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# *Welding with Rotary Friction: An Overview*

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## *Abstract*

*Friction welding is the sole method for joining comparable and dissimilar metals that have been discovered yet. It is a common welding procedure in a variety of industries, including automobiles, aerospace, submarines, and heavy-duty vehicles. Friction welding is a force welding method that is not commonly used. It is a well-thought-out and most viable approach to overcoming the challenges of traditional connecting methods. The most common application is for combining materials with varying mechanical and physical qualities. We have focused our efforts mostly on Rotary Friction Welding (RFW). Our primary goal is to grasp the fundamental concepts of friction welding. Kinetic energy is converted to heat energy in this approach, resulting in a high-quality weld with an unusually high-efficiency coefficient. Experimental experiments employing various factors such as rotational speed, temperature, and pressure on material demonstrated the efficiency of this rotational friction welding technology. Experiments on the mechanical strength of similar and dissimilar materials as well as their experimental determination in real-time are essential for comprehending and characterizing the main process step and parameter optimization.*

**Keywords:** *Friction Welding, Rotary Friction Welding, Continuous-drive Friction Welding (CDFW), Similar Joint, Friction Welding (RFW), Dissimilar Joint*

## INTRODUCTION

The rotary Friction welding (FRW) method is a solid-state special welding process that uses mechanical friction to create heat between work parts in relative motion, as well as a sideways force called "upset" to plastically dislocate and fuse the materials. Friction welding is not a fusion welding procedure in the traditional sense but rather a forge welding technique because no melting happens.

Friction welding is used in a range of aviation and automotive applications using metals and thermoplastics. It offers exceptional reproducibility, high productivity, and low cost, and its most common application is in the joining of comparable and dissimilar material joints in the automotive, aerospace, nuclear, and marine industries.

For plastics, rotary friction welding (RFW), also known as spin welding, uses machinery with two chucks, one fixed and the other revolving, to distribute the items to be welded. In the RFW, one part spins at a predetermined speed while the other is positioned, aligned, and moved by a hydraulic piston to touch the spinning part. The drive motor and chuck are coupled in direct-drive friction welding (also known as constant drive friction welding). The chuck is repeatedly driven through the heating phases by the drive motor. In most cases, a clutch is utilized to disengage the drive motor that starts the chuck, and then a brake is used to stop it.

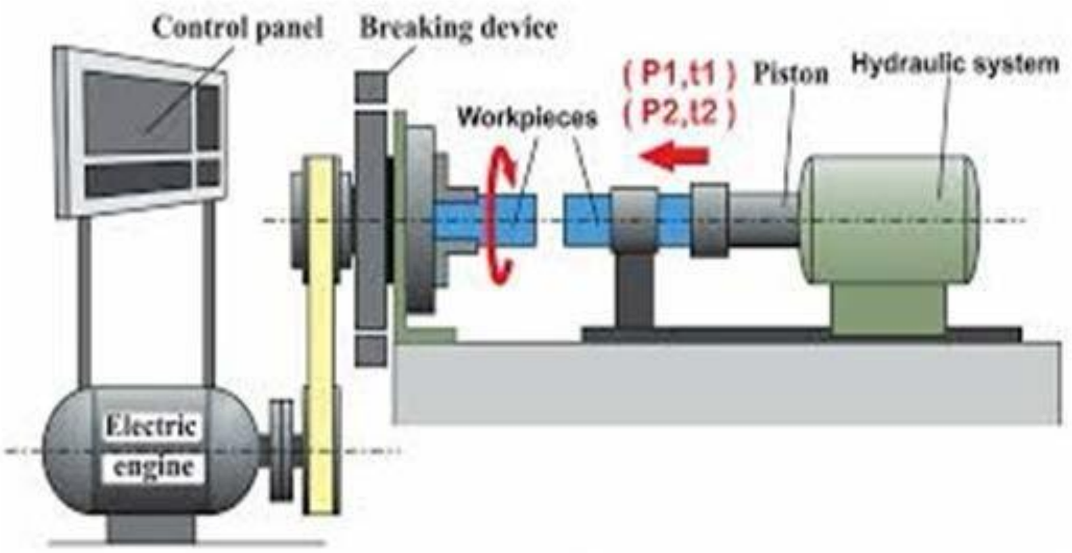

*Fig.1 Rotary friction welding*

## What Is Rotational Friction Welding?

Friction in Rotation Welding is a solid-state joining procedure that causes coalescence in metals or non-metals by transferring heat between two surfaces by a combination of mechanically applied rotational rubbing motion and applied force. Fraying surfaces do not melt under typical conditions.

