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Friction Welding - A Review

***Amit Handa*[1*]*--- Vikas Chawla*[2]**

[1]PhD Research Scholar, Punjab Technical University, Kapurthala, (Punjab) India
[2] Director-Principal, Ferozepur College of Engineering & Technology, Ferozepur, (Punjab) India

Abstract

Conjoining of divergent materials is one of the most indispensable need of industries. There are many conventional welding techniques that have been developed to obtain suitable joints in various applications. Conventional fusion welding techniques of many such dissimilar metal combinations is not expedient due to the accumulation of brittle and low melting intermetallics due to large differences in melting points, difference in metallurgical properties and thermal mismatch. However, friction welding is a joining process that allows more materials and material combinations to be joined than with any other welding process. Friction welding is a solid state joining process which is extensively used due to its advantages such as low heat input, ability to join dissimilar materials and environment friendliness. Friction welding can be used to join different kinds of materials which cannot be welded by conventional fusion welding processes.

Keywords: Friction welding, dissimilar materials, mechanical properties, metallurgical properties.

Contents

* *Corresponding Author*

1. Introduction

Dissimilar joints between austenitic stainless steel and low alloy steel are extensively used in many high temperature applications in the energy conversion system [1, 2]. There is a wide need for unlike metal joints in power plant constituents, due to the stark gradients in mechanical in addition to thermal loading. In central power stations, the components of the boiler that are lay open to lesser temperatures, are manufactured of low alloy steel for monetary reasons. The additional parts, operating at advanced temperatures, are fabricated with austenitic stainless steel. Therefore, transition welds are desirable between these two constituents. The joining of unlike materials is normally more challenging than those of the alike materials due to variance in thermal, metallurgical and physical properties of the parent metals. The specific problems associated with welding of austenitic stainless steel are formation of delta ferrite, sigma phase, stress corrosion cracking, and sensitization at the interface [1]. Friction welding is one such solid state welding process widely employed in such situations [3-6]. Main advantages of friction welding are high material saving, low production cost, and ability to weld dissimilar materials [7]. Friction welding is one of the versatile and well established welding processes [3] that are capable of giving good quality welds; it gives solid state joining of the materials through the controlled rubbing of the interfaces. Due to thus produced heat softens the material and brought the localized faces into the plasticized form which results in good quality welds [8]. In this process heat energy is produced by the interconvertion of mechanical energy into thermal energy at the interfaces of the rubbing components [9]. There are two variations in the friction welding process. In the original process one part is held stationary and the other part is rotated by motor which maintains an essentially constant rotational speed. The two parts are fetched in interaction under force for a quantified period of time with a definite pressure. Rotating power is disconnected from the revolving piece and the pressure was amplified. When the rotating piece halts the weld is concluded. This procedure can be precisely well-ordered when speed, pressure and period are closely structured.

In direct drive friction welding, one of the work pieces is attached to the rotating head while the other is restrained from rotation. The stationary part must be held rigidly to resist the axial force and prevent it from rotating. The rotating work piece is rotated at a predetermined constant speed. Revolution is sustained until the whole joint is heated sufficiently. The work pieces to be welded are forced together and then the axial force is applied. Heat is generated as the facing surfaces rub together. The rotational driving force is discontinued and the rotating work piece is arrested by the application of a breaking force. The friction welding force is maintained for some time after rotation ceases. In this case, the welding process variables are rotational speed, axial force, welding time, and upset force. Since energy must be provided at the rate necessary to make the weld, the process requires a relatively high-powered drive motor.

The additional variation is called inertia joining. Here a flywheel is rotated by a motor till a pre-set speed is touched. It, in turn, revolves one of the pieces to be joined. The motor is disconnected from the flywheel and the further part to be welded is fetched in contact under pressure by the revolving part. During the pre-set time through which the rotational speed of the part is reduced, the flywheel is taken to an instant stop and supplementary pressure is provided to complete the joint. A weld is made by applying an axial force through the rotating work piece while the flywheel decelerates, transforming its kinetic energy to heat at the joint. The weld is accomplished when the flywheel halts. The welding variables for this process are the flywheel moment of inertia, flywheel rotational speed, axial force, and upset force.

2. Principle of Friction Welding

Friction welding is a solid state joining process wherein coalescence is produced by the heat produced from mechanically induced sliding motion between rubbing surfaces. The work parts are seized together under force. The process involves rotating of one component at high speed against the stationary one to generate heat which is liberated due to frictional resistance. Once sufficiently heat is generated, the rotation is ceased to form the joint.

