Parameters Influencing on Inertia Friction Welding and Rotary Friction Welding: A Review

[1]Usmani A Mannan M, [2]Snehal Trivedi, [3]Prashantsingh Tomar

[1]PG Fellow, [2]Head of the Dept, [3]Assistant Professor
[1,2,3] Department of Mechanical Engineering,
[1,2,3] Parul Institute of Technology, Parul University, Vadodara, India.

Abstract: The combination of different materials is widely increasing in industrial applications. There are several welding methods that have been developed to obtain stable joints in various applications. However, friction welding is a solid-state joining process used to join similar and dissimilar material which is impossible with other available technique. The friction welding method has been widely used in production methods due to advantages such as high material savings, low production times, no filler material, environment-friendly, no flux, the smaller area affected by the heat and good welded joints. Over the years, the development of better welding for similar/ dissimilar material in terms of mechanical properties and productivity is sensational research work for researchers. This article presents the pervasive and spacious history of Inertia Friction Welding (IFW) and Rotary Friction Welding (RFW) processes based on a literature review conducted in this area.

***Index Terms* - Inertia Friction Welding, Rotary Friction Welding, Ultimate Tensile Strength, Taguchi orthogonal array.**

I. INTRODUCTION

Rotating friction welding (RFW) is a solid-state welding process in which coalescence is produced by the heat obtained by the mechanically induced sliding movement between the rubbing surfaces. Work pieces are held together under pressure. The temperatures developed are lower than the melting point of the metals to be welded, but sufficiently high to create a plastic flow and an intermolecular bond. Friction welding (FRW) is a rotational pressure welding process and is a technique commonly used in the production of aircraft engine shafts, automobile exhaust valve (Johannes et al.[1]). Friction welding is finding varied applications for joining steels, super alloys, non-ferrous metals and combinations of metals. It frequently replaces brazing and (metallic) arc, electron beam, pressure, and flash or resistance butt welding. The schematic diagram is shown in figure.

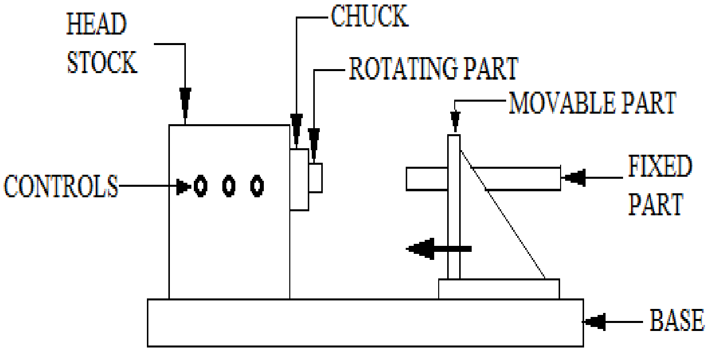

Figure 1: Friction Welding Machine

It has been shown that friction weld quality and productivity is dependent upon the following variables such as relative speed, friction pressure, and duration of heating (burn-off), forge pressure and so on.

II. WORKING PRINCIPLE OF ROTARY FRICTION WELDING (RFW)

The two components to be welded by friction are kept in axial alignment. One component that is held in the chucking spindle of the machine is rotated to the desired speed. The other component held in the movable clamp moves forward to make contact with the rotating component. Pressure and rotation are maintained until the resulting high temperature makes the component metals plastic for welding with sufficient metal behind the interface becoming softened to permit the components to be forged together. During this time, the metal is slowly extruded from the welding area to form an upset. When sufficient heating has taken place the power drive is uncoupled, a brake is applied to stop rotation and the axial force is usually increased to forge the two components together. This produces further deformation. There is no use of any filler material, flux, additives and do not generate any kind of toxic gas so that it is completely environment-friendly.

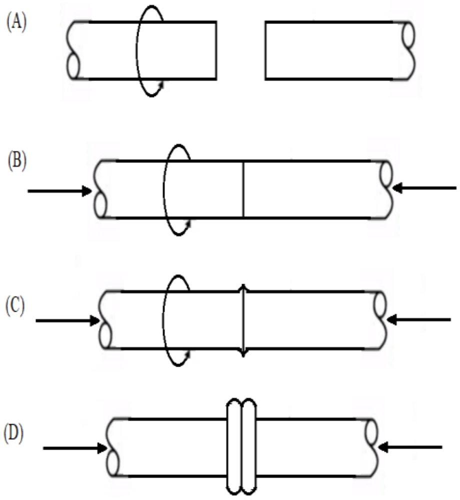

Figure 2: Operational steps in friction welding

III. LITERATURE REVIEW

Johannes Löhe et al [1] carried out work on Improvement of the quality parameter for Inertia Friction Welding by preparing optimal control algorithm. They derived optimal feedback control strategy which was control upset and angular orientation. There is a significant improvement in control of the upset.

