# A Study review on Rotary Friction Welding

Savitharoja P[1], Prof. M.Deepak Kumar[2], Prof.D.Noorullah[3]
[1]PG Scholar Department of Metallurgical Engineering, Government college of Engineering Salem.11
[2]Assistant professor Department of Metallurgical Engineering, Government college of Engineering Salem.11
[3]Professor and Head of the Department, Department of Metallurgical Engineering, Government college of Engineering Salem.11

***Abstract* - Rotary Friction welding is a solid-state welding system which welds materials without authentic melting it. It is an only till date known method to weld similar as well as dissimilar metals. It is an ordinarily used welding process in industries like automobile industries, submarine engineering industries aeronautical industries, and heavy duty industries. This study explores papers of different researchers on the friction welding method and it has been observed that the welding parameters like friction time, friction pressure, forge time and forge pressure highly affect properties of welded joints. The reason for this investigation is to exhort industry and the insightful world regarding advantages of revolving friction welding so the technique may be utilized in an ideal manner.**

***Keywords: rotary friction welding, Similar and dissimilar welding, friction and forge pressure, friction and forge time.***

## 1. INTRODUCTION

In recent years, many industries are opting for wide variety of material in their product for improving the performance and reducing the cost; due to this the demands to weld dissimilar metals have increased in a large scale. Rotary friction welding (RFW) is a solid-state joining process which works by rotating one workpiece relative to another while under a compressive axial force. It is a pressure welding process that produce high integrity and full contact joints. In this welding process, no filler material, flux or shielding gases are required. The friction between the surfaces produces heat, causing the interface material to plasticise. The compressive force displaces the plasticised material from the interface, expelling the original surface oxide layer and other contaminants and promoting metallurgical and/or surface interlocking joining mechanisms. This deformation process forms a flash collar and causes the workpieces to shorten in the direction of the compressive force. Once the required shortening has been achieved (known as burn-off distance) the rotation movement is ceased and a forging force is often held, or increased, for a period of time to help consolidate the weld.

## 2. WORKING PRINCIPLE

Friction welding uses the principle of heat generation by friction between two members. During the friction welding process, two surfaces to be welded are made to rub against each other at a very high speed. The developed friction between the rotating and non-rotating surface produces enough heat at the weld interface. Once the required welding temperature is generated, a uniformly increasing external pressure is applied till both the workpieces form a permanent joint.

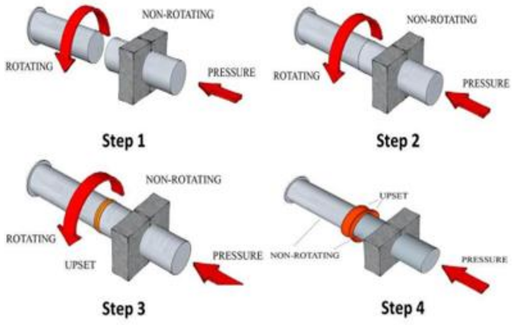

Fig.2.1 Schematic diagram of working principle

## 3. WELDING PARAMETERS

- Friction force - The force applied normal to the faying surfaces during the time that there is relative movement between the components.
- Forge force - The force applied normal to the faying surfaces at the time when relative movement between the components is ceasing or has ceased.
- Friction pressure - The pressure (force per unit area) on the faying surfaces resulting from the friction force.

- Forge pressure - The pressure (force per unit area) on the faying surfaces resulting from the forge force.
- Friction time - The time during which relative movement between the components takes place at friction speed and under application of the friction force.
- Forge time - The time for which the forge force is applied to the components.

## 4. MICROSTRUCTURE AND MECHANICAL PROPERTIES

Rotary friction welds are similar in appearance in that they have several distinct zones: a weld centre zone (WCZ), a thermo-mechanically affected zone (TMAZ) and a heat affected zone (HAZ). The extent and microstructural composition of these zones are dependent on the material and processing conditions used. The weld region is surrounded by a flash collar. When optimum processing conditions are used, RFW can produce joints that are superior or similar in strength to the parent material. This is true for many similar and dissimilar material combinations.

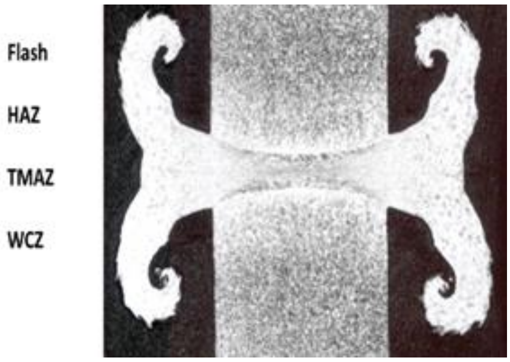

Fig.4.1 Different Zones of Rotary Friction welds

## 5. APPLICATION

RFW is widely implemented across the manufacturing sector and has been used for numerous applications, including:

- Turbine shafts
- Automotive parts including steel truck axels and casings
- Monel-to-steel marine fittings
- Piston rods
- Tubular transition joints combining dissimilar metals (Aluminium-Titanium and Aluminium-Stainless steel, for example)
- Copper-aluminium electrical connections

## 6. LITERATURE REVIEW

[1] Shubhavardhan R.N et.al carried out the research on joining of dissimilar materials AA6082 aluminium alloy and AISI 304 stainless steel. They investigated the welded joints by using various tests like tensile test, Vickers micro hardness test, fatigue test, Impact test, and SEM-EDX (energy dispersive X-ray). From this investigation, they concluded that the strength of the joints varied with increasing upset pressure and upset time keeping friction pressure and friction time constant. The joint strength increased, and then gradually decreased after reaching a maximum value, with increasing upset pressure and upset time. Joint strength depended on the size and shape of the tensile test piece. Also observed that St-Al joints consist of some intermetallic compounds by using EDX measurements.

[2] Demouche Mourad et.al were conducted an experiment on the resulting properties of similar 100Cr6 steel welded joints and the joints were produced from 100Cr6 steel rods having different diameter and different interface geometries. A microstructural characterization was carried out of friction welded specimens by optical microscopy. The Vickers hardness distribution at the weld joint was examined. It was shown that high hardness in the central zone, which was characterized by a martensitic structure. A change in microstructure between the center zone and the edge zone was observed. A difference in the extent of the weld joint, when the interface is convex, the plastically deformed zone is wider, resulting in greater axial shortening.

[3] Masaaki Kimura et.al were experimented the tensile strength of friction welded joint between Al-Mg alloy (A5052) and pure copper (OFC). The joining phenomena during the friction process and the effects of friction welding condition such as friction pressure, friction time and forge pressure on the joint strength have been investigated and the metallurgical characteristics of joints have been also observed and analysed. They observed that the adjacent region of the weld interface at the A5052 side was upset during the friction process, although that of the OFC side was hardly upset. From this, they concluded that the joint should be made with a low friction pressures such as 20 MPa to prevent generating of the mechanically mixed layer.

[4] Djamel Eddine Heddar et.al investigated that the effect of rotational speed on mechanical properties

and microstructural evolution of welded dissimilar metal A60 steel-copper bars by rotary friction welding. They evaluated the thermal behavior of the welded joint by measuring the temperature of the central zone of the welded joint. The main techniques of characterization were tensile test and hardness measurements, optical microscopy, scanning electron microscopy equipped with energy dispersive X-ray. They found that the use of high rotational speed decreases the ultimate tensile stress of joint. The hardness values in the central zone of the welded joint were higher for the higher rotational speed.

[5] Truyen The Le et.al carried out rotary friction welding on similar metal joints of high-strength titanium alloys. They developed a thermomechanical model to predict the upset and temperature and identify the safe and suitable range of parameters. The upset predicted by the finite element simulations was compared with the upset obtained by the experimental results. High upset rates due to generated power density and forging pressure overload that occurred during the welding process were investigated. The performances of the welded joints were evaluated by conducting microstructure studies and Vickers hardness at the joints. It was found that an increase in the forging pressure produces an increased upset therefore, a small forging pressure is preferred in the friction welding process.

[6] Chatha Jagjeet Singh et.al studied the rotary friction welding and observed that the welding parameters like friction time, friction pressure, forge time and forge pressure highly affects the properties of welded joints. From this study, they concluded that the tensile strength value of welded material at the joint increase with increase in rubbing time and forge stress values.

[7] Karthick K. et.al were analyzed the mechanical properties and microstructural characteristics of rotary friction welded dissimilar joint of armor steel and medium carbon steel. They showed that the ultimate tensile strength of the dissimilar joint was around 775 MPa and the failure occurred at the medium carbon steel side. The impact toughness value of dissimilar joints was higher than medium carbon steel and lower than armor steel. The microstructure across the dissimilar joint has distinct features and a complex pattern was observed at the weld interface.

[8] Jwan Khalil Mohammed et.al were investigated the impact strength and microstructure behavior of friction welded AISI 304 austenitic stainless steel joints. The specimens were divided into two groups, the surface of the first group was flat while the interface of the second group was designed by fabricating a pin and hole. They examined the effect of different forging pressure on impact toughness and microstructure behavior of AISI 304 by using Charpy impact tester and optical microscope. Finally, it was shown that the friction welded joints with 288.6 MPa exhibited the maximum impact strength for pin and flat interface and the friction welded joints with 192.4 MPa exhibited the minimum impact strength for pin while minimum impact strength in flat interface at the joint welded at 240.5 Mpa.