Friction welding, illustrated sequentially in Figure 1 is a solid-state process that accomplishes joining with the heat produced by means of the compressive force generated by the work pieces rotating or moving in relation to each other, causing the displacement of material from the faying surfaces. Friction welding machines are therefore designed to convert mechanical energy into heat at the joint to be welded. Initially one piece is mounted on the chuck and rotated to the required speed and the other piece is clamped. The process of friction welding, in practice is accomplished in four phases.

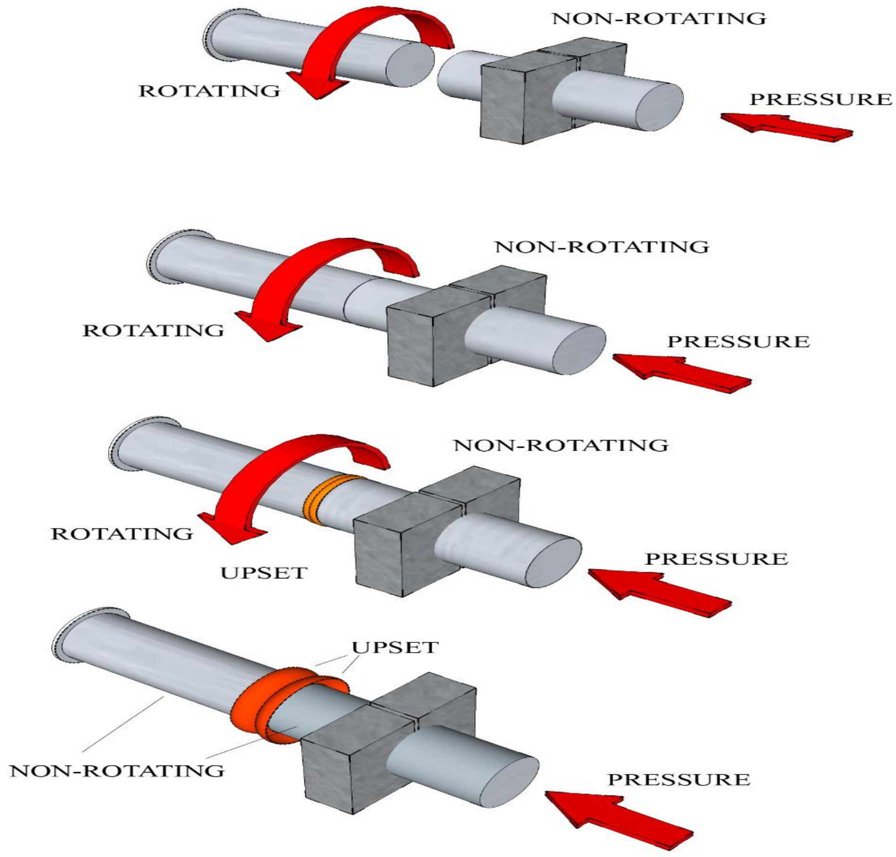

Figure-1. Schematic illustration of friction welding

3. Remarks about Friction Welding

Watanabe, et al. [8] tried to butt-weld an aluminum alloy rod to a mild steel rod by friction welding, and investigated the effects of rotation speed. The behavior of the oxide film on the faying surface of the mild steel during welding was examined. Welding of an aluminum alloy to mild steel was easily and successfully achieved by friction welding. The extreme tensile strength of the joint remained about 86% of that of the base metal. A small amount of intermetallic compounds was formed at the upper part of the mild steel/aluminum interface, while no intermetalic compounds were observed in the middle and bottom parts of the interface. The areas where the intermetallic mixtures formed appeared to be fracture paths in the joint. Many fragments of the mild steel were scattered in the aluminum alloy matrix and the oxide film removed from the faying surface of the steel by the rubbing motion of a rotating pin was observed at the interface between the mild steel fragments and the aluminum alloy matrix.

Applications described by Vill' [9] include the production of long steel bolts by the welding of short pieces of hexagon bar to long round bars of similar diameter, idler shafts for belt conveyors and the welding of discs to rods to form gear blanks with attached shafts. According to Vill' [9], for friction welding one of the parts to be welded is round in cross section; however, this is not an absolute necessity. Visual examination of weld eminence can be centred on the flash, which follows around the outside boundary of the weld. Normally, this flash will extend beyond the outside diameter of the parts and will curl around back towards the part but will have the joint extending beyond the outside diameter of the part. If the flash twigs out comparatively straight from the joint, it is an indication that the period was too little, the pressure was too short, or the speed was too high. If the flash curls moreover far back on the exterior diameter, it is a signal that the time was too long and the pressure was also high. Between these extremes is the precise flash shape.

Handa and Chawla [10] experimentally joined the AISI 1021 by using the friction welding techniques using three rotational speeds and five different axