressure (Mpa)	Speed of Rotation (RPM)	Burn off Length (mm)	Tensile Strength (MPa)	Interface temperature (°C)	Maximum Heat Flux (x 10^5 W/m^2)	
							EN 08	AISI 316L
Sample 1	95	118	1000	3	548.09	479	3.15	1.2
Sample 2	118	130	1500	5	603.51	592	4	1.5
Sample 3	141	141	1500	3	648.67	512	3.4	1.3

Table 3. Parameters of the weld joint and its results

The tensile strengths were determined using an electromechanically controlled Universal Testing Machine. The tensile testing revealed that the failure occurred at AISI 316L region as shown in Figure 1.

Fig.1. Fracture zone of the specimens after tensile testing

A. Finite element modeling of weld joints

For the simulation of thermal and mechanical stress, "QuickField" analysis software by TERA Analysis Ltd., was used. A 2D model of the specimen was created using AutoCad and imported into the QuickField program in DXF format. Properties such as Young's modulus, thermal conductivity, convective heat transfer coefficient, Poisson's ratio and maximum allowable stresses were given as input. The boundary conditions were set to the model and the problem was solved. In thermal analysis, the specimen was subjected to conduction along its length on both faces and convection at the top and bottom surfaces. In structural analysis, one end of the sample was fixed and the other end was subjected to a pressure perpendicular to the face, to simulate the conditions of tensile testing. Results such as Heat Flux, Von Mises stress and temperature were derived at the end of the simulation. The relationship between Heat flux and Von Mises stress was established. Cenk Misirli et.al shows the effects of temperature at the weld joint on the mechanical and metallurgical properties of the joint. Simulation has been carried out and has substantiated it [10]. An analytical temperature solution was presented in an article based upon a weld piece and ambient temperature at chuck by Rich, T. and Roberts, R. [11]. Sluzalec [12] followed by Moal [13] developed a FEM code computing the strain and stress fields in the welded components. Also, Fu and Duan [14] carried out a coupled deformation and heat flow analysis using FEM.

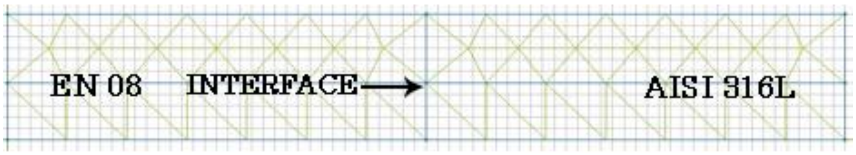

Fig.2. Meshing of two materials

The 2-D meshed model of the specimen is shown in Figure 2. The temperature of the chuck was found to be 55^{0}C and the clamp temperature is approximately 40^{0}C immediately after welding. These temperatures were used as boundary conditions during thermal analysis. Applying ambient temperature as boundary condition, convective heat transfer into air was simulated.

