

Rotary Friction Welding and its Applications: An Overview

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Abstract

Friction welding is the only till date known method to weld similar as well as dissimilar metals. It is an ordinarily used welding method in various industries like automobile, aeronautical, submarine and heavy-duty industries. Friction welding is a non-conventional force welding process. It is a well-thought-out, most viable alternative to overwhelmed the difficulties faced in conventional connection techniques. Mostly used for joining material with variable mechanical and physical properties. We have mostly been attentive to Rotary Friction Welding (RFW). Our main objective is to understand the fundamental understanding of Friction Welding. This method changes kinetic energy into heat energy, manufacturing high-quality weld with a strangely high-efficiency coefficient. Experimental tests demonstrate the efficiency of this rotational friction welding system by using various parameters like rotational speed, temperature, pressure on the material. Also, experiment on the mechanical strength of the similar and dissimilar material, its experimental determination in real-time is fundamental for understanding and characterised the main process step and optimisation of parameters.

Keywords: - *Friction Welding, Similar joint, Dissimilar Joint, Continuous-drive Friction Welding (CDFW), Rotary Friction Welding (RFW), Tensile strength, Hardness, Microstructure*

INTRODUCTION

Rotary Friction welding (FRW) is a solid-state unique welding method that forms heat over and is done with mechanical friction between workpieces in relative motion to one another, with the addition of a sideways force called "upset" to dislocate and fuse the materials plastically. Because no melting occurs, friction welding is not a fusion welding

process in the old-fashioned sense but more of a forge welding technique.

Friction welding is hand-me-down with metals and thermoplastics in a wide variety of aviation and automotive applications. It provides excellent repeatability, high productivity, and low cost. Its greatest application is joining similar and

dissimilar material joints used in automobile, aeronautical, aerospace, nuclear and marine fields.

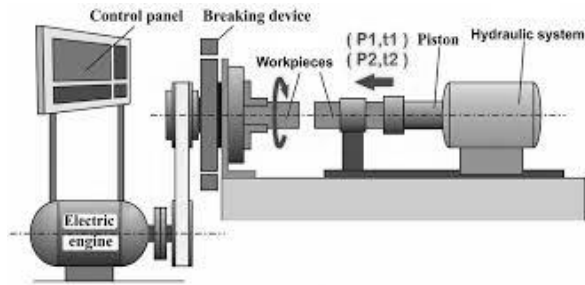


Fig.1 Rotary friction welding

For plastics, rotary friction welding (RFW), also known as spin welding, uses machines with two chucks for allotting the things to be welded, one of which is fixed and the other rotating. In the RFW, the predetermined speed and the other is positioned, aligned, aligned, and moved by a hydraulic piston to touch the spinning part.

The drive motor and chuck are linked in direct-drive friction welding (also called constant drive friction welding). The drive motor is repeatedly driving the chuck through the heating stages. Generally, a clutch is used to disengage the drive motor commencing the chuck, and a brake is then used to stop the chuck.

What is Rotational Friction Welding?

Rotational Friction Welding is a solid-state linking process that produces coalescence in metals or non-metals using the heat settled between two surfaces by an arrangement of mechanically brought rotational rubbing motion and applied load. Under normal conditions, the fraying surfaces do not melt.

There are three basic types of Rotational Friction Welding: Inertia Welding, Direct Drive Welding, and Hybrid. Other variations embrace Radial, Orbital, Linear or Reciprocating Welding and Friction Stir Welding.

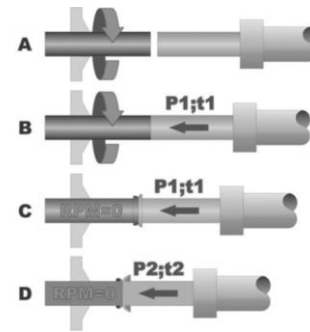


Fig.2 Phase of conventional Rotary friction welding

Why Rotational Friction Welding?

