Evaluation of Mechanical Properties of Friction Welded Stainless Steel alloy 304 and Aluminium alloy 6063 joint

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Abstract

The aim of the present research paper is the Investigation of Mechanical Properties and Microstructure of Welded Joint of Stainless Steel 304 and Aluminium alloy 6063 by Friction Welding Process. The aluminum alloy 6063 and stainless steel alloy 304 was successfully welded with the friction welding process. The friction welding process was performed on a lathe machine with a Special fixture. Friction time and forge pressure are the two parameters that varied for specimens, and the rest remain constant. All samples of aluminum alloy 6063 and stainless steel alloy 304 prepared using friction welding technique with different parameters were examined with the help of x-ray radiography mainly at the weld joint to observe any defects. The Tensile test, X-ray radiography, and microstructure analysis were performed to relate the weld joint properties. It was revealed that the aluminum alloy matrix shows fine grain structure, and stainless steel alloy structure remains uniform, which leads to sound weld joint and good weld strength. The X-Ray Radiography was performed to analyze the various internal defects like porosity, concavities, cracks, cold laps, slag, etc. The highest tensile strength was found for a joint fabricated at forge pressure 85 kg/cm^2 and friction time 40 seconds, and the lowest tensile strength was found for a joint welded at forge pressure 75 kg/cm^2 and friction time 40 second.

Keywords: *Steel 304, Aluminium 6063, Tensile strength, X-ray radiography.*

I. INTRODUCTION

Friction welding is a technique discovered in the 1940s, but it has not been used in large, even when many interests and applications have been re-discovered using this technique. The principal advantages of frictional welding being a solid-state process like low distortion, absence of melt-related defects, and high joint strength. Friction welding is a solid-state welding process; in this welding, the two components are forced to rotate against each other (friction phase), thereby generating heat at the interface. Once the desired upset length or process time has been reached, the rubbing motion stops (braking phase), the pressure rises (swelling time), and the components are pressed against each other (forging phase) until they are cooled down [1]. The principle of the Friction welding process is the changing of mechanical energy into heat energy. One component is gripped and rotated about its axis while the other component to be welded to it is gripped and does not rotate but can be moved axially to make contact with the rotating component. When fusion temperature is reached, then rotation is stopped, and forging pressure is applied. Then heat is generated due to friction and is concentrated and localized at the interface; grain structure is refined by hot work [2]. Ali Moarrefzadeh 2012 studied Friction welding (FW) process advantages compared to the fusion processes like joining conventionally non-fusion weldable alloys, reduced distortion, and improved mechanical properties of weldable alloys joints due to the pure solid-state joining of metals [3]. The thermal effect of friction welding that especially depends on the friction type and temperature field of it in the work piece is the primary key to analyzing and optimizing this process. Gourav Sardana and Ajay Lohan 2013 investigated a method of measuring the forge pressure on the conventional lathe machine [4]. Pressure is measured by the special arrangement of the fixture on the tailstock side of the machine. Shubhavardhan RN and Surendran S 2012 investigated to join and assess the development of solid-state joints of dissimilar material AA6082 aluminum alloy and AISI 304 stainless steel, via continuous drive friction welding process, which combines the heat generated from friction between two surfaces and plastic deformation [2]. The joints' strength varied with increasing friction pressure and friction timekeeping upset pressure and upset time constant. D. Ananthapadmanaban 2011 investigated the Microstructure and mechanical properties of the weld point of two different combinations, namely Low Carbon Steel-Stainless Steel and Aluminium-Copper [5]. During the investigation, the experiment to weld these metals is done on a friction welding machine. Mechanical property data such as Tensile Strength, Hardness, and Impact Strength and bend tests have been performed. The weld and parent metal's micro structural features have been studied, and correlations with Mechanical properties have been done. SEM fractography has been carried out to study friction welding parameters on nature and type of fracture.

II. EXPERIMENTATION

SS 304 alloy's chemical composition was tested on a global discharge spectrometer (Model: GDS 500A, Leco, USA) at Munjal casting private limited, Ludhiana. The spectrography results are shown in Table 1. Aluminum alloy 6063, one of the most popular alloys in the 6000 series, provides good extrudability and a high-quality surface finish.

