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Investigation of Rotary Friction Welded 6063 – T6 and 6082 – T6 aluminum Alloy Joint Properties

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Abstract: Rotary friction welding is a novel welding approach of Friction Welding. The joint is made in a solid condition in the rotary friction welding, where the heat is produced by friction at the interface between the components at the axial pressure rotation. This work aimed to evaluate the advancement of solid-state joints made up of dissimilar aluminum 6063 – T6 and 6082 – T6 alloys, that can be used in tanks for liquid propellant as well as in other communications satellite automotive parts. The joints between aluminum 6063 – T6 and 6082 – T6 alloys were created by the RFW method, which integrates heat from friction between two surfaces with plastic deformation. Welding was carried out using various parameters of the RFW welding process. Metallographic tests, Vikar hardness test, and tensile test have been used for the analysis of impacts of various RFW welding parameters on weld quality.

Keywords: Friction Welding, Rotary Friction Welding, Dissimilar Aluminium alloy, Macro Structure, Weld Joint Strength

1 Introduction

Friction welding is one of the most novel approaches for fabricating two dissimilar aluminum alloys. Lighter, high mechanical strength, lower metal quantity, and strong corrosion resistance have been used as substitutes for traditional steel structures.[1] Such interconnections are of great significance in the production of emerging technology in the aerospace industry because they make it possible to structurally combine the structures, subsystems, and components made of aluminum alloys. The challenges in welding similar, as well as dissimilar aluminum alloys by fusion welding processes, is a great challenge to the industry because the problems arise due to the low melting point of the aluminum alloys, high thermal conductivity. It leads to unnecessary heat dispensation, which can make welding tricky and unintended distortion of parts due to some kind of higher heat input.

Friction Welding methods are being classified by the American Welding Society (AWS) at the moment. Rotary Friction Welding and Friction Stir Welding are the two primary types of friction welding.[2] The friction welding process is Rotary Friction Welding is the most efficient welding technique to join two round aluminum bars.[3] It includes one moving component to produce a sufficient quantity of heat relative to the other component and afterward introducing side force (called upsetting force) to plastic displacement and join. This heating takes place because one part is fixed, the other part is pressed and highly rotating.[4] Figure 1 shows the working principle of the RFW process.

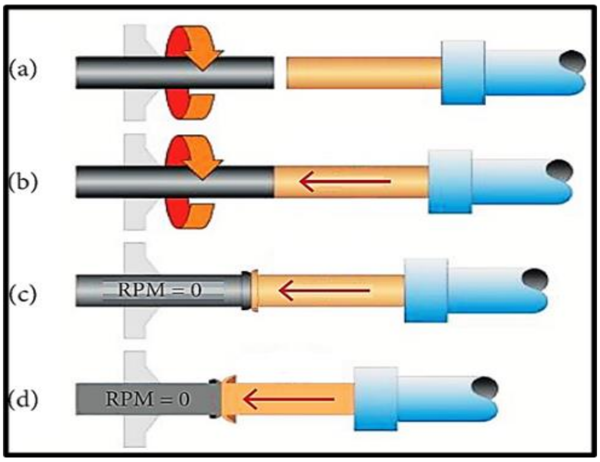


Fig. 1: Principle of Rotary Friction Welding[5]

During the RFW welding process, joining metals are not melted. Thus, it is also not a welding operation but a method of forging.[6] Rotary Friction Welding does not require extra materials for filling. As a result, the characteristics are unaffected, and the welding does not last as long as other types of welding that rely on the inclusion and porosity of the material.[7] Furthermore, it is a very simple operation, as the HAZ (heat-affected zone) in the base metal is considerably less than other welding processes.

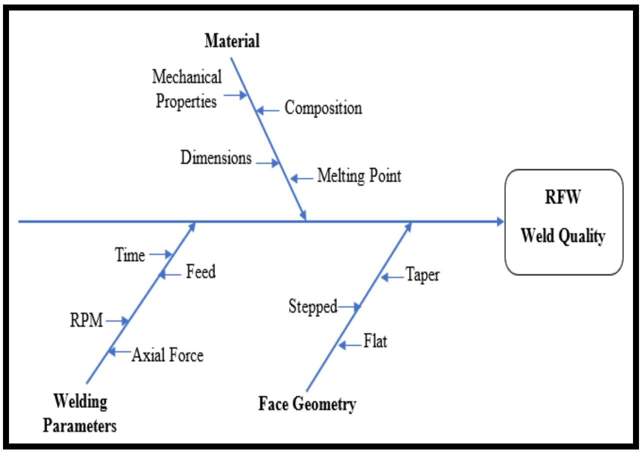


Fig. 2: Case & Defect Diagram [14]

Figure 2 diagrammatically indicates various influencing parameters of the RFW process. The resulting weld is also stronger than the other welding process. Friction welding can be used to make 100% metal-to-metal contact.[8] RFW is increasingly accepted in the advanced manufacturing business and has been employed for a variety of purposes, such as aerospace industries, tool manufacturing industries, automotive industries, wire manufacturing factories, marine industries, railway, and nuclear industries. [9,10,11,12,13] Thus, in current research work, the rotary friction welding process is used to obtain the quality joint between aluminum alloy 6063 – T6 and 6082 – T6 for structural application.