Rotational Friction Welding does not compromise the reliability of the parent materials through welding – ensuing in more challenging welds, more constant part properties, and greater joint efficiencies. Even materials and geometries supposed un-weldable can be joined spending Rotational Friction Welding.

Working principle

The working principle of this rotary friction welding process is altering the mechanical energy into heat energy through the friction process. One workpiece is rotated about its axis using a 3 HP Induction motor while the other workpiece to be welded to it is stationary and does not revolve by only can be moved axially to make contact with the rotating workpiece. The rotation is stopped at the point forging pressure, and fusion is applied axially to the stationary workpiece. The hot work causes refinement of grain structure, and welding is done without melting the parent metal.

ADVANTAGES OF ROTATIONAL FRICTION WELDING

- Since dissimilar metals can be joined, significant cost savings are possible.
- Expensive forgings and castings can be replaced with less expensive forgings welded to bar stock, tubes, plates, etc.

- Significantly faster than conventional methods of welding.
- Consumables are not required— no flux, filler material, or shielding gases are needed.

LITERATURE SURVEY

J. Alex Anandaraj, S. Rajakumar

Detailed the mechanical properties and microstructural behaviour of friction welded dissimilar joints. The optimised welding parameters are friction pressure 220 MPa, friction time 10 sec, forging pressure 220 MPa, forging time 8 sec, rotational speed 1300 rpm. The transverse tensile test has been assessed at room temperature with the aid of a universal testing machine and recorded the maximum fracture strength of 652 MPa. The hardness survey was carried out on a micro-scale along the weld cross section, which records the lower hardness in the TMAZ region. The macrostructure was used to study the flow behaviour of rotary friction welding in lower magnification. The microstructure analysis was carried out in weld and adjacent regions to impose the characteristics of dissimilar joints. Finally, the results concluded that most of the failure had been observed in the steel side thermo mechanical affected region (TMAZ). Although the ultimate aim of this research is to emphasise the dissimilar weld joint characteristics for aerospace and defence application.

Bingwang Leia, Qingyu Shia, Likun Yang

Development of rotary friction welding (RFW) is critical for extending the RFW technology to join large-scale structures, such as rods/pipes for generators rotors nuclear power plants. Finite element (FE) analysis is employed to analyse the thermal-mechanical process during low-pressure rotary friction welding (RFW), and the dynamic

evolution process of interface contact is illustrated. The low-pressure RFW process of the D50Re steel rod with a diameter of 100 mm is investigated by using the fully coupled thermal-mechanical FE analysis. The formation and expansion of the contact zone are in a thermo-mechanical fully coupled manner. Since the temperature is not uniform across the friction interface, the contact area is first formed in the high-temperature area, and the expansion of the contact area occurs subsequently. When the temperature at the interface is uniform, almost full contact would be achieved over the friction interface.

M. Deepak Kumar, P.K. Palani,

V. Karthik Friction welding can join different ferrous and non-ferrous metals that conventional fusion welding processes cannot weld. The concept of design of experiments (DOE) has been used to perform and analyse the experiments, and it is found that heating time has a greater influence on the joint strength. The increase in collective strength with increasing upset load and heating time is observed. The maximum joint strength of 610 MPa was achieved at an upset load of 1200 kg and heating time of 20 sec. The effect of parameters for various interactions was analysed, and it shows that heating time, upset load are the effective parameters. Scanning electron microscope (SEM) analysis reveals ductile and brittle fracture patterns for weld specimens' high and low tensile strength values.