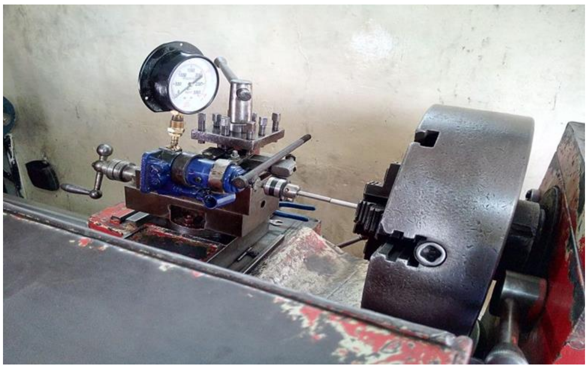

Fig 1: Experimental setup for FWP

In the heat-treated condition, alloy 6063 provides good resistance to general corrosion, including resistance to stress corrosion cracking. It is easily welded or brazed by various commercial methods. The chemical composition of AL 6063 alloy was tested on a global discharge spectrometer (Model: GDS500A, Leco, USA) and is shown in Table 2.

The samples of aluminum alloy 6063 and stainless steel 304 had been cut from the Aluminum rod of 10 mm diameter, and 4-inch length each and stainless steel rod is of 8 mm diameter and 4-inch length respectively at very slow speed, to avoid any temperature rise. After this, finishing samples was done. The conventional Disc brake Lathe machine used in the experiment for friction welding processing was placed at the BS auto industry at Ludhiana. It is fully automatic machine with a maximum 2000 rpm speed with four-stage gear control. It is also mounted with a special fixture to control the axial movement and axial pressure. Therefore, for measuring the forge pressure on the conventional lathe machine, a special arrangement of fixture on the machine's tailstock side was made. The fixture consists of a hydraulic bottle jack of 2-ton capacity with a pressure gauge. Besides, a drill chuck of 10 mm size was welded on the head of ram of hydraulic bottle jack for holding a workpiece, and a male part is welded on the base of the jack, which made the fixture axially stable. That pressure gauge shows the forge pressure applied by the operator on a steady job. After the arrangement of special fixtures on the tool post of the convention Lathe machine, the final experimental setup is shown in Fig 1.

III. TESTING

After completing the Friction welding process of aluminum alloy 6063 and stainless steel 304, the processed samples were analyzed by performing various destructive and non-destructive tests. The samples were analyzed to meet the following objectives:

- X-Ray Radiography Testing

  To check the discontinuity or defect at the weld joint of aluminum alloy 6063 and stainless steel alloy 304.

- Tensile Testing

  It was done to check the weld joint's strength of aluminum alloy 6063 and stainless steel alloy 304 at what load it will fail.

- Microstructure Testing

  To check the change in the Microstructure of both the materials (Al 6063 and SS 304)

A. X-Ray Radiography Testing

. The X-Ray Radiography was performed to analyze the various internal defects like porosity, concavities, cracks, cold laps, slag, etc. All samples of aluminum alloy 6063 and stainless steel alloy 304 prepared using friction welding technique with different parameters were examined with the help of x-ray radiography mainly at the weld joint to observe any defects. No sign of defect or discontinuity was seen in all samples except sample number 3, in which a very small crack was observed, which reduced weld joint strength. It may occur due to sufficient heat produced during the friction phase, which leads to large plastic deformation at the interface, and the forge pressure applied was insufficient for the sound weld. Moreover, the higher heat generation caused a slow cooling rate, leading to the formation of coarse grains in the weld zone. Friction welded joints are free from solidification related defects since there is no melting takes place during welding, and the metals are joined in a solid-state itself due to the heat generated by the friction between workpieces

B. Tensile Test.

Title The effect of friction welding process parameters, i.e., friction time and forge pressure on the ultimate tensile strength, is evaluated with the help of tensile testing. It is the mechanical and destructive test in which the samples got damaged during testing. After the welding was performed, tensile tests were carried out to evaluate the joints' ultimate tensile strength. According to ASTM E 8M (2004), the welded specimens were machined and subjected to tensile tests on a UTM Machine model UTN-40 with a load cell of 100 KN at room temperature 25°C and a test speed of 3 mm/minute. It was observed that all the specimens were failed from the weld zone, which indicates that the weld region's strength is weaker than that of the original parent. The results of the tensile test for all samples are given in table 3.

C. Microstructure test

The microstructural behavior of aluminum alloy 6063 and stainless steel alloy 304 processed by Friction Welding Processing was studied at different parameters. Due to the big difference in mechanical properties of aluminum alloy and stainless steel, the Microstructure of stainless steel alloy remains uniform and unchanged after welding with the friction welding process. The micrographs were taken of both best, and worst friction welding processed samples. In the microstructure test of the best sample selected based on the tensile test report, it was seen that the aluminum alloy matrix shows fine grain structure, and stainless steel alloy structure remains uniform, which leads to a sound weld joint which leads to good weld strength**.** The micrographs of aluminum alloy and stainless steel alloy shown in fig 2 and fig 3.