2 Experimental Methodology

During the research work, experimental work of joining two different aluminum alloys 6063 – T6 and 6082 – T6 using 3 different face geometries are performed on a conventional lathe machine at 1600 RPM. Tables 1 & 2 are representing the chemical composition of 6063 – T6 and 6082 – T6 aluminum alloys, respectively.

Table 1: Chemical Composition of 6063 – T6 aluminum alloy [15]

Component	Al	Cu	Fe	Mg	Mn	Si	Ti	Zn
% Weight	Balance	0.01	0.18	0.48	0.04	0.44	0.01	0.01

Table 2: Chemical Composition of 6082 – T6 aluminum alloy [16]

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Other
% Weight	Balance	Max 0.25	Max 0.1	Max 0.5	0.6 – 1.2	0.4 –1	0.7 – 1.3	Max 0.1	Max 0.2	Max 0.15

Tables 3 & 4 signifies the mechanical as well as thermal properties of the 6063 – T6 and 6082 – T6 aluminum alloy, respectively.

Table 3: Properties of 6063 – T6 Aluminium alloy [15]

Properties	**Value**
Hardness (HV)	83
Tensile Strength	241 MPa
Yield Strength	214 MPa
Melting Point	616 – 654˚C

Table 4: Properties of 6082 – T6 Aluminium alloy [16]

Properties	Value
Hardness (HV)	100
Tensile Strength	295 MPa
Yield Strength	280 MPa
Melting Point	555 ˚C

Fig. 3: Lathe Machine

As demonstrated in Figure, rotary friction welding (RFW) is done on a traditional lathe machine. The welding is performed at 1600 rpm which is selected based on previous research. The 6063 – T6 alloy has a female portion of face geometry and is attached to the chuck during the welding process. While 6082 – T6 Aluminium alloy has a male face geometry part and is attached to the tailstock of the lathe machine. Three different types of face geometry are used to investigate the quality of the weld joint namely: a) Flat b) One stepped and c) Tapper as shown in Figure 4. In flat face geometry, the face of both rotary and fixed workpieces has flat faces having 12 mm diameter as shown in Figure 4(a). In step geometry, the circular portion of the male part having 12 mm diameter has raised circular profile with a height and diameter of 5 mm. Whereas females have the same geometry withdrawn having the depth and diameter of 4.5 mm as shown in Figure 4(b). In tapper geometry, the male part with having a 12 mm base diameter has raised cone portion at center having 38˚. Whereas the female part has a center punch for cantering purposes as shown in Figure 4(c). For every three-face geometry, Figure 5 depicts the experimental setup. Figure 5(a) shows the flat face geometry fabrication process. Figures 5(b) and 5(c) depict the fabrication process for stepped and conical face geometries, accordingly.

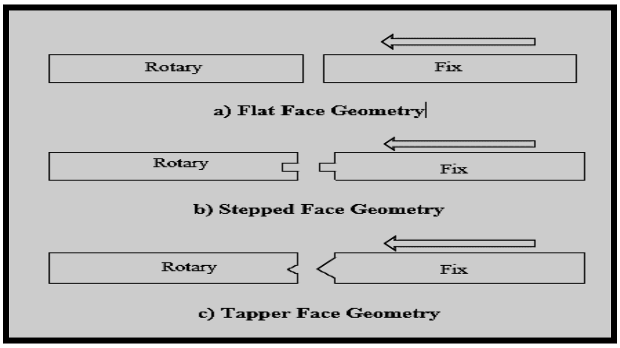
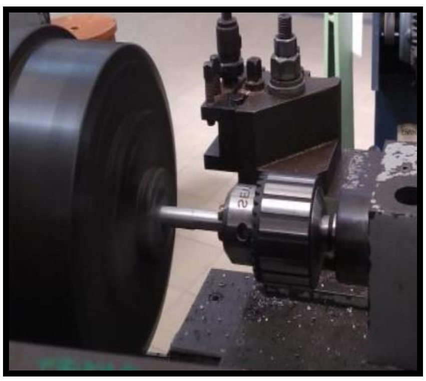
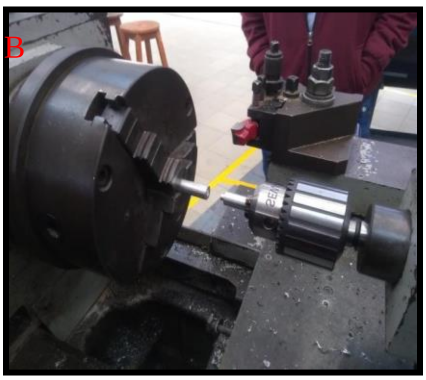