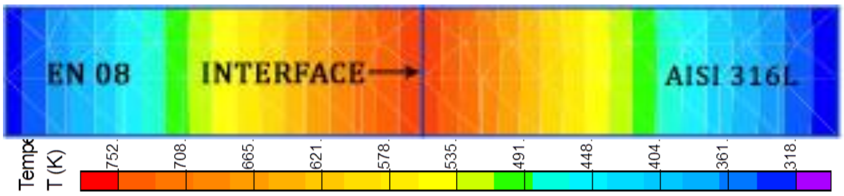

Fig.3. Temperature distributions for Sample 1

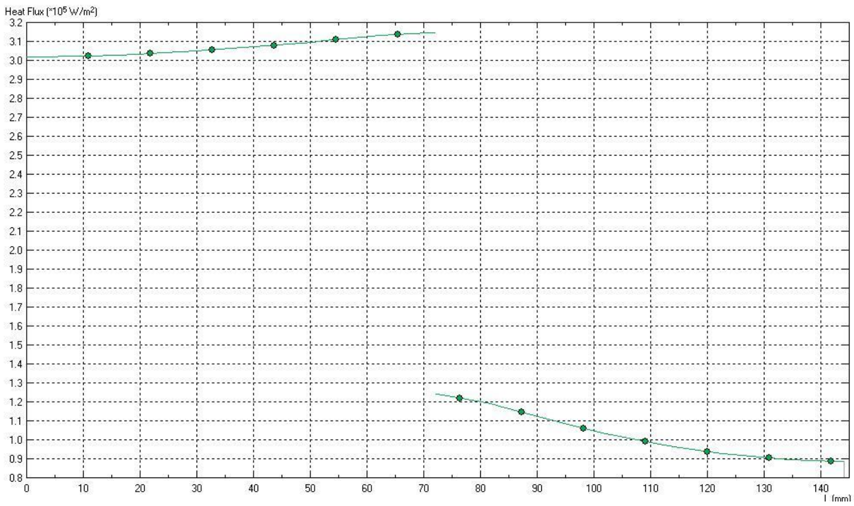

Fig.4. Heat flux variation for Sample 1

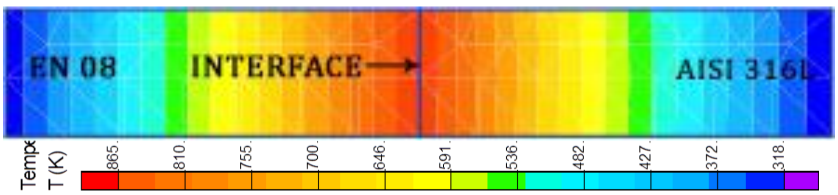

Fig.5. Temperature distribution for Sample 2

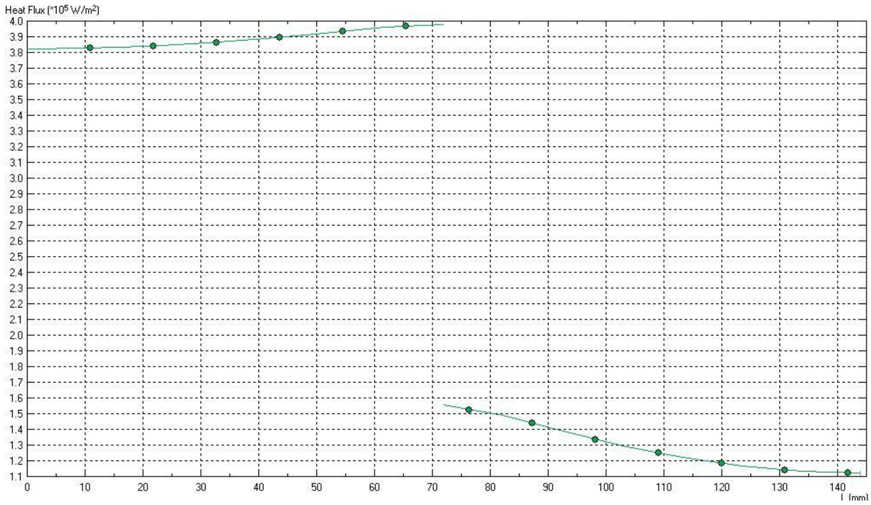

Fig.6. Heat flux variation for Sample 2

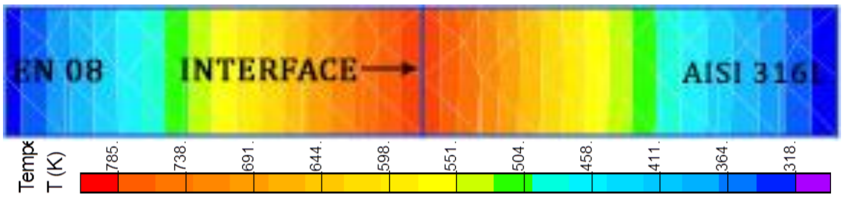

Fig.7. Temperature distribution for Sample 3

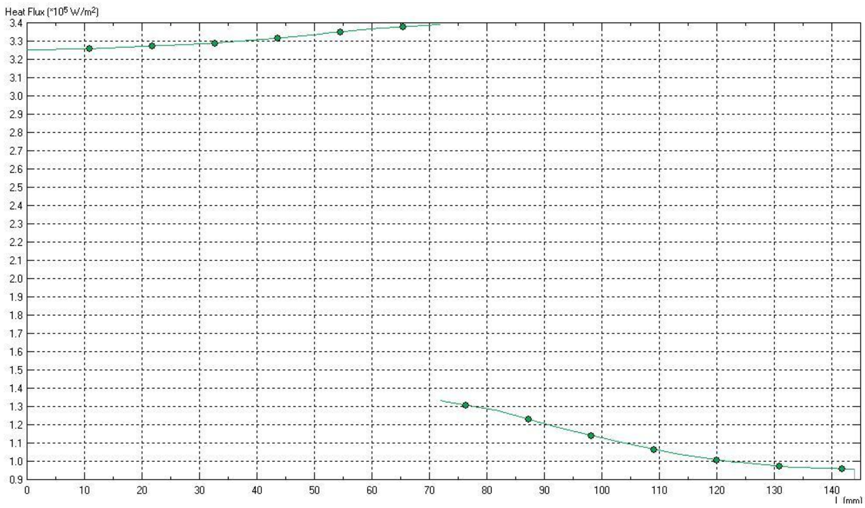

Fig.8. Heat flux variation for Sample 3

B. Structural Analysis

During experimental determination, failure took place at the stainless steel region during tensile testing. It was due to the low ductility of the stainless steel. This implies that stress values in stainless steel region are high compared to EN 08. This statement was validated