IV. CONCLUSIONS

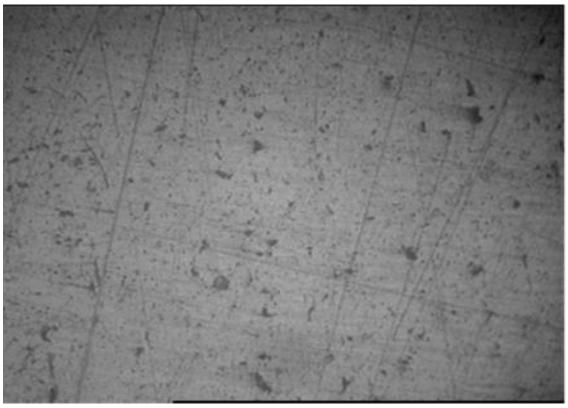

Fig 2 Aluminum alloy

From the present experimental investigation, the following conclusions are derived:

1. In the x-ray radiography test, no defect or discontinuity was seen in all samples except sample 3, which means friction welding is a technique in which there was very little chance of weld joint defect if done properly. The result is best at Forge Pressure 85 kg/cm^2 and Friction Time 40 second.
2. The result is worst at Forge Pressure 75kg/cm^2 and Friction Time 40 second.
3. The tensile strength increased with an increase in Forge pressure and friction time and vice versa.
4. No change occurs in the Microstructure of both the materials in the worst sample case.
5. Minor changes occur in the Microstructure of both the materials in the best sample case.

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REFERENCES

[1] P. Rombaut, W. De Waele, and K. Faes, Belgium, Laboratory Soete, Belgium "friction welding of steel to ceramic."

[2] Shubhavardhan RN, Surendran S "Friction Welding to Join Dissimilar Metals" 2012.

[3] Ali. Moarrefzadeh "Study of Heat Affected Zone (HAZ) in Friction Welding Process" 2012.

[4] Gourav Sardana, Ajay Lohan "Friction Welding on Lathe Machine with special Fixture" 2013.

[5] D.Ananthapadmanaban "Studies on friction weldability of low carbon steel with stainless steel and aluminum with copper" 2011.

TABLE.1: **Composition of stainless steel 304 (% weight)**

Stainless Steel	C%	Si%	Mn%	Ph%	S%	Cr%	Ni%	Other%	Fe%
304	.025	0.386	1.47	.038	.013	19.11	8.13	0.348	70.28

TABLE.2: Composition of Aluminum Alloy 6063 (% weight)

Aluminum Alloy	Cu%	Mg%	Si%	Fe%	Mn%	Zn%	Ti%	Other%	Bal%
6063	0.025	0.63	0.43	0.19	0.031	0.007	0.015	0.011	98.42

TABLE 3. Tensile test result

S. No.	Speed (rpm)	Forge pressure (kg/cm^2)	Friction time (Second)	Forge time (Second)	Tensile strength (N)
1	1500	85	40	30	23680.0
2	1500	80	40	30	20060.0
3	1500	75	40	30	15860.0
4	1500	85	35	30	22020.0
5	1500	80	35	30	16480.0
6	1500	75	35	30	15920.0
7	1500	85	30	30	21620.0
8	1500	80	30	30	18300.0
9	1500	75	30	30	15900.0

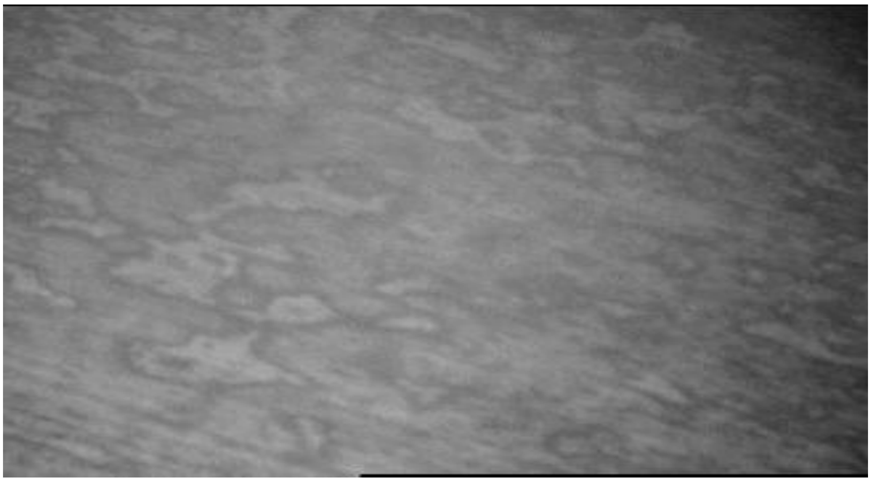

Fig: 3 Stainless Steel alloy