Billel Chenitia, Djamel Miroud

Dissimilar rapid Rotary Friction Welding of WC-Co cermet to AISI 304 L austenitic stainless steel has been conducted using different friction times. The micro structural examination showed that the increase in friction time from 4s to 12s increases

the grain size in both the heat-affected zone and the thermo-mechanically affected zone and enlarges the extent of the fully dynamically recrystallised zone. EDS analysis revealed a FeCrW rich band and the WC-Co/AISI 304 L interface in the central region of the weld joint and its absence from the peripheral region. The formation of this band suggests a mutual interdiffusion between the cermet and the steel, which enhanced the metallurgical bonding of the interface. The mechanical behaviour investigated by nano-indentation measurements and nano-scratch tests revealed that regardless of the friction time effect and the 304 L ASS side, the highest hardness (HIT) and the lowest Young's modulus (EIT) values were recorded in the fully dynamically recrystallised zone.

N. Rajesh Jesudoss Hynes, P. Shenbaga Velu

Joining of Ti-6Al-4V to AA6061 has tremendous applications in aerospace, automotive and medical industries. Dissimilar Ti-6Al-4V/AA6061 of the fluid coupler in aircraft industries are recently made employing friction welding technique. In this research work, an experimental investigation was carried out on the effect of rotational speed on the quality of integrity of dissimilar Ti-6Al-4V/AA6061 joints. The impact of the most important process parameter, rotational speed, on the mechanism of bonding at the interface is investigated by observing changes in the microstructure of the welded specimen. An increase in rotational speed raises frictional heating at the interface. It leads to dynamic recrystallisation with the recovery of recrystallised equiaxed grains, which is highly favourable for enhancing joint strength. . Experimental results of mechanical testing such as tensile strength and

impact strength reveal enhanced collective strength be achieved with 1000 rpm as rotational speed. Micrograph at fractured surface shows river pattern with few dimples. Tensile strength as much as 186.59 MPa could be achieved using this technique.

Alves et al.

When using the rotary friction welding process to the uniform of two similar and dissimilar materials, it is very important to know the temperature in the bonding interface because it directly interferes with the formation of the crystal structure of the mechanical and metallurgical properties the welding joint. In rotary friction welding, the heat generation occurs differently from the welding process for fusion, which is similar in the temperature distribution on the joint of the union of base metals.

Burakowski and Wizerchonet al.

The whole heat necessary for welding is produced by converting mechanical power energy into thermal energy one. It is a problematic complex metallurgical method that involves a series of variables such as time, travel speed, rotational speed, physical phenomenon, atomic diffusion plastic deformation, heat generation by friction, and the formation of intermetallic compounds. A significant amount of heat is dissipated during the relative motion of surfaces, causing temperature increase, even with small loads and sliding speed values.

Nisarg Shete1, S. U. Deokar et al.

Friction welding is a non-conventional force welding process. It is a well-thought-out, most viable alternative to overcome the difficulties tackled in the conventional fitting together technique. They are generally used for linking

material with varying physical and mechanical properties. We have primarily focused on Rotary Friction Welding (RFW). Friction Welding method kinetic energy is changed into heat energy, creating high-quality weld and unusually high-efficiency coefficient.

Friction welding has immensely high potential in the field of thermo mechanical processing of various alloys. This thesis presents an experimental investigation of friction welding. The mechanical properties and the resultant microstructure for friction weld were presented for different combinations of axial force, rotational and translational speeds.

The correlation of mechanical properties and microstructure with the process parameters for the optimisation of the process is a unique approach that has been the main motivation behind this project. From the present experimental investigation, the following conclusions are derived:

Material showing different mechanical and thermal properties can be welded. This is mainly useful in aerospace, where it is used to joint lightweight aluminium stock to high-strength steel. Welded bond is stronger than the parent metal itself.

Friction welding is also used with thermoplastics, which act analogous to metals below heat and pressure. The heat and pressure used on these materials are greatly lower than metals, but the technique can join metals to plastics with the machining of the metal boundary. The technique can be used to join eyeglass edges to the pins in their hinges. The lesser energies and pressures

used allows for a wider variety of techniques to be used.

A very efficient and economical utilisation of heat is possible because of strictly localised heat generation. This heat generation eliminates the oxide films and levels of the surface.