by a simulation. The deformation characteristics of the specimen during the simulation were quite similar to that of experimental failure.

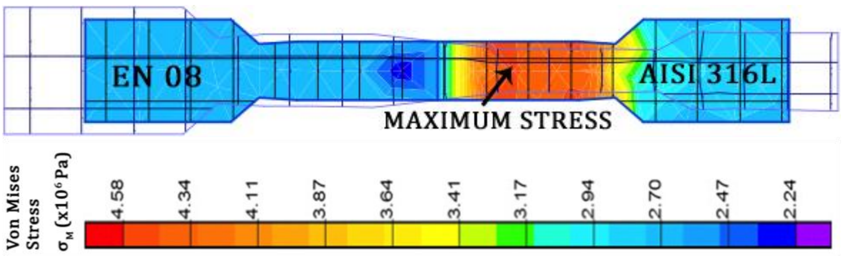

Fig.9. Simulation of tensile testing for Sample 1

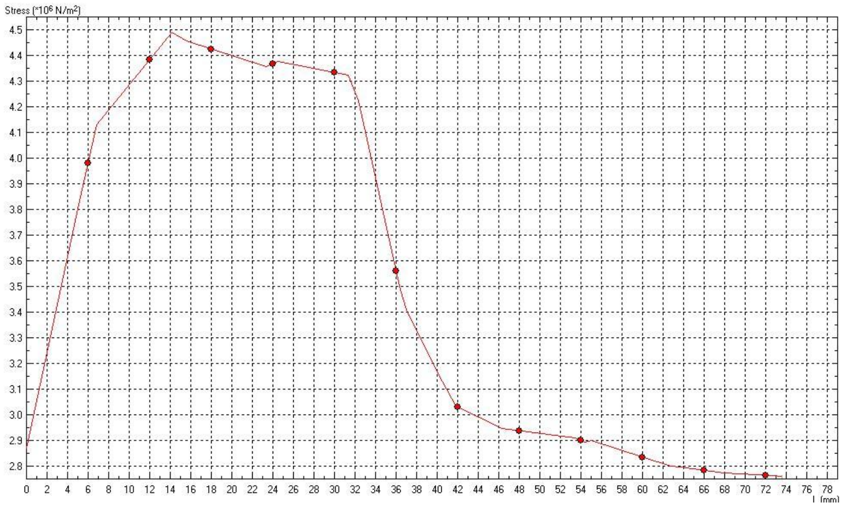

Fig.10. Variation of stress along the length of Stainless Steel specimen

It is inferred that the maximum stress value occurred at a distance of 18 mm towards the right of the interface, which closely agrees with the experimental results. The heat flux values for EN 08 were higher whereas, the Von Mises stress for the same is comparatively lower for the same sample. This proves that the Von Mises stress and heat flux are inversely proportional. The figure 8 & 9 shows the stress analysis for low and high tensile strength specimens.