Fig. 4: Three Different Face Geometry

A



B



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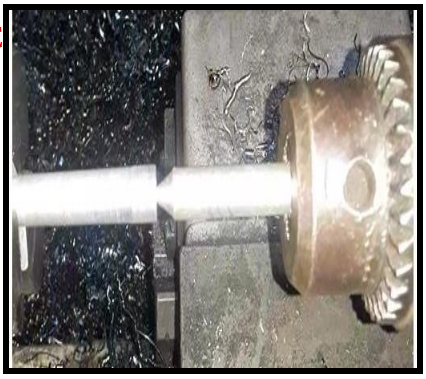


(a) Flat Face Geometry (b) Stepped Face Geometry (c) Conical Face Geometry

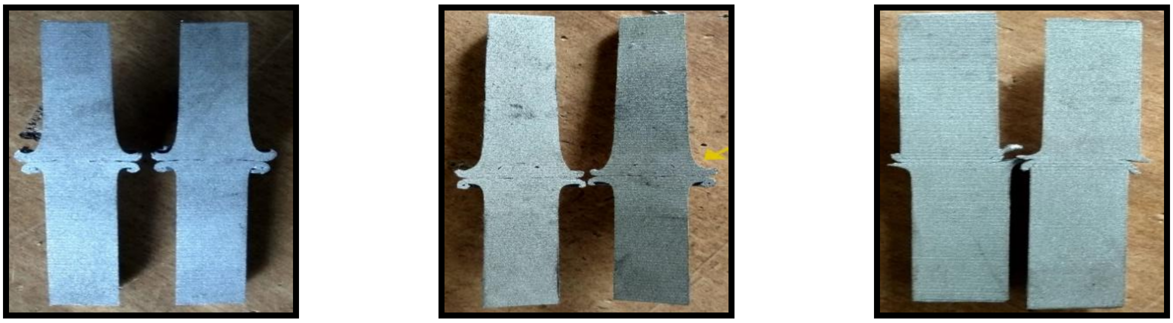
Fig. 5: Experimental Setup

3 Experimental Results

During the welding process, 6063 – T6 aluminum alloy bar is installed at the fixed end, and 6082 – T6 aluminum alloy bar is fixed in the chuck which is moveable at pre-defined speed. Figure 6 shows 6082 – T6 and 6063 – T6 aluminum alloy weld joints.

The macrostructure, tensile test, and hardness specimens are made using the EDM wire cut machine after joining the aluminum alloy 6063 – T6 and 6082 – T6. Figure 7 represents the cross-section area of the RFW weld joint for the observation of macrostructure.

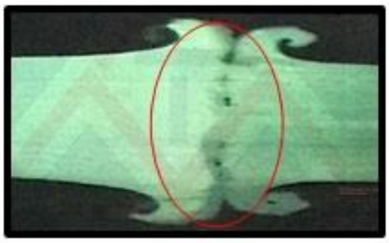
Fig. 6: RFW Weld Joint

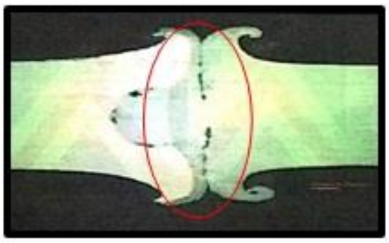


Cross-section of Flat Geometry　　Cross-section of Stepped Geometry　　Cross-section of Conical Geometry

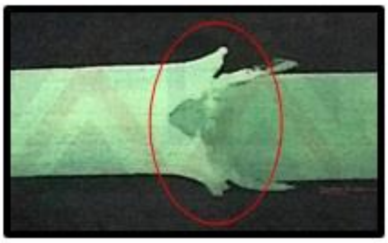
Fig. 7: Cross-section Area for Macrostructure Observation

When these cross-section areas are analyzed in the microscope, it looks like as shown in Figure 8. Figure 8(a) and Figure 8(b) represent the macroscopic view of the flat face joint and stepped face joint workpiece. Porosity is observed at the root area during macroscopic observation. In addition to that, the crake is observed in the weld joint of steeped geometry at the male portion of the metal rod. Whereas macrostructure of the weld metal and heat-affected zone of conical face geometry as in Figure 8(c) shows complete fusion and freedom from cracks. According to macroscopic observation, external flashes are also observed more in flat and steeped face geometry join compared to conical face geometry.





(a) (b)



(C)

Fig. 8: Macrostructure: (a) Flat Face (b) Stepped Face and (c) Conical Face

To know the capacity of the joint against stretching and pulling before the break, a tensile test has been done on the RFW specimens of all three different face geometry on Universal Testing Machine as represented in Figure 9. Furthermore, the joint's localized resistance of plastic deformation is measured on the Rockwell Hardness Testing Machine, which is shown in Figure 10. The outcomes of the experiments are represented in Table 5. Table 5 enlists the tensile strength, Rockwell hardness, and time is taken to join two roads. The outcomes indicate that the tensile strength of the conical face geometry is followed by a flat face geometry and a stepped face geometry. The hardness of the joint prepared by the geometry of the conical face is 28 RHN, which seems to be the greatest among all joints. Also, the time taken by the conical face geometry is comparatively less than the other two geometries.

Fig. 9: Universal Testing Machine

Fig. 10: Rockwell Hardness Testing Machine

Table 5: Experiment Result

Face Geometry	Ultimate Tensile Strength (MPa)	Hardness (RHN)	Time (Sec)
Flat	175.53	20	21
Stepped	160.75	19	18
Conical	205.86	28	14

The matter of inaccuracy is encountered during welding in flat face geometry between moveable and stationary workpieces. Because of this misalignment, the joint becomes porous, and flashes are developed at the joint area. These burs and porosity weaken the joints and decrease the strength. Whereas in stepped geometry, stepped projection on the male and female part of the workpiece provides proper alignment during the welding. So, the alignment problem found in the flat face geometry workpiece is eliminated in stepped geometry. However, the chances of damage to a raised step projection are the biggest issue of stepped face geometry and can be seen clearly from the stepped face geometry macrostructures. Which tends to a weakening of the joint and a drop in joint strength. The issue of damage that can occur in raise projection as in stepped geometry is not encountered in conical face geometry as per Figure 8(c) macrostructure of conical face geometry. Because conical face geometry gives greater strength to the raised conical projection.

4 Conclusion

The analysis is conducted on Rotary Friction Welded two different aluminum alloys using three different face geometries. Some of the conclusions from this analysis are summarized as below:

- Rotary Friction Welding is an extremely effective welding method for joining two different aluminum alloys 6063 and 6082.
- As per the result, the use of different weld face geometries is advisable to join different metals through Rotary Friction Welding. Because friction is not the same on both sides of metal. Hence soft metal can easily heat comparatively hard metal.
- In the case of conical face geometry, the gases escape more easily. So that weld becomes porosity less, crack less, and with better fusion.
- Conical face geometry attains a maximum of tensile strength with less welding time in comparison to flat and stepped face geometry as per Figure 11.
- Also, conical face geometry accomplishes good hardness in recoding less time as represented in Figure 11.

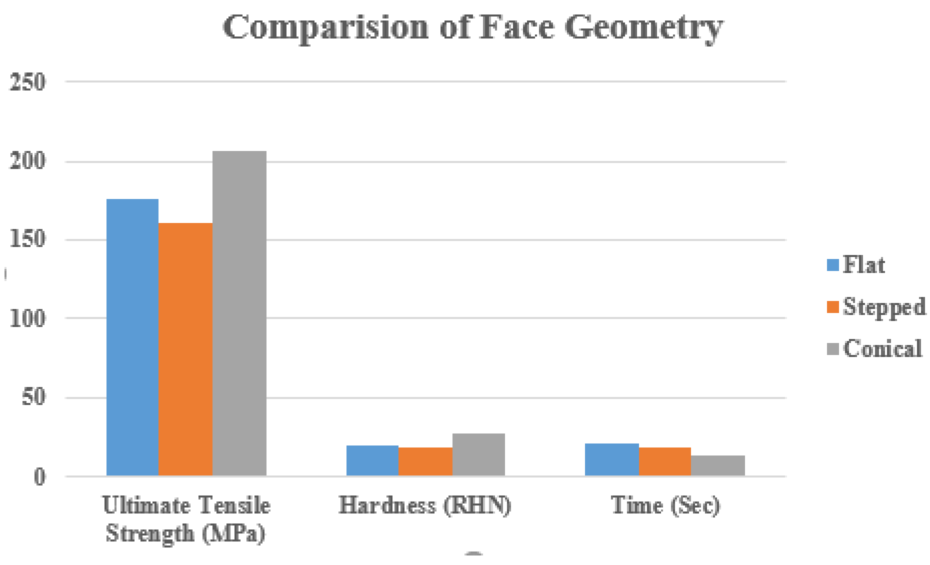


Fig. 11: Comparision Chart of Different Face Geometry

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