[9] B.Seshagirirao et.al were carried out the tensile and hardness tests of weldments on an aluminium (H-30) and mild steel (AISI-1040) by Rotary Friction welding process at different spindle speeds. They evaluated the temperatures, time taken for welding, tensile test and hardness test of weldments and compared at different spindle speeds of two different diameter materials (10mm & 12mm). The welding was conducted at both similar and dissimilar combinations. It was found that 2095 rpm gives optimum speed for similar welding of mild steel (10 mm & 12mm) and similar welding of Aluminium (10mm & 12mm) got better results at the speed of 1372 and 2095 rpm. Similar welding of mild steel at the diameter of 12mm has generated a highest temperature of $767^0$C. The maximum breaking load for aluminum was found 206.43N at 2095rpm and for mild steel maximum breaking load was 482.13N at 2095rpm.

[10] Nikita Dhutre et.al were investigated the rotary friction welding parameters of similar austenitic stainless steel (SS316) welded joints. The effects of temperature, Pressure, Time for weld, hardness, microstructure and Heat affected zone were analyzed. It was found that as the grain size increases, Strength of the material decreases. Fineness of the material, smaller is the grain size, higher is the tensile strength, hardness and larger breaking load is required to break the material. It was observed that from the tensile test, weld was stronger than SS316 parent material and material broke at parent material rather than weld centre.

[11] Eder Paduan Alves et.al had done an experiment on dissimilar welded joints of AA1050 aluminium with AISI 304 Stainless steel to determine the temperatures at bonding interface. They analyzed the heating rate and cooling and the

maximum temperature was determined during welding and characterized every phases of process. They observed that the highest rates of heating occurred in the first 10s of the heating phase tend to stabilize as a function of deformation and plastic flow of the AA1050 aluminum. The maximum temperature of $374^0$C and it was shown that the temperature at the bonding interface during welding coincides with the range of hot forging of AA1050 aluminium.

[12] Vaibhav V. Kulkarni et.al studied and experimented the Rotary Friction welded samples of stainless steel SS 304 at different diameters 8mm & 10mm. The various parameters studied for the process was spindle speed, weld time, temperature, pressure, heat affected zone, and the 2D modeling and steady state transient thermal analysis has been carried out for the selected specimen. They analyzed that the tensile strength for specimen of diameter 8 mm was 271.67 MPa and the strain obtained was 6.9 % and for specimen of diameter 10 mm was 292.361 MPa and the strain obtained was 6.6 %. It has been observed that if the diameter increases, tensile strength also increases and the rotational speed increases, the tensile strength also increases. They also found that from the thermal analysis, the stresses generated because of temperature distribution along weld specimen.

[13] B. Abhijith was enhanced the weldability of Inconel 600 and SS 304 using Rotary Friction welding by inserting a third inter layer in between them. The feasibility of using inter layer between Inconel 600 and SS 304 has been carried out using finite element analysis to assess the penetration, sticking and sliding characteristics at the interfaces along with deformation properties. Taguchi’s deign of experiments was employed to find the significant major parameters of rotary friction welding. He concluded that penetration, sticking and sliding characteristics were greatly affected by the frictional pressure.

[14] D. Manideep et.al conducted the Rotary Friction welding on Austenitic Stainless Steel AISI321 and Ferritic Stainless Steel AISI430 with various combinations of process parameters. They studied that the process optimization, microstructure and mechanical property correlation. The welded joints were produced by varying friction pressure, upset pressure and burn-off length, values of upset time and speed were constant. Metallurgical properties of the welds were examined using optical microscopy and mechanical behaviour of the welded interface was examined with Vickers hardness test. They revealed that the higher upset pressure exhibits fine grain size and increased friction pressure aids in grain coarsening. Also, they observed that the lower friction pressure results lower hardness values at the interface and the higher upset pressure & burn-off length results higher hardness values.

[15] F. KHALFALLAH et.al were investigated the Rotary Friction welding of AA1100 aluminum alloy with mild steel and they optimized the welding parameters of these dissimilar materials such as friction pressure and friction time, forging pressure and forging time, rotational speed by using Response Surface Methodology (RSM). They had determined that the mechanical properties of the welded joints by using tensile test and micro-hardness measurements and also analyzed the welded joints using scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) in order to investigate the formation of intermetallic compound (IMC) layer at the weld interface. From this investigation, they conclude that the tensile strength of the weld increases with increasing the forging pressure and forging time.

## 7. CONCLUSION

The process of rotary friction welding of dissimilar welding is much different than conventional fusion welding process. The variation in the rotary friction welding parameters directly affect the weld strength. The optimization of friction welding parameter is required for getting higher strength. Important parameters which affect are forge time, forge stress, rubbing time and friction pressure. The tensile strength value of welded material at the joint increase with increase in rubbing time and forge stress values. The tensile value increase till critical point further it starts declining. No harmful emission is discharged during the process. The optimal variable must be chosen for the optimum results. Process is suitable to weld materials which are considered not suitable for traditional welding technique. There is a good scope for studying the performance of continuous drive friction welding of aluminium and low carbon welding.

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