A Literature Review on Friction Welding Process

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Abstract- *Friction welding 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. In this research paper, review of research papers related to friction welding is done.*

Keywords- Friction Welding, Dissimilar Metal Welding, Rotary Friction welding.

I. INTRODUCTION

Friction Welding

Friction welding is a solid-state welding process that allows material combinations to be joined than with any other welding process. In continuous drive friction welding, one of the work pieces is attached to a motor driven unit while the other is restrained from rotation as. The motor driven work piece is rotated at a predetermined constant speed. The work piece to be welded are forced together and then a friction force is applied. Heat is generated because of friction between the welding surfaces. This is continued for a predetermined time. The rotating work piece is halted by the application of a braking force. The friction force is preserved or increased for a predetermined time after the rotation is ceased. Figyre1also illustrates the variation of welding speed, friction force and forging force with time during various stages of the friction welding process. With friction welding, joints are possible between not only two solid materials or two hollow parts, but also solid material hollow part combinations can be reliably welded. However, the shape of a fusion zone in friction welding is dependent the force applied and the rotational speed. If the applied force is too high or the rotational speed is too low, the fusion zone at the centre of the joint will be narrow. On the other hand, if the applied force is too low or the rotational speed is too high, the fusion zone at the centre of the joint will be wider. In both the cases, the result is poor weld joint strength.

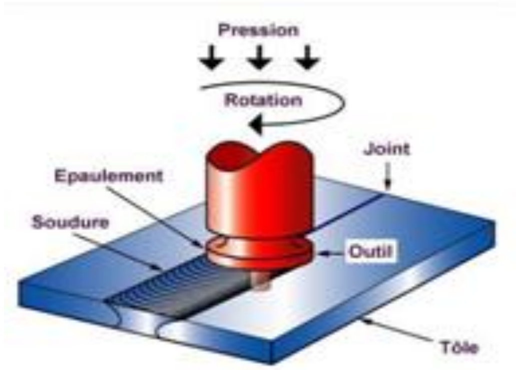
The foremost difference between the welding of similar materials and that of dissimilar materials is that the axial movement is unequal in the latter case whilst the similar materials experience equal movement along the common axis. This problem arises not only from the different coefficients of thermal expansion, but also from the distinct hardness values of the dissimilar materials to be joined.

The Microstructural evolution interface of medium carbon steel/austenitic stainless steel depends on thermo-chemical interactions between the two materials. Joint and edge preparation is very important to produce distortion free welds. The solid-state diffusion is slow in the wider joints .The intermetallic com-pounds can change the micro hardness near the joint interface of dissimilar metals.

Hence, friction welding of dissimilar metals needs to be eased by ensuring that both the work pieces deform similarly. In this context, the objective of the present work is to modify the joint design for the joining interface of 1050 alumi-num/1050 mild steel. The fatigue life is determined for all the joints fabricated by the friction welding.

Rotary friction welding is the most common form of friction welding and has become the industry standard for a number of processes including welding API drill pipes and drill rods, joining of axle cases and spindles and welding of piston rods. Rotary friction welding involves holding one component still while spinning the other component and brining the two together.

Thompson Friction Welding are the world leaders in rotary friction welding having supplied over 500 machines and have over 45 years experience. In order for a join to be successful the following processes must take place



ADVANTAGES OF FRICTION WELDING

1. Enables joining of dissimilar materials normally not compatible for welding by other joining methods.
2. Creates narrow, heat-affected zone
3. Consistent and repetitive process
4. Joint preparation is minimal – saw cut surface used most commonly
5. Faster Turn-around Times - compared to the long lead time of forgings.
6. Greatly increases design flexibility – choose appropriate material for each area of a blank
7. Suitable for diverse quantities – from single prototypes to high-volume production
8. No fluxes, filler material, or gases required
9. Environmentally friendly process – no fumes, gases, or smoke generated
10. Solid state process – no possibility of porosity or slag inclusions
11. Creates cast or forge-like blanks – without expensive tooling or minimum quantity requirements
12. Reduces machining labor, thereby reducing perishable tooling costs while increasing capacity
13. Full surface weld gives superior strength in critical areas
14. Reduces raw material costs in bi-metal applications.

II. LITERATURE REVIEW

Sahin et al., [1] have studied friction welding of plastically deformed steel bars. They worked oncontinuous drive friction welding of same material but different diameters bars. They used carburizing steel for that purpose.