Feng Jin, JinglongLi et al.

Rotary friction welding was conducted on austenitic superalloy A286 with a diameter of $\phi 25\text{mm}$ under 300, 900 and 2100 rpm to understand the structural response of the joint welded at different rotation speeds. Joint morphologies, grain structures inside the morphologies and the corresponding mechanism that governs its formation were characterised and investigated using electron backscattered diffraction

(EBSD), which focused on three featured zones located at the centre, $1/2R$ and periphery of the joint. The joint morphology evolves from 'disk shape' to 'near-line shape' and 'scissors shape' as the rotation speed increases from 300 rpm to 2100 rpm. At low rotation speed, refined and recrystallised grains were formed inside disk shape morphologies. Whereas sub-grains and deformed grains were evolved at the middle (900 rpm) and high (2100 rpm) rotation speed. The recrystallised grains surrounded by the 'disk shape' morphology positively affect the joint strength compared with the sub-grains and deformed grains confined by the 'near-line shape' and 'scissors shape' morphologies.

Richard D Kasleret al.

A friction welding apparatus has first and second clamps for respectively holding first and second parts to be welded by rotary friction welding, a device for producing relative rotation between the

first and second clamps and a forge for applying an axial forging pressure to the parts to be welded when the parts are located in the clamps. The second clamp is mounted on the first half of a coupling. The second half of the coupling is movable axially between the first and second positions. In the first position, the second half of the coupling is engaged with the first half to prevent rotation of the second clamp and enable relative rotation between the first and second clamps. In the second position, the second half of the coupling is disengaged from the first half to enable rotation of the second clamp and stop relative rotation between the first and second clamps.

Sahin et al.

Studied Friction Welding of plastically deformed steel bars. They worked on continuous drive friction welding of similar material by dissimilar diameter bars and used carburising steel for that friction welding process.

MuminSahin et al.

Have worked on computer programed simulation of how wedding process flashed occur in welded joints of similar or dissimilar medium carbon steel 1040. He concludes that the optimum welding parameters getting from similar diameter specimens cannot be used in welding specimens with various diameters and widths. As a result, in welding specimens having a dissimilar size, the optimum parameters of the joint should be ordinarily selected in the experimental analysis.

Li W, Wang F et al.

Modelling of continuous drive friction welding of mild steel a two-dimensional model was developed for continuous drive friction welding (cdfw) of mild steel based on the redevelopment

environment of Abaqus software. The effects of axial pressure and rotating speed on boundary temperature and axial shortening were examined. The results show that the weld interface can reach a quasi-stable temperature more quickly with growing axial pressure, and the axial shortening will be larger. Similar findings were observed with increasing the rotating speed. In addition, with the rise of friction time, the interface temperature remains stable and axial shortening increases linearly with time. Experiments with mild steel bars were also conducted. The simulation results are comparable to the experiments.

M. Maalekian et al.

Friction welding is well-known nowadays to join many dissimilar types of materials because it has proved itself to be a reliable and economical way of producing high-quality welds. The present paper presents different friction welding processes, their shortcomings and their advantages. The past of friction welding and typical applications are also studied. In the perspective of friction welding, several subjects, such as frictional joining mechanism, behaviour, interface temperature and heat generation, still exist. Other investigators have proposed different concepts for explaining the physical mechanisms. To simplify some inconsistencies in the interpretation of the friction welding process, a thorough review and critical assessment of the literature associated with this process is tried.

Serdar Mercana, Sinan Aydin a, Niyazi Ozdemir

AISI 2205 duplex stainless steel, generally used in its class and effective AISI 1020 steel coupled with low carbon content, were connected using different operation parameters through friction

welding. The tension test and rotary bending fatigue test were helpful in the welded connections, and the impact of the welding limits on fatigue strength was examined. It was discovered that when the welding factors used in connecting AISI 2205 and AISI 1020 steel couple through friction welding were selected correctly, the fatigue strength of the connection would rise compared to the main material, and in compliant parameters reduced fatigue strength. AISI 2205/AISI 1020 steel couple having different chemical compounds were connected using continuous drive friction welding using different production parameters, and the impact of the operation parameters of the welded connections on the microstructure and mechanical features were examined.