Inertia Welding, Direct Drive Welding, and Hybrid are the three fundamental forms of Rotational Friction Welding. Radial, Orbital, Linear or Reciprocating Welding, and Friction Stir Welding are some of the other variants.

## Why Rotational Friction Welding?

Welding with Rotational Friction Welding does not affect the parent materials' reliability, resulting in tougher welds, more consistent part qualities, and higher joint efficiency. Even materials and geometries that are thought to be unweldable can be bonded by Rotational Friction Welding.

## Working principle

The concept of operation for this rotary friction welding technique is to convert mechanical energy into thermal energy via friction. One workpiece is rotated around its axis by a 3 HP induction motor, while the other workpiece to be welded to it is stationary and not spinning and can only be moved axially to make contact with the rotating workpiece. The rotation is stopped when forging pressure and fusion are applied axially to the stationary workpiece. Hot work refines the gain structure, and welding is performed without melting the parent metal.

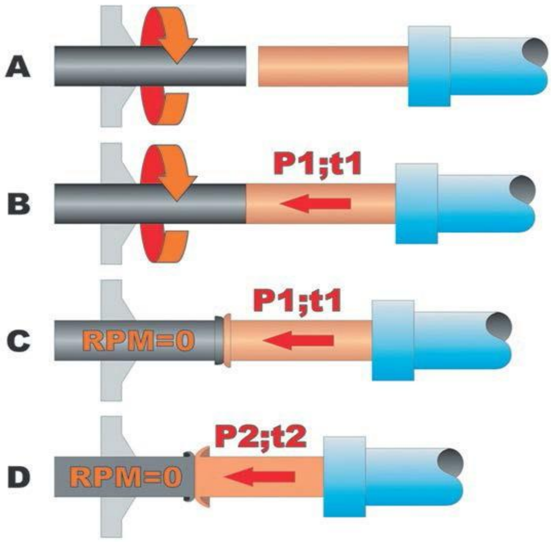

*Fig.2 Phase of conventional Rotary friction welding*

## ADVANTAGES OF ROTATIONAL FRICTION WELDING

- Due to the ability to combine incompatible metals, significant cost savings are conceivable.
- Expensive forgings and castings can be replaced with forgings welded to bar stock, tubes, plates, and other materials.
- Significantly faster than traditional welding procedures.
- There are no consumables needed—no flux, filler material, or shielding gases are required.

## LITERATURE SURVEY

**J. Alex Anandaraj, S. Raja kumar**

The mechanical characteristics and microstructural behaviour of friction welded dissimilar joints were studied in great detail. Friction pressure 220 MPa, friction time 10 sec, forging pressure 220 MPa, forging time 8 sec, and rotational speed 1300 rpm are the optimal welding conditions. The maximum fracture strength of 652 MPa was measured in a transverse tensile test at room temperature using universal testing equipment. The hardness investigation was carried out on a micro-scale along the weld cross Section, which revealed that the TMAZ region has a reduced hardness. In lower magnification, the macrostructure was employed to investigate the flow behaviour of rotary friction welding. To impose the properties of dissimilar junctions, a microstructure study was carried out in the weld and neighbouring region. Finally, the findings revealed that the majority of the failures occurred in the steel-side thermomechanically damaged region (TMAZ). The final goal of this research project is to highlight the differences in weld joint properties for aerospace and defence applications.

**Bingwang Leia, Qingyu Shia, Likun Yangc**

The development of rotary friction welding (RFW) is crucial for extending RFW technology to join large-scale structures such as generator rotor rods/pipes and nuclear power facilities. The thermal-mechanical process during low-pressure rotary friction welding (RFW) is analyzed using finite-element (FE) analysis, and the dynamic evolution process of interface contact is depicted. The fully coupled thermal-mechanical analysis is used to analyze the low-pressure RFW process of D50Re steel rod with a diameter of 100 mm. The contact zone is formed and expanded in a thermomechanically completely linked way. Because the temperature at the friction interface is not uniform, the contact area forms first in the high-temperature area, and the contact area expands later. Almost full contact would be achieved over the friction interface if the temperature at the interface was consistent.

**M. Deepak Kumar, P.K. Palani, V. Karthik**

Friction welding can be used to join various ferrous and non-ferrous metals that cannot be welded using traditional fusion welding processes. The design of experiments (DOE) concept was used to carry out and analyze the experiments, and it was discovered that heating time has the greatest influence on joint strength. The increase in joint strength is observed as the upset load and heating time are increased. At an upset load of 1200 kg and a heating time of 20 seconds, the maximum joint strength of 610 MPa was achieved. The Effect of parameters on various interactions was investigated, and it was discovered that heating time and upset load are the most effective parameters. Scanning electron microscopy (SEM) analysis reveals ductile and brittle fracture patterns for weld specimens with high and low tensile strength values.

**Billel Chenitia, Djamel Miroud**

Rotary friction is dissimilar to that of rotary friction; that is, Different friction periods were used for welding WC-Co cermet to AISI 304 L austenitic stainless steel. The increase in friction time from 4s to 12s increases grain size in both the heat-affected zone and the thermo-mechanically impacted zone, as well as the extent of the fully dynamically recrystallized zone, according to microstructural analysis. EDS analysis revealed the presence of a FeeCreW rich band in the centre portion of the weld joint and its absence in the peripheral region along with the WC-Co/AISI 304 L interface. The existence of a mutual interdiffusion between the cermet and the steel, which strengthened the metallurgical bonding of the interface, is suggested by the creation of this band. Regardless of the friction time effect and considering the 304 L ASS side, the highest hardness (HIT) and lowest Young's modulus (EIT) values were recorded in the dynamically recrystallized zone, as demonstrated by nanoindentation measurements and nano-scratch tests.

**N. Rajesh Jesudoss Hynes, P. Shenbaga Velu Joining**

Ti-6Al-4V to AA6061 offers a wide range of uses in the aerospace, automotive, and medical industries. Friction welding has recently been used in the aircraft industry to make fluid couplers that are dissimilar to Ti-6Al-4V/AA6061. The influence of rotational speed on the quality of integrity of different Ti-6Al-4V/AA6061 joints was investigated experimentally in this study. By examining changes in the microstructure of the welded specimen, the Effect of the most critical process parameter, rotating speed, on the mechanism of bonding at the interface is examined. Increased rotational speed causes frictional heating at the contact, resulting in dynamic recrystallization and the recovery of recrystallized equiaxed grains, which is beneficial to joint strength. Mechanical testing results, such as tensile strength and impact strength, show that increased joint strength can be achieved with a rotational speed of 1000 rpm. A river pattern with a few dimples can be seen in a micrograph of a shattered surface. Using this method, a tensile strength of up to 186.59 MPa may be achieved.

**Alves et al.**

When using the rotary friction welding process to join two similar or dissimilar materials uniformly, it's critical to understand the temperature at the bonding interface because it has a direct impact on the formation of the crystal structure, which affects the welding joint's mechanical and metallurgical properties. The heat generation in rotary friction welding differs from that of fusion welding, which has a comparable temperature distribution on the base metals' union joint.

**Burakowiski and wizerchonet al.**

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

**Nisarg Shete1, S. U. Deokar et al.**

Friction welding is a force welding method that is not commonly used. It is a well-thought-out and most viable remedy to the problems encountered in traditional fitting together techniques. Usually used to join materials with different physical and mechanical qualities together, We've mostly concentrated on Rotary Friction

Welding (RFW). The kinetic energy of friction welding is converted into heat energy, resulting in a high-quality weld and an extraordinarily high-efficiency coefficient.

In the realm of thermomechanical processing of diverse alloys, friction welding has enormous potential. The experimental examination of friction welding is presented in this thesis. For various combinations of axial force, rotational, and translational speeds, the mechanical characteristics and resulting microstructure of friction welds were given.