R.P. Turner et al [2] calculated the energy required to undergo the conditioning phase of a titanium alloy inertia friction weld. It considers the various parameters such as Inertia mass, initial rotational speed, applied pressure, FE model (thermal profit of deformation). They observed that no deformation observed until the total energy entirely dissipated. Minimum of 18-20kJ energy is required for deformation before a successful weld interface bond.

F.F.Wang et al [3] worked on Process parameters analysis of inertia friction welding nickel-based super alloy. Process parameters optimization axial pressure on temperature and axial shortening the axial pressure is significance to the width of high temp zone for a rapid shortening stage. The axial pressure and flywheel kinetic energy are two important parameters of the welding and axial shortening.

O. Iracheta et al [4] studied on the microscopic structure which is affected by parameters affecting residual stress production in finite modelling of the IFW process". Residual stress to take into account the transformation strain component in FEM. Characterization in heat affected zone (HAZ) in weld trial a fast cooling rate may lead to crack nucleation and crack growth in the initial cooling. Results: Better distribution of axial stresses and better control of material flow in the radial & hoop direction which is results in lower residual stress within HAZ.

L. Fu et al [5] reported on divide whole deformation zone into finite element and analysis. Finally, concluded that Numerical Simulation of Inertia Friction Welding Process by Finite Element Method to predict temperature evolution, stress, strain, and the final geometry of inertia friction welded parts. The calculated results of the deformation also fit excellently with those experimentally observed. This model can be used as an industrial tool.

L. W. Zhang et al [6] worked on analysis of the transient temperature field by finite element model during inertia friction welding of GH4169 alloy. They worked on thermal properties, heat input, contact interface, deformation affected by transient temperature distribution. There has been set up a two-dimension numerical model for IFW. They obtained that calculated temperature is in good agreement as experimental temperature.

Yongbo Hu et al [7] developed a joint of Al/Cu Dissimilar by New Friction Welding Method. It is concluded that Elastic-plastic stress analysis by FEM. The experiment was conducted on the dissimilar joint between A2017 duralumin and C1100 pure copper. They get the result as 60% joint efficiency larger than that in the conventional process and also observed that precise position could be determined from the change of oxygen content near the interface.

S. S. Deulkar et al [8] experimented for joining dissimilar materials, Al-63400 Alloy, and Fe 410WA. It was observed that upset pressure is a most important parameter for axial shortening, as upset pressure increases axial shortening also increases. For obtaining minimum axial shortening, it was found that the optimum values of parameters are 1300 rpm rotational speed, 15 bar friction pressure and 32 bar upset (forging) pressure and 2.5-sec upset time. They observed that upset time is the most important parameter for tensile strength, as upset time increases tensile strength decreases up to a particular value of upset time and then again increases. For obtaining maximum tensile strength, it was found that optimum values of parameters were 1300 rpm rotational speed, 25 bar friction pressure, 48 bar upset pressure and 3.5-sec upset time. It was observed that tensile strength depend on selected parameters, but at the same time, there were also other influencing factors affecting the tensile strength like the temperature at the weld zone, inter-metallic compounds formed at the interface, amount of friction at the interface and friction time, etc.

L. D Alvisea et al [9] worked on Finite element modelling of the inertia friction welding process between dissimilar materials. They considered the development and experimental validation of a finite element code for simulation and derived the equation of various terms such as inertia, forces, and friction also developed the numerical tool. They derived the equation of friction law and its parameters on the basis of experimental acceleration curves so proved that equation by experimental data.

Jeswin A James et al [10] revealed two group member studied on Effect of Interlayer in Friction Welding for Dissimilar Steels: SS 304 and AISI 1040. They worked on the various parameters such as spindle speed, forging pressure and friction time for optimization and performed Taguchi orthogonal array. The experiment is showed that forging pressure greatly influenced on the Ultimate tensile strength.

Ho-Seung Jeong et al [11] worked on Inertia Friction Welding Process Analysis and Mechanical Properties Evaluation of Large Rotor Shaft in Marine Turbo Charger. They determined the optimal welding process parameters by using the finite element simulation and the optimal tempering temperature evaluating the mechanical properties of friction welded part for manufacturing large rotor shaft. The contact surfaces turned soft and were deformed by the friction heat, the flywheel energy decreased with the increase in upset length. The upset length increased with the increasing the flywheel energy and the upset force. They performed both Q-T and SR heat treatment test. And finally, concluded the property is better in Q-T test than stress relieving.

C.J. Bennett et al [12] worked on the finite element model to assess the thermo elastic effects (thermal expansion) during the inertia friction welding process of the nickel-chromium alloy, Inconel 718. The welding pressure had a more significant effect on the variation in the area of contact considering the range of both parameters investigated caused the peak temperature at the interface and the initial heating rates to vary over the same range.