Satyanarayan et al.

He has carried out a study on continuous drive friction welding of austenitic ferrite stainless steel. The parent metal used for that study was austenitic stainless steel AISI 304 and ferrite stainless steel AISI 430. He used the ANOVA technique of the Yates algorithm to study and analyse the result obtained by the experiment.

Uday kumar et al.

Carried out an experimental investigation of metallurgical and mechanical properties of superior duplex stainless steel rod welded by friction welding. They carried experiments on a specimen of austenitic stainless steel UNS S32760 of 16-millimetredia and length 100 millimetres. A factor three-level central composite design was used to determine optimal factors of the friction welding process of super duplex stainless steel.

Winiczenko et al.

He has investigated friction welding of ductile iron with stainless steel. They used stainless steel interlayer in two ductile iron bars to weld it by continuous drive friction welding.

Seli et al.

Studied the mechanical properties of MS and Aluminium welded rods to understand the thermal effects. They analyse one-dimensional finite difference methods to approximate the heating and cooling temperature distribution of the joint. They concluded that the thermal effects of the friction welding lowered the welded material's hardness compared to the parent materials.

Dey et al.

Have chosen titanium and stainless steel to weld by continuous drive friction welding. They investigate optimum friction welding parameters that produce stronger joints than the titanium base material as confirmed by tensile test and test failure occurs in the titanium base material.

CONCLUSIONS

Friction welding has immensely high potential in the field of thermo mechanical processing of various alloys. The mechanical properties and the resultant microstructure for friction weld were presented for different combinations of axial force, rotational and translational speeds. The correlation of mechanical properties and microstructure with the process parameters for the optimisation of the process is a unique approach that has been the main motivation behind this project.

As speed increases, impact strength and Ultimate Tensile Strength increase up to a certain peak point and then decrease, and the intermetallic layer's thickness increases.

An increase in axial pressure cause a decrease in the impact strength

An increase in Friction Time increases UTS unto peak level and then decreases and increase the shortening (reduction in length in mm per FT).

Shortening increases cause an increase in the UTS.

Grain size in weld zone reduces with increment in friction time.

In the RFW process of Al-Ti alloys, the thicker IMCs generation cause failure of the weld joint because it is brittle. (Al_3Ti is brittle).

Using any interlayer material (Cu, Nb) reduces the chances of the formation of IMCs.

The FP, FT and rotation speed is the function of the UTS.

Rotary friction Weld quality can be improved by using

Optimisation of weld parameters

Use of interlayer

Changing geometric shape

Pre and post-processing

Weld friction parameter

Rotational speed

Friction pressure

Upset pressure

Upset time

Friction time

Material showing different mechanical and thermal properties can be welded. This is mainly useful in aerospace, where it is used to join light weight aluminium stock to high-strength steel.

Welded bond is tougher than the parent metal itself.

Friction welding is also used with thermoplastics, which act analogous to metals under heat and pressure. The heat and pressure used on these materials are much lower than metals, but the technique can join metals to plastics with the metal interface being machined. The technique can be used to join eyeglass frames to the pins in their hinges for case in point. The lower energies and pressures used allows for a wider variety of techniques to be used.

Significantly economic and efficient utilisation of heat is possible because of strictly localised heat generation.

This heat generation eliminates the oxide films and levels of the surface.

Weld quality checked by using tensile strength test, fatigue test, microstructure test, impact test, hardness test.

All forgeable engineering metals can be friction welded

The optimum welding parameters that obtain from equal parts diameter can't be used in different parts

It is required to optimise the friction welding parameter to get good weld quality and strength and weld geometry.

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