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Temperature Determination of St-Al Joints During Friction Welding

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Abstract. The joining of dissimilar materials is of great importance in industry. Especially, if it is used as the lightest part of the machine parts, materials such as aluminum and magnesium can be joined with steels. Friction welding is one of the methods getting higher share among the other welding methods. In the process, heat is generated by conversion of mechanical energy into thermal energy at the interface of the work pieces during rotation under pressure. Some of the advantages of friction welding are high material save, low production time and being possible of welding of parts which are made by different metals or alloys. Friction welding can also be used in order to join the components that have circular or non circular cross – sections. In this study, stainless-steel and aluminum materials which is the example material was used in the friction welding experiments. The temperature distributions are experimentally obtained in the interface of joints that is formed during friction welding of joints having same geometry. This study was made using thermocouples at different locations of joint-interface.

Introduction

All Heat is generated by the conversion of mechanical energy into thermal energy at the interface of the work pieces during rotation under pressure in the friction welding method. Some advantages of friction welding are that is economical as regards material, it requires low production time and it offers greater possibilities when it comes to the welding of different metals or alloys. Friction welding can also be used in order to join components that have circular or non circular cross-sections. The most interesting parameters in friction welding are friction time, friction pressure, upset time, upset pressure and rotation speed [1].In general, friction welding is divided into two methods: continuous drive friction welding and inertia friction welding.

Many studies have been published in this area, and these are given below: Vill [1] directed a study on the friction welding of metals. Rich et al. [2] presented an analytical temperature solution based upon a finite welding piece and ambient temperature chuck ends. They discussed the establishment of the boundary conditions using the continuous drive method to join AISI 4140 steel tubes. Imshennik et al. [3] examined the heating properties in friction welding. Healy et al. [4]carried out an analysis of frictional phenomena in the friction welding of mild steel. Kinley [5] directed a study on the friction welding set-up. Sluzalec [6] developed a finite element model to simulate this process and to represent the work pieces and surface contact conditions. The predictions of the temperature distribution, thermal expansion and thermo-plastic stresses were obtained from this model. The comparison of the analytic results to the test data were presented and discussed by the author. Nentwig [7] investigated the effect on cross section differences of components on the joint quality of friction welding and stated that friction pressure, upset pressure and rotation speed must be changed in the friction welding of the different cross-sections. Bendzsak et al. [8] investigated a numerical model in friction welding. Fu et al. [9] carried out an analysis of the coupled thermo-mechanical problem during friction welding by using a finite element method, according to the constitutive relation of a large elasto-plastic deformation and the principle of the virtual work in their studies. Then, the heat flow and stress-strain process at the heating stage of the friction welding were simulated, and the law of the variation of temperature, stress and the strain fields during friction welding were systematically investigated by the authors. In this study, AISI 304 stainless-steel and aluminum were used in the experiments. However, the temperature distributions are experimentally obtained in the interface of the joints that is formed during the friction welding of St-Al joints with the same geometry. This study was carried out by using thermocouples at different locations of the joint-interface. The results obtained were compared with previous studies and comments were made.

The Experimental Procedure

The Experimental Set-up. The set-up was designed and constructed according to the principals of continuous drive welding machines. A drive motor with 4 kW power and 1410 rpm was selected as adequate for the torque capacity in the friction welding of the steel bars within 10 mm. diameter taking into account the friction and the upset pressures. The set-up was designed and constructed according to the principals of continuous drive welding machines. A drive motor with 4 kW power and 1410 rpm was selected as adequate for the torque capacity in the friction welding of the steel bars within 10 mm. diameter taking into account the friction and the upset pressures.

Test Parts and Geometry of Parts. In the experiments, AISI 304 austenitic-stainless steel and aluminum materials were used. The chemical composition and tensile strength of austenitic stainless steel is given in Tables 1. Table 2 also shows chemical composition obtained using chemical analysis and tensile strength of aluminum used in the experiment. The experiment specimens were machined from AISI 304 steel and aluminum on the geometry below.

Table 1. Chemical Composition And Tensile Strength Of Austenitic-Stainless Steel

Material	% C	% P	% S	% Mn	% Si	% Cr	% Ni	Tensile Strength(MPa)
AISI 304 (X5CrNi1810)	<0,07	< 0,045	<-0,03	<2,0	< 1,0	17-19	8,5– 10,5	825

Table 2. Chemical Composition And Tensile Strength Of Aluminum

Aluminium	
0,005	% Sn
0,0336	% pb
1,14	% Zn
0,118	% Mn
0,574	% Fe
0,0122	% Ni
0,554	% Si
0,171	% Mg
0,003	% Sb
0,0242	% Cr
0,0134	% Ti
0,593	% Cu
96,76	% Al
200	Tensile Strength (MPa)

Selection of the Optimum Parameters. The parameters used for joining the test parts in this study are the optimum parameters obtained in a previous study successfully carried out by the author [10] and these optimum parameters were used in these experiments. Therefore, optimum parameters are friction time= 4 sec., friction pressure= 30 MPa., upset time = 12 s and upset pressure = 60 MPa.

The Measurements of the Temperatures. In this study, 4 pieces of ϕ1mm diameter holes to aluminum part having ϕ 10 mm diameter were machined with the wire electrical discharge machining method to perform the temperature measurement in the friction welding experiment. The position of the thermocouples is shown schematically in "Fig. 1". To the each of these holes, thermocouples, made from thin wires, which have two different compositions, were inserted from the back of the specimen to the welding surface. Electrical insulation was obtained with a slow-drying adhesive so as not to cause a short circuit between the thermo-element wires, inserted to the thin hole, and the metal rod. One end of the thermo-element couple was connected to an environment with the same type thermo-element, at the identified temperature and taken as reference, in order to carry out temperature compensation. After this temperature compensation, the obtained value from the thermo-element in the test specimen was instructed by a 4-channelled data logger and was then registered to a database to obtain data at every second for each channel with time dependence. A DataTaker DT8 data register was used for these registering processes. Friction welding was carried out in the continuous drive friction machine. When the experiment was started, the friction welding machine was first operated for about 4 seconds. The two parts were then pressed together under an applied pressure (30 MPa), and the temperature changes in the interface of joints were monitored using the thermocouples installed in the specimens. The temperature data was acquired through a data-logger. After the motor stopped, pressure was increased to 60 MPa. The latter pressure was maintained until the parts cooled down (12 seconds). The temperature changes in the interface of joints were monitored until the temperature decreased to the levels below room temperature.

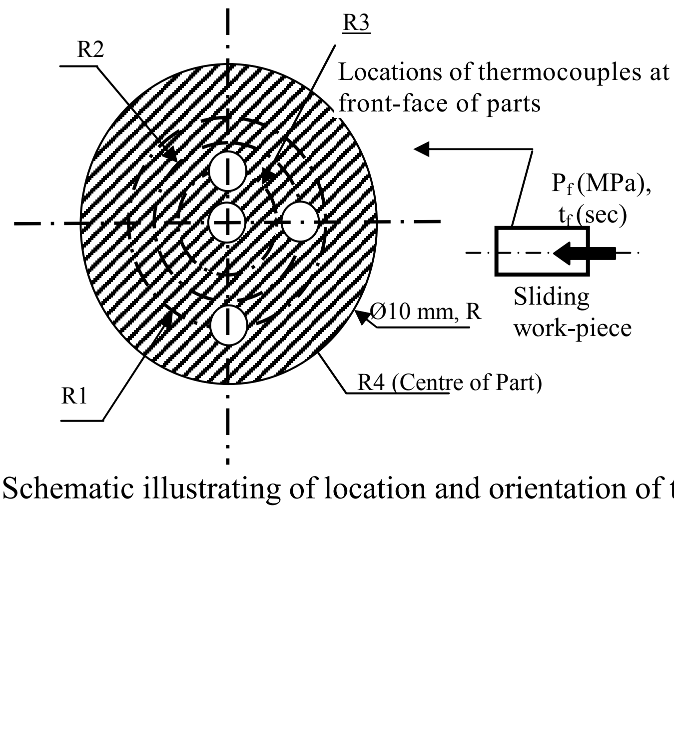

Figure 1. Schematic illustrating of location and orientation of thermocouples

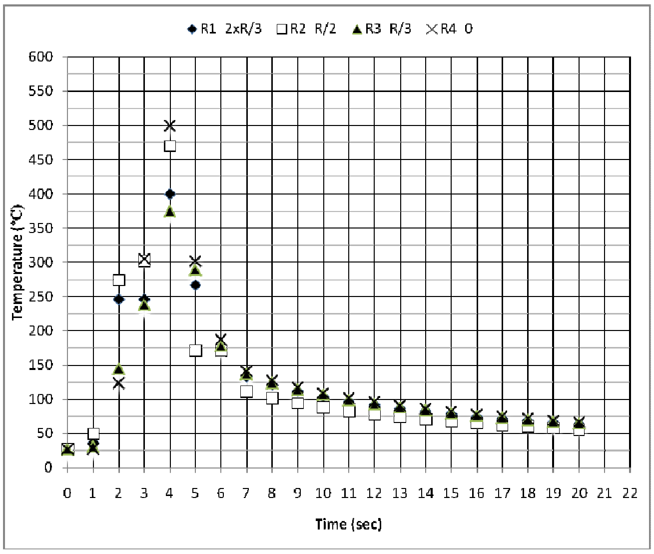

Figure 2. Measured temperature values in friction welds

Results and Discusions. The sensor of the data register was changed with the thermo-elements and calibrated according to sensors relatively. This calibration work was carried out by a sensitive digital gauged thermo furnace at the Mechanical Engineering Department Laboratories of Trakya University. The friction welding specimens that will be used in the friction welding and into which the thermo-element was located were connected to the data register computer. The values which have intervals of 100 °C beginning from room temperature were read from the monitor. With the help of interpolation and by using those calibration values, this gave an opportunity to read higher temperature values occurring in the friction welding. The obtained temperature values in the experiments are given in table 3.

Consequently, because of the separate registration for these values of each channel for each second, the temperature variation graphic obtained from the datum is given in "Fig. 2".

The temperatures rise up to a maximum value during a time period of 4 sec. of the frictional contact. They then remain at a somewhat steady state level at the end of the heating stage and during the forging stage. Thus, steady conditions are approached during the deformation stage.

Table 3. Temperatures Values Obtained In The Experiments

Time (sec)	Temperatures (0C)			
	R1=2xR/3	R2=R/2	R3=R/3	R4=0
0	27	29,99	27,01	27
1	36,9	49,82	30,86	27,53
2	246,23	273,74	144,66	124,01
3	246,23	301,67	237,7	304,88
4	400	470	375	500
5	267	171	289	302
6	172	171	178	187
7	133	111	137	141
8	121	101	124	128
9	112	94	114	117
10	104	88	107	109
11	97	82	99	102
12	92	78	93	96
13	87	74	88	91
14	83	70	84	86
15	79	68	80	82
16	75	65	76	78
17	72	62	73	75
18	69	60	70	72
19	66	58	67	69
20	64	56	65	67

Conclusions

In this study, temperature variations were measured at different points by thermocouples.

The variations in the welding pressures primarily affect the rate of the deformation of the rubbing surfaces and the temperature gradient.

Temperature has a substantial effect on the mechanical and metallurgical properties of the joint.

It is important to note that the measurement process was successfully accomplished in this study although it was particularly difficult to obtain a temperature measurement due to the large deformations at the interface.

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