Mumin Sahin, [2] have worked on computer program simulation of how weld flashes occur in welded joints of equal or different diameter of AISI 1040 (Medium carbon steel). He investigated that the optimum welding parameters obtained from equal diameter parts cannot be used in welding of parts that have different diameter and width. As a result, in welding of parts having different diameter and width, the optimum parameters of the joints should be ordinary selected in the experiments.

Mumin Sahin, [3] have worked on friction welding of high speed steel (HSS—S 6-5-2) and medium carbon steel (AISI 1040) (both of 10 mm dia.). He investigated optimum welding parameters for these combinations of metals. Also, he finds that the tensile strength of welded part is close to that of medium carbon steel (AISI 1040).i. e. the part having weaked of medium carbon steel (AISI 1040).

AtyaSnarayana et al., [4] have carried out a study on continuous drive friction welding of austeniticferritic stainless steel. The parent metal used for that study was AISI 304 austenitic stainless steel and AISI 430 ferritic stainless steel. He used ANOVA technic of Yate's algorithm to analyze the results obtained by experiments.

Meshram et al., [5] conducted an investigation of dissimilar metal joining combinations: Cu–Ni, Fe– Cu, Fe–Ti, Cu–Ni Fe–Ni and Cu–Ti. They observed the influence of interaction time on microstructure and tensile properties of the friction welding of five dissimilar metal combinations.

Moat et al., [6] have studied Microstructural variation across inertia friction welded SCMV (high strength low alloy Cr–Mo steel) and Aermet 100 (ultra-high strength secondary hardening steel).They carried out micro-hardness testing and hard X-ray diffraction mapping on inertia friction welded samples of SCMV steel and super high strength Aermet 100 steel in the as-welded postweld heat-treated condition.

Dey et al. [7] chose titanium (18 mm dia. & 100 mm length) and 304L stainless (14 mm dia. & 100 mm length) steel to weld by continuous drive friction welding. During this work they have investigated optimum friction welding parameters that produce joints that are stronger than the Ti base material as confirmed by tensile test, and tensile test failure occurred in the Ti base material.As-welded bend test samples failed with almost zero bend ductility. The bend ductility was improved to 5° PWHT (Post weld heat treatment).Corrosion test showed corrosion rate of 10 mpy (milli-inch per year) with boiling nitric acid.

Seli et al., [8] have studied mechanical properties of mild steel and aluminum welded rods tounderstand the thermal effects. They used an explicit one-dimensional finite difference method to approximate the heating and cooling temperature distribution of the joint. They observed thermal effects of the friction welding to have lowered the welded materials hardness compared to the parent materials.

Winiczenko et al., [9] have investigated friction welding of ductile iron with stainless steel (both 20 mm dia. & 100 mm length). They used stainless steel interlayer in two ductile iron bars to weld it by continuous drive friction welding.

Udayakumar et al., [10] have carried out experimental investigation of mechanical and metallurgical properties of super duplex stainless steel bars welded by friction welding. They carried experiments on specimens of super austenitic stainless steel (UNS S32760) of 16 mm diameters and 100 mm length. A four factor, three level central composite designs (CCD) was used to determine optimal factors of friction welding process of super duplex stainless steel.

Ahmet Hascalik, Nuri Orhan [11] investigate the feasibility of joining Al2O3 reinforced Al alloy composite to SAE 1020 steel by rotational friction welding. The aluminum based MMC material containing 5, 10 and 15 vol% Al2O3 particles with average particle sizes of 30 and 60 micro m was produced by powder metallurgy technique. The integrity of the joints has been investigated by optical and SEM, while the mechanical properties assessment included micro hardness and shear test. Results indicated that Al/ Al2O3 composite could be joined to SAE 1020 steel by friction welding. However, it was pointed out that the quality of the joint was affected negatively with the increase in particle size and volume % of the oxide particles in the MMC.

Mumin Sahin [12] investigate experimentally the micro-structural properties and welding strengths of the joints using austenitic-stainless steel (AISI 304) parts. The experiments were carried out using a beforehand designed and constructed experimental friction welding set-up, constructed as continuous-drive. Firstly, welding experiments under different friction time and friction pressure were carried out to obtain optimum parameters using statistical approach. Later,the strengths of the joints were determined by tension, fatigue and notch-impact tests, and results were compared with strengths of materials. Hardness variations and microstructures in the interfaces of the joints were also obtained and examined. Then, obtained results were compared with those of previous studies.