M. Stütza et al [13] worked on Rotary friction welding for molybdenum components to join the dispersion strengthen alloy TZM. It was shown that extensive plastic deformation of the entire weld zone occurred due to higher thermal diffusivity and lower strength of molybdenum compared to TZM. It required higher axial pressures than Mo to achieve comparable plastic deformation due to the higher strength of TZM compared to Mo. Upset thresholds were determined between 4mm and 12mm for small-size specimens of Mo and TZM. Below 4mm insufficient bonding was observed, above 12mm the welding process became unstable and corrosion resistance of weld was remarkable.

H.C. Dey et al [14] welded between titanium and 304L low carbon stainless steel. The result concluded that welding of Ti to 304L SS results in a stronger weld in which failure occurs in the Ti base metal during tensile testing. According to the parametric investigation, the weld is stronger than the base material. Strain hardening was reduced by PWHT after the welding.

H. S. Jeong et al [15] worked on the engine valve to weld Nimonic80A for the head and SNCrW for the stem for low-speed marine diesel engines. It held various test such as tensile test, hardness test, microstructure observation for weld quality. The flywheel energy decreases with the increase in upset length because the contact surface becomes soft and it is deformed by the friction heat. The upset length increased with the increase in flywheel energy and upset force. Concluded the weld material property is improved than its individual properties.

S. Fukumoto et al. [16] investigated on Friction welding of 5052 Al alloy to austenitic stainless steel. Weld was performed on 5052 aluminum alloy and austenitic stainless steel 304. The welding process was investigated by microstructure observation, tensile testing, and electrical resistmetry measurements. Strength increased up to maximum and then decreased when increased friction time. Sufficient heat does not generate with shorter time. Due to the long-time duration, the excess formation produced at the interface. Electrical resistivity is used to measure and evaluate the weld between Al and 304.S.

Fukumoto et al. [17] work was carried out on friction weld interface of 1050 aluminum to austenitic stainless steel by microstructure, the aluminum was greatly deformed, and the grains were elongated and refined near the weld interface. Various test performed such as the hardness test of welded material. Aluminum was deformed and the grains were elongated in the vicinity of the weld interface. The hardness of aluminum at the center was higher than that at the periphery for shorter frictional times. The friction welding mechanism of this system was based on inter diffusion of each constituent in solid state.

N. O zdemir [18] reported Investigation of the mechanical properties of friction-welded joints between AISI 304L and AISI 4340 steel as a function rotational speed. The result showed that above dissimilar materials were welded by the friction welding process using five different rotational speeds. They have also investigated parameters for desired properties. The micro hardness across the interface perpendicular to the interface was measured and the strength of the joints was determined with tensile tests. It was concluded that the tensile strength of friction-welded 304L/4340 components was affected by rotational speed.

V.V. Satyanarayana et al [19] investigated on dissimilar metal friction welding of austenitic-ferritic stainless steels, Parameter optimization, microstructure-mechanical property correlation, and fracture behaviour was a major contribution of the study. In friction welding of austenitic-ferritic stainless steel, deformation is confined to ferritic stainless steel only. They analyzed that forge pressure resulted in fine grain size and grain coarsening increased because of friction pressure. The toughness and strength properties of dissimilar metal welds are better than the ferritic stainless steel parent metal.

Hakan Ates et al [20] analyzed the effect of friction pressure on the properties of friction welded MA956 iron-based super alloy. The effect of friction pressure on the properties of friction welded hot rolled MA956 iron-based super alloy plate, produced by mechanical alloying, had been investigated. They concluded that HAZ width decreased and tensile strength increased up to a certain value then decreased slightly with increasing the forging pressure. This effect was probably due to the easy deformation of a soft metal at high forging pressure. The best mechanical properties were obtained on the sample joined with friction pressure higher than 50 MPa.

IV. LITERATURE SUMMARY

The concept of friction welding process is explored well based on literature review conducted. The literature survey shows influence of various parameters such as rotational speed, friction pressure, upsetting pressure and upsetting time on the ultimate tensile strength (UTS) of weld joint.

Taguchi orthogonal array is used for parameter optimization. The purpose of the Taguchi method is to maximize robustness and to minimize variation. According to a literature review selection of material was the most important factor for analysis whether it was similar or dissimilar. The application of design of experiment (DOE) and ANOVA (Analysis of Variance) played an important role in the parametric investigation of similar or dissimilar material.

V. OBJECTIVES

The objective of the present study is to analyze the effect of Rotational speed, Friction Pressure, Upsetting Pressure on tensile strength of obtained weld during Rotary Friction Welding of Stainless Steel 304 and Mild Steel.

VI. CONCLUSION

Rotary friction welding of high strength can be obtained by proper selection of welding parameters for similar or dissimilar material. During the rotary friction welding process, misalignment problem is to be taken care for obtaining good weld joint. Rotational speeds, friction pressure, upsetting pressure, upsetting time are the significant parameters influencing on Rotary Friction Welding of identified material.

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