The connection of mechanical characteristics and microstructure with process parameters for process optimization is a novel technique that is the driving force behind this project. The following findings can be drawn from the current experimental investigation:
Welding can be done on materials with varying mechanical and thermal properties. This is mostly used in the aerospace industry to attach the lightweight aluminium stock to high-strength steels. The parent metal is stronger than the welded bond.

Thermoplastics, which behave similarly to metals under heat and pressure, are also utilized for friction welding. Although the heat and pressure applied to these materials are far lower than that applied to metals, the process can be used to attach metals to polymers with the metal border machined. The technique, for example, can be used to attach the edges of eyeglasses to the pins in their hinges. Because of the lower energy and pressures used, a larger range of procedures can be applied.

Because of the closely localized heat generation, extremely efficient and cost-effective use of heat is available. The surface oxide coatings and levels are removed as a result of the heat generation.

**Feng Jin, JinglongLi et al.**
To understand the structural response of the joint welded at different rotation speeds, rotary friction welding was performed on austenitic superalloy A286 with a diameter of f25mm at 300, 900, and 2100 rpm. Using electron backscattered diffraction, joint morphologies, grain structures within the morphologies, and the corresponding process that governs their development were defined and examined. (EBSD), which focused on three distinct zones at the joint's core, 1/2R, and perimeter. As the rotation speed

increases from 300 to 2100 rpm, the morphology of the joint changes from 'disc shape' to 'near-line shape' and scissors shape.' Refined and recrystallized grains were generated inside disc shape morphologies at modest rotation speeds. At the moderate (900 rpm) and high (2100 rpm) rotation speeds, sub-grains and deformed grains emerged. When compared to sub-grains and deformed grains contained by the 'near-line shape' and scissors shape morphologies, the recrystallized grains surrounded by the 'disc shape' morphology have a beneficial influence on joint strength.

**Richard D Kasleret al.**

First and second clamps for 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 are all included in a friction welding apparatus. The second clamp is attached to the coupling's initial half. The coupling's second half can be moved axially between the first and second positions. The second half of the coupling is engaged with the first half in the first position, preventing the second clamp from rotating and allowing relative rotation between the first and second clamps. The second half of the coupling is detached from the first half in the second position, allowing rotation of the second clamp while preventing relative rotation between the first and second clamps.

**Sahin et al.**

Studies Plastically deform steel bars are friction welded. They experimented with continuous drive friction welding of identical materials using bars of different diameters. For the friction welding process, they use carburizing steel.

**MuminSahin et al.**

Have worked on computer programed simulation of how wedding process flashed occur in welded joints of similar or dissimilar of medium carbon steel 1040. He concluded that the optimum welding parameters getting from similar diameter specimens could not be used in the welding of specimens that have 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 mild steel continuous drive friction welding Based on the rebuilding environment of Abaqus software, a two-dimensional model for continuous drive friction welding (cdfw) of mild steel was built. On boundary temperature and axial shortening, the effects of axial pressure and rotational speed were investigated. The findings show that as axial pressure increases, the weld contact can attain a quasi-stable temperature faster and the axial shortening increases. When the rotational speed was increased, comparable results were seen. Furthermore, when friction time increases, the interface temperature remains steady and axial shortening increases linearly. Mild steel bars were also used in the studies. The modelling and experiment results are comparable.

**M. Maalekian et al.**

Friction welding is currently widely used to combine many different types of materials since it has been shown to be a reliable and cost-effective method of making high-quality welds. The current research discusses various friction welding procedures, as well as their drawbacks and benefits. Friction welding's history and usual applications are also examined. A variety of subjects, such as frictional joining mechanism, behaviour, interface temperature, and heat generation, still remain in the context of friction welding, and different investigators have presented diverse perspectives for explaining the physical mechanisms. Detailed analysis and critical assessment of the literature linked with the friction welding process is attempted to clarify certain contradictions in the understanding of this method.

**SerdarMercana, Sinan Aydin a, NiyaziOzdemir**

Friction welding was utilized to link AISI 2205 duplex stainless steel, which is commonly used in its class, and an effective AISI 1020 steel coupling with low carbon content. The welded connections were tested using tension and rotating bending fatigue tests, and the impact of welding restrictions on fatigue strength was investigated. When the welding factors used to link AISI 2205, and AISI 1020 steel pair through friction welding were chosen correctly, the connection's fatigue strength increased relative to the main material, while incompliant parameters lowered fatigue strength. The impact of the operating parameters of the welded connections on the microstructure and mechanical properties of an AISI 2205/AISI 1020 steel coupled with different chemical compounds was investigated utilizing continuous drive friction welding with different production parameters.

**Satyanarayan et al.**

He conducted research on austenitic ferrite stainless steel continuous drive friction welding. Austenitic stainless steel AISI 304 and ferrite stainless steel AISI 430 were chosen as parent metals in that investigation. To research and analyze the results of the experiment, he employed the ANOVA approach of the yates algorithm.

**Uday kumar et al.**

He investigated the metallurgical and mechanical features of superior duplex stainless steel rod welded by friction welding in an experimental setting. They tested austenitic stainless steel UNS S32760 specimens with a diameter of 16 millimetres and a length of 100 millimetres. The ideal factors of the friction welding process of super duplex stainless steel were determined using a factor three-level central composite design.

**Winiczenko et al.**

He looked at friction welding ductile iron with stainless steel, and they placed a stainless steel interlayer between two ductile iron bars to weld them together using continuous drive friction welding.

**Seli et al.**

To understand the thermal impacts, he tested the mechanical properties of MS and Aluminum welded rods. They use one-dimensional finite difference methods to estimate the heating and cooling temperature distribution of the junction, and they find that the friction welding's thermal impacts have reduced the welded material's hardness in contrast to the parent materials.

**Dey et al.**

He's going to use continuous drive friction welding to join titanium and stainless steel. They look at the best friction welding parameters for producing joints that are stronger than the titanium base material, as evidenced by tensile tests and tensile test failure.

## CONCLUSIONS

In the realm of thermomechanical processing of diverse alloys, friction welding has enormous potential. For various combinations of axial force, rotational, and translational speeds, the mechanical characteristics and resulting microstructure of friction welds were given. The connection of mechanical characteristics and microstructure with process parameters for process optimization is a novel technique that is the driving force behind this project.

Impact strength and Ultimate Tensile Strength grow up to a specific peak point, then fall, and the thickness of the intermetallic layer increases as speed increases.

A decrease in impact strength is caused by an increase in axial pressure. Increased Friction Time raises UTS to a peak, then drops, resulting in increased shortening (reduction in length in mm per FT).

Increases in the UTS are caused by shortening. With increasing friction time, the grain size in the weld zone shrinks. The thicker IMCs generated during the RFW process of Al-Ti alloys cause the weld joint to fail because it is brittle. (Al3Ti is naturally fragile.) IMCs are less likely to form when any interlayer material (Cu, Nb) is used. The UTS is responsible for the FP, FT, and rotation speed.

**Rotary friction Weld quality can be improved by using**

Weld parameter optimization
The interlayer is used.
Changing the geometric form
Pre-processing and/or post-processing

**Weld friction parameter**

Rotational velocity
The force of friction
Pressure build-up
It's upheaval time.
Time for friction

Welding can be done on materials with varying mechanical and thermal properties. This is most commonly used in aircraft to link lightweight aluminium stock to high-strength steel.

The welded bond is more durable than the parent metal. Thermoplastics, which behave similarly to metals under heat and pressure, are also utilized for friction welding. Although the heat and pressure utilized on these materials are significantly lower than on metals, the process can be used to attach metals to polymers with a machined metal interface. The technique, for example, can be used to connect eyeglass frames to the pins in their hinges. Because of the lower energy and pressures used, a larger range of procedures can be applied.

Because of the closely localized heat generation, the very cost-effective and efficient use of heat is achievable. The surface oxide coatings and levels are removed as a result of the heat generation. Tensile strength, fatigue, microstructure, impact, and hardness tests are used to inspect weld quality. Friction welding is possible with any forgeable engineering metal. The best welding settings can't be applied in different sections because they're based on equal parts dimeter. To achieve optimum weld quality, strength, and shape, the friction welding parameter must be optimized.

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