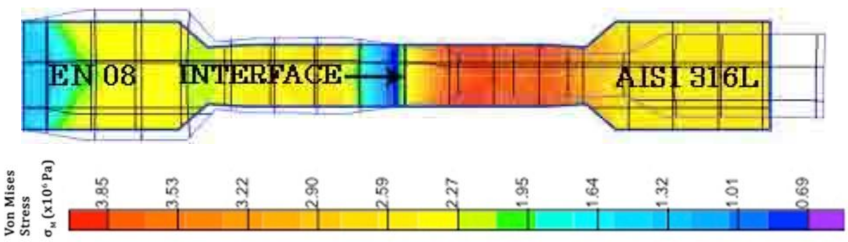

Fig.11. Simulation of tensile testing for Sample 3

IV. Conclusion

- It is found that the heat flux values for EN 08 were found to be way higher compared to that of AISI 316L.This is due to the fact that heat flux directly depends on the thermal conductivity of the material. Since EN 08 has higher thermal conductivity compared to AISI 316L, heat flux for EN 08 is found to be higher.
- Weld joints of dissimilar metals (AISI 316L and EN 08) were made using continuous direct drive friction welding technique.
- Maximum tensile strength of 648 MPa was obtained experimentally using an Universal Testing Machine. Failure took place at stainless steel region after friction welding.
- The fracture of all the three samples took place away from the weld joint, which shows the integrity and reliability of the joint.
- Interface temperatures were determined experimentally. Temperature distribution and structural analysis was made by QuickField analysis.
- Tensile strength is based on the temperature distribution and heat flux.
- Heat flux was more on the medium carbon steel side EN8 side owing to its high thermal conductivity

During tensile testing, the fracture of AISI 316L occurred 20 mm away from the weld interface. Simulation result shows that the fracture of AISI 316L occurring at a point 18mm away from interface which closely agrees with experimental value.

V. References

[1] Sahin M., 2004, "Simulation of friction welding using a developed computer program", Journal of Material Process Technology, 153(4), pp.1011–1018.

[2] Vill., 1962, "Friction Welding of Metals", AWS, Newyork.

[3] Manideep D and Balachandar.K, 2012, "Welding Parameters-Metallurgical Properties Correlation of Friction Welded Austenitic Stainless Steel and Ferritic Stainless Steel", Journal of applied sciences., pp.1013-1019.

[4] AmitHanda and VikasChawla., 2013, "Mechanical characterization of friction welded dissimilar steels at 1000 rpm", Materials Engineering - Materiálovéinžinierstvo20., pp.102-111

[5] Ananthapadmanaban D., 2009,"A study of mechanical properties of friction welded mild steel to stainless steel joints", Materials and Design., pp.2642−2646.

[6] Mumim S., 2007, "Evaluation of the joint interface properties of austenitic stainless steel joined by friction welding", Materials and Design., pp.2244−2250.

[7] Mumin S., 2004, "Simulation of Friction welding using a developed computer program", Journal of material processing and technology., pp.1011-1018

[8] Ahmet CAN., 2009, Mumin SAHIN and Mahmut KUCUK, "Thermically Evaluation and Modelling of Friction Welding", Strojarstvo51.,vol. 1, pp.5-13.

[9] P.Sathiya, S.Aravindan and A.Noorul Haq., 2005, "Mechanical and metallurgical properties of friction welded 304 stainless steel", International Journal of Advanced Manufacturing Technology, vol. 26, pp.501-511.

[10] Cenk Misirli , Mumin Sahin, Hilmi Kuscu., 2012, "Temperature Determination of St-Al Joints During Friction Welding", Advanced Materials Research., vol. 463-464, pp.1538-1542.

[11] Rich, T, Roberts, R., (1971), "Thermal Analysis for Basic Friction Welding", Metal Construction and British Welding Journal., pp.93- 98.

[12] A. Sluzalec., (1988), "Thermal effects in friction welding", International Journal of Mechanical Science., vol. 32 (6)., pp.467–478.

[13] A. Moal., 1992, "Modélisation numérique par la méthode des éléments finis du soudage par friction inertielle", Ph.D. Thesis, ENSMP-CEMEF.

[14] L. Fu, L. Duan., 1998, "The coupled deformation and heat flow analysis by finite element method during friction welding", Welding Jounal Research Supplement., pp. 202–207.