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Mechanical Characterization of Friction Welded AISI 304 Steels

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Abstract

There are many industries where austenitic stainless steel needs to be welded specially in power generation industries. Unfortunately the austenitic stainless welding has several fabrication and metallurgical drawbacks when welded by using conventional fusion welding methods, which can often leads to in-service failure. The most pronounced fabrication faults are hot cracks due to inadvertent use of incorrect welding electrodes, primarily carbon steel electrodes. The use of carbon steel electrode results in the formation of very hard, crack-susceptible bulk structure on the stainless steel side. Such hard and brittle zones may render to localized pitting corrosion attack, hydrogen embrittlement, sulfide stress cracking, and stress rupture. Thus conventional fusion welding of many metalsare not feasible owing to the formation of brittle and low-melting inter-metallic. Solid state welding processes that limit extent of intermixing are generally employed in such situations. Friction welding (FRW) is one such solid state welding process that can be employed in such situations. In the present investigation an experimental set-up was made in order to achieve friction welding of plastically deformed AISI 304 steels.In this experimental study austenitic stainless steel (AISI 304) was welded under different welding parameters and afterwards the mechanical properties such as tensile strength, impact strength and hardness were experimentally determined. It is the strength of welded joints, which is fundamental property to the service reliability of the weldments and hence present work was undertaken to study the influence of axial pressure and rotational speed in friction welded joints.

Keywords: Friction Welding; Axial Pressure; Rotational Speed; Mechanical Characterization; AISI 304 steel.

Introduction

Welding is one of the fast growing principal technologies used for joining materials which is almost used by all the fabricating industries.There are stringent needs of today’s fabrication industry demand the use of cost effective materials and procedures apart from quality and safety standards. Friction welding is one of the versatile and well established welding processes [1] that are capable of giving good quality welds; it gives solid state joining of the materials through the controlled rubbing of the interfaces. Due to thus produced heat softens the material and brought the localized faces into the plasticized form which results in good quality welds [2]. In this process heat energy is produced by the inter conversion of mechanical energy into thermal energy at the interfaces of the rubbing components [3]. Thus friction welding is a class of solid-state welding process that generates heat through mechanical friction between two components where metallic bonding is produced at temperatures lower than the melting point of the base metals with a relative velocity, a load, normal to the welding plane, is applied to plastically displace and join the materials. In friction welding two work pieces are brought together under load with one part rapidly revolving. Frictional heat is developed at the interface until the material becomes plastic, at which time the rotation is stopped and the load is increased to consolidate the joint. A strong welded joint is formed by metallic bonds that arise between the contacting surfaces. The surface films and inclusions are broken up by friction and removed from the weld area, in radial direction, such that they don’t interfere in the formation of bonds so that a marked plastic deformation takes place on the surface. Mechanical energy is directly converted into heat which is liberated on the rubbing surfaces and rapidly arise the metal to a temperature necessary to produce a welded joint.

Experimental Set-up

Experimental set-up used for friction welding consists of a heavy duty lathe machine having foot brakes so as to cease the motion when friction welding takes place. A load cell was designed [4] and fitted on the lathe machine for measuring axial pressures.Test samples with 20mm diameter and 100 mm length were prepared for friction welding experiments. Prior to friction welding the contacting surfaces was faced on the lathe machine and then cleaned using Acetone [5]. The rotational speed for this study selected was 1000 rotational speed [5]. The required rotational speed was set by the levers attached on this machine. Within a fraction of seconds, the constant speed was achieved; subsequently the axial alignment of the specimens was checked. Then the axial pressure was applied. The welds were prepared at different axial pressures in the steps of 15MPa starting from 75MPa to 135MPa to form different welds for the study. The welding joint so formed was allowed to cool down for 4-5 minutes. In this way, necessary number of weldments were prepared and subjected to various tests for evaluation of their mechanical characterization. Figure 1 shows the friction welding of the specimens.

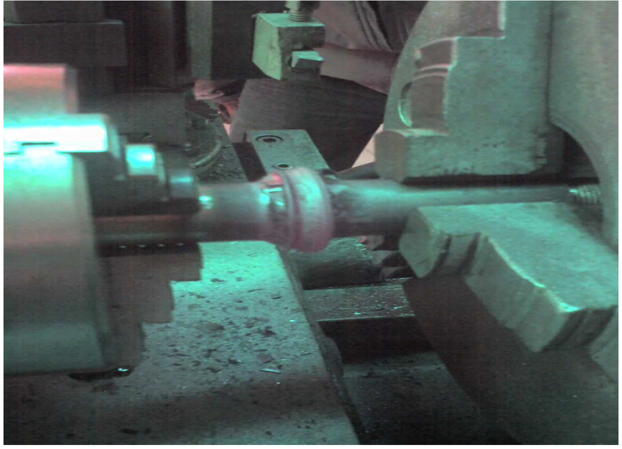

Fig. 1 Shows the Friction Welding of AISI 304 Specimen.

AISI 304 bars were selected for the present study; these austenitic stainless steel bars were selected due to their wide application in the manufacturing industry and their corrosion resistant properties. Table no 1 Shows the nominal and actual chemical composition of the material after conducting spectroscopy.

Table 1 Chemical Composition of Austenitic Stainless Steel

	Metal	Cr	Ni	C	Mn	Si	P	S	Fe
NCC	AISI 304	17-20	9-13	0.08	2	0.75	----	----	Balance
ACC	AISI 304	17.350	10.241	0.04	1.880	0.782	0.021	0.020	Balance

Mechanical Testing

Welded joints were subjected to variety of mechanical tests to determine their suitability for the anticipated service applications. They were necessary to carry out so as to ensure the quality, reliability and strength of the weldment. There are two methods of testing the quality of the friction welded joint; destructive testing and non-destructive testing. In the former type of testing usually mechanical properties like tensile strength, impact strength and hardness are evaluated. In the present study the destructive type of testing is employed. In the destructive testing generally the parts were damaged after the test.

Tensile Test-:Tensile test was performed on the Universal Testing Machine of make HIECO having the capacity 60T. This test was carried out on the AISI 304 austenitic stainless steel to measure its strength in tension. In this test the specimen was subjected to axial tensile load till its failure occurs.

Charpy Impact Test-:A pendulum type single blow impact test, in this the specimen was supported at both ends as a simple supported beam and was broken by a falling pendulum on the face opposite to the notch and the energy absorbed was noted.

Micro Hardness Test-:For micro hardness testing Vickers hardness testing machine was used. In this test a square based pyramid type diamond indenter was used and the hardness variation on the weld interface was obtained by applying a constant load of 500gf. The indentations were made at the weld interface and on along the axis of the welded specimen shaft at the regular intervals of 1mm apart so as to find out the heat affected zone due to frictional heat generated at the weld interface.

Description of Achieved Results

The friction welded specimens of five different welding combinations were prepared by varying the axial pressures at constant speed of 1000rpm; it was observed that with the flash has been produced during friction welding process and the amount of flash increases with the increase in axial pressure. The formation of flash has been presented in Fig. 1.

Tensile test results: - Universal testing machine of HEICO make having the maximum capacity of 600KN load with load accuracy of 1% and displacement accuracy of 1% was used. In this test the specimens were loaded gradually until its fracture. The graphs were plotted on the basis of the results obtained from this test. Tensile test results of friction welded specimens are reported in table 2, it has been observed experimentally that all the specimens were failed at the joint interface. The specimens welded at axial pressures 75MPa, 90MPa and 105MPa were failed at the interface, though the specimens welded at 120MPa and 135MPa were also failed at the weld interface but they show necking behavior before getting failed at the interface. Also it has been noted that these specimens took more time before fracture than the others.

Table 2 Tensile and Impact Toughness values of AISI 304 Steel available at 1000rpm

Specimen	Axial Pressure (MPa)	Peak Stress (MPa)	Peak Strain	Charpy Impact Strength (J)	Fracture Location
A 1	75	350	0.11	27	Weldinterface
A 2	90	372	0.19	26	Weldinterface
A 3	105	396	0.29	27	Weldinterface
A 4	120	408	0.32	27	Weldinterface
A 5	135	398	0.30	24	Weldinterface

The maximum stress available was at 120MPa and the maximum value of strain was also available at the same axial pressure. In general it has been observed that with the increase in axial pressure the value of tensile strength increases, this might be attributed that with the increase in axial pressure more mass is thought to be transferred at the interfaces [6]. Figure 2 and Figure 3 shows the variation of stress valuesand strain values at different axial pressures respectively and it has been depicted that the value of stress as well as the value of strain both goes on increases with the increase in axial pressure.

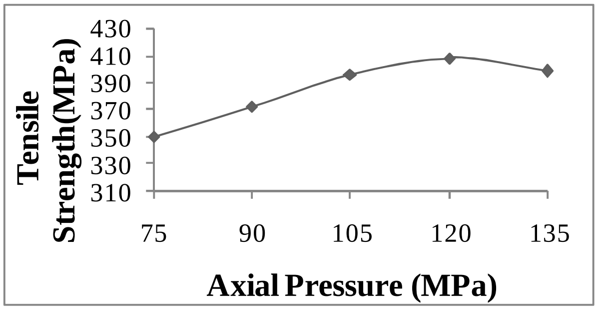

Fig. 2Shows the variation Stress values with axial pressures.

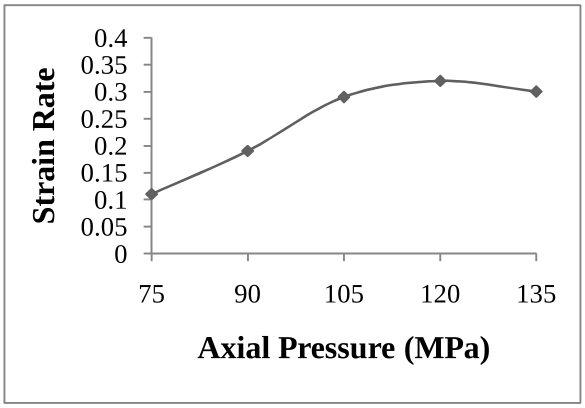

Fig. 3Shows the variation Strain rate values with axial pressures.

Impact test results: -The notch impact toughness tests were carried out to find amount of energy absorbed during fracture. Charpy impact test was carried out to know the impact toughness strength of the weldments. The samples prepared for impact testing were according to ASTM standards A370-12.The results of charpy impact toughness results in terms of fracture energies have been reported in the Table 2. Fig. 4 shows the variation of impact strength with axial pressure, it reveals that the impact strength of charpy impact, firstly decreases with the increase in axial pressure, then rises a little bit and then remains constant up to 120MPa pressure and after that with the increase in axial pressure declines sharply. Fig. 4 shows the variation of impact strength with the rise in axial pressure. The similar results have been reported in the literature [7].

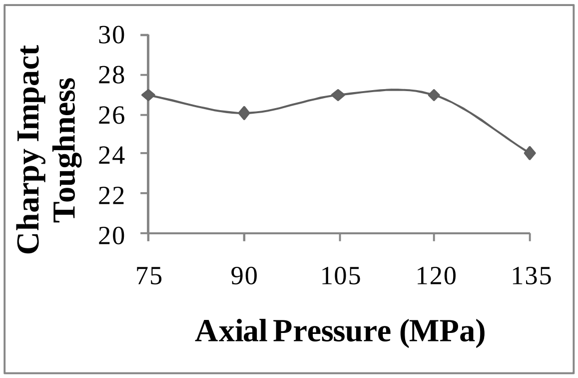

Fig. 4Shows the variation Charpy Impact Strength with axial pressures.

Micro Hardness test results: -The micro hardness variations were obtained on Vickers Hardness Testing Machine, The hardness variations at the weld interface and across the weld interface were obtained by applying a constant load of 500gf and have been reported in the Table 3. The hardness was measured at the weld interface and on the either side of the parent materials.

Table 3 Variation of Hardness values with the increase in axial pressures.

Specimen	Axial Pressure (MPa)	Micro Hardness (Hv) at a distance from weld interface (mm)				
		0	1	2	3	4
A 1	75	232	232	226	216	208
A 2	90	238	236	230	222	214
A 3	105	242	240	234	222	212
A 4	120	242	237	231	224	212
A 5	135	248	246	239	231	220

Fig. 5 shows the hardness variations at the weld interface and along the axis of the specimen at an interval distances of 1mm apart.It has also been observed that the maximum hardness was obtained at the weldinterface for all the joints [8].

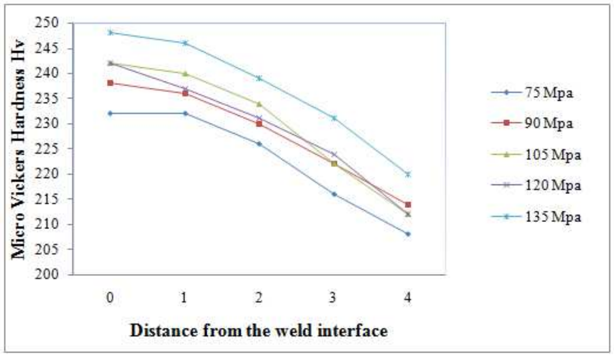

Fig. 5Shows the variation Micro Hardness values with axial pressures.

In addition to that the higher values of hardness at the weldinterface were probably due to the oxidation process which takes place during friction welding [9].The peak hardness of friction welded joints increases with the increase in axial pressure [10].

Conclusions

The axial pressure has been found to be an influential parameter for the friction welding process, which has been optimized for the process based upon the results of the present study. The mechanical properties of the friction welds were found to vary with the applied axial pressure, which indicates that axial pressure is an important welding parameter. The axial pressure could be successfully optimized for the friction welding process on the basis of the results of the current investigation.The maximum tensile strength for welded bars was achieved with an applied axial pressure of 120MPa, but the specimen fails in a brittle manner, whereas small amount of necking appears on the specimens which were prepared at an axial pressure of 120MPa and 135MPa axial pressures. It has also been observed that the impact strength both for charpyimpact toughness was also found to be maximum at 120MPa axial pressure.The hardness of all the samples was found to me maximum at the weld interface. With the increase in the axial pressure the value of hardness increases.

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