Mumin Sahin [13] an experimental set-up was designed in order to achieve friction welding of plastically deformed austenitic-stainless steels. AISI 304 austenitic-stainless steels having equal and different diameters were welded under different process parameters. Strengths of the joints having equal diameter were determined by using a statistical approach as a result of tension tests. Hardness variations and microstructures using scanning electron microscope (SEM) analysis in the welding zone were obtained and examined. Subsequently, the effect on the welding zone of plastic deformation was analyzed. It has been established that plastic deformation of AISI 304 austenitic-stainless steel has neither an effect on the process nor on the strength of the welding joint.

Mumin Sahin, H. Erol Akata, Turgut Gulmez [14] deals with the importance of welding in manufacturing methods. There are various welding methods that have been developed to obtain suitable joints in various applications.However, friction welding, which is an alternative manufacturing method, is one of the methods that have been widely used for many years. Mumin Sahin et. al. present an experimental friction welding set-up, which is a continuous drive friction welding set-up, was used in the experiments. Firstly, optimum parameters were obtained to join parts having equal diameter.

Ahmet Z. Sahin, Bekir S. Yibas¸, M. Ahmed, J. Nickel [15] the heat-transfer mechanism initiating the friction welding process was examined and a transient two-dimensional heat conduction model for the welding of two dissimilar cylindrical metal bars was introduced. The bar materials consist of copper and steel. To relate the theoretical predictions with the resulting welds, experiments are conducted under different welding conditions by means of which metallurgicaland microprobe analysis of the weld cross-sections was carried out. This provides visualization of the melted zones and of the diffusion depths. A statistical analysis was carried out for the affecting parameters on the mechanical properties of the resulting welds. The factors affecting the weld include the speed of rotation, the weld duration (burn off time), and the friction load, while the mechanical properties include the tensile strength, the yield strength, the ultimate yield strength and the micro hardness of the weld cross-sections.

D. Ananthapadmanaban, V. Seshagiri Rao, Nikhil Abraham and K. Prasad Rao [16] mechanical property variation under different friction welding conditions for mild steel stainless steel joints by D. Ananthapadmanabam et. al.Yield strength, ultimate tensile strength, percentage elongation of the welded joints and hardness variations across the weldinterface has been reported. The integrity of the joints has been investigated using optical microscopy and scanning electronmicroscopy.

F. Rotundo, L. Ceschini, A. Morri, T. S. Jun, A. M. Korsunsky [17] evaluate the possibility of using the linear friction welding (LFW) technique to produce sound joints on a

2124Al/25 vol.% SiCp composite. The MMC joints were subjected to micro structural and mechanical characterization, including hardness, tensile and fatigue tests, without any post weld heat treatment. The micro structural analyses showed substantially defect-free joints, with a uniform particle distribution in the central zone and a relevant plastic flow of the aluminium matrix alloy. The hardness decrease in the welded zone was approximately 10% in respect to the base material. The joint efficiency was higher than 80%, both in respect to the ultimate tensile strength and fatigue strength at 107 cycles. S-N probability curves were calculated using themaximum likelihood method. Generally the fracture occurred in the Thermo-Mechanically Affected Zone (TMAZ), with a relevant reduction in the elongation to failure.Hakan Ates,

Mehmet Turker and Adem Kurt [18] effect of friction pressure on the properties of friction hotrolled MA956 iron-based super alloy plate, produced by mechanical alloying, has been investigated. Joining processes were carried out by various friction welding parameters. Tensile strengths and hardness values of the weld interface were determined and the microstructure features of these samples were investigated. Optimum friction pressure for this material was determined.

Hazman Seli, Ahmad Izani Md. Ismail, Endri Rachman, Zainal Arifin Ahmad [19] friction welding of two dissimilar materials, two rods are welded together by holding one of them still while rotating the other under the influence of an axial load which creates frictional heat in the interface. In this study, mechanical properties of mild steel and aluminum welded rods were evaluated to understand the thermal effects, and an explicit one-dimensional finite differencemethod was used to approximate the heating and cooling temperature distribution of the joint. The thermal effects of the friction welding were observed to have lowered the welded materials hardness compared to the parent materials. The tensile strength of the welded rods is lower than the parent rods due to incomplete welding. The preliminary predictions were compared to actual thermocouple data from welds conducted under identical conditions and were shown to be in fairagreement. The finite difference method proposed in this work will provide guidance in weld parameter development and will allow better understanding of the friction welding process.

H.C. Dey, M. Ashfaq, A.K. Bhaduri and K. Prasad Rao [20] gives the details of mechanical tests, microstructure analysis using optical and scanning electron microscopy. The dissimilar metal joint of titanium (Ti) to 304L stainless steel (SS) is essential in the nuclear industry for the dissolution of spent fuel that is carried out in boiling nitric acid in the dissolver vessel (made of Ti) and the dissolved solution is transported through the 304L SS pipes to the other plantcomponents made of 304L SS. Because of the radioactive environment, leak tightness and corrosion resistance of this dissimilar joint are important. In this work, friction welding process was attempted to join Ti to 304L SS. Direct friction welding of Ti to 304L SS results in a stronger weld in which failure occurs in the Ti base metal during tensile testing.However, the joints have almost zero bend ductility that has been attributed to the formation of intermetallics due to mechanical alloying, strain hardening of Ti near the joint interface and residual stresses. Post-weld heat treatment marginally increases the bend ductility to 5° because of relieving of the effects of strain hardening and of residual stresses at the joint interface. Corrosion test in boiling nitric acid is as per ASTM A-262 practice. The average corrosion rate is 10 mpy with the joints remaining intact after the corrosion test.

Hyung-Seop Shin, Jung-Soo Park, Yoon-Chul Jung, Jung-Ho Ahn, Yoshihiko Yokoyama, Akihisa Inoue [21] the friction welding of three kinds of Zr-Cu-Al bulk glassy alloys (BGAs) which show eutectic or hypoeutectic compositions to similar and dissimilar BGAs and crystalline metals has been tried. The shape and volume of the protrusion formed at the weld interface were investigated. In order to characterize the friction welded interface, micrographic observation and X-ray diffraction analysis on the weld cross-section were carried out. A successful joining of Zr-Cu-Al bulk glassy alloys to similar and dissimilar BGAs was achieved without occurrence of crystallizations at the weld interface through the precise control of friction conditions. In addition, the joining of Zr50 Cu40 Al10 BGA to crystalline alloys was tried, but it was only successful for specific material combinations. The residual strength after welding of dissimilar BGAs was evaluated by the four-point bending test.

Hyung-Seop Shin, Young-Jin Jeong, Ho- Yeon Choi, Hidemi, Kato, Akihisa Inoue [22]friction welding of Zr based bulk metallic glass (Zr55 Al10 Ni5 Cu30 alloy) has been tried. Friction time and friction pressure were chosen as the control parameters for the friction welding process. Their influences on the shape and volume of the protrusion formedfrom the welded interface were investigated. Temperature distribution around the interface during friction was measuredusing an infrared thermal imager. Successful joining of Zr55Al10 Ni5 Cu30BMG was accomplished through the precise control of friction time and friction pressure.

I. Mitelea, C.M. Craciunescu [23] the influence of the main friction welding parameters, such as the axial pressure,the friction stroke and the upsetting temperature on the compositional, structural and hardness gradient is shown for dissimilar joints made out of carburized and volume-hardened steels. The expulsion of the carbon-enriched layer in the burr as a qualitative factor is analyzed. Low axial pressure and long friction time favors' to the presence of a carburized layer in the joint plane. A high axial pressure, as well as increase in the friction stroke favors' the expulsion of the carbon-enriched layer from the joining area into the burr. A high upsetting pressure leads to an increase of the plasticized material expulsionin the burr.

A. A. Essa, A. S. Bahrani [24] methods of solid phase bonding of metals to ceramics are reviewed with particular emphasis on friction welding. The results of experiments on the direct friction welding of an aluminum alloy to 94% alumina are reported in this study by A. A. Essa et. al. High strength bonds between the aluminum alloy and the alumina were achieved but there were problems with the cracking of the alumina. It was not possible to friction weld mild steel toalumina and copper to alumina. A mechanism was proposed for the friction welding of metals to ceramics.

III. RESULT AND DISCUSSION

The process of friction welding of dissimilar welding is much different than conventional fusion welding process. Result of variation in parameters of friction welding process on the weld strength and weld geometry is needs to be studied. There is a good scope for studying the performance of continuous drive friction welding of aluminium and low carbon welding.

1) Friction welding has been successfully employed to weld dissimilar metals. Strength of the joints obtained was good.
2) During tensile testing, high UTS was observed in sample no. 7 due to carbon migration from SS to weld zone during welding.
3) Highest micro hardness values were observed in the specimen on the side of SS due to high friction and high heat at the welding zone. The reason for higher micro hardness was observed to be recrystalization.
4) At interface and AL maximum area fraction of un-dissolved regions was formed through the SEM examination. These un-dissolved regions results in higher micro hardness values.
5) Temperature modelling of friction welded joint has efficiently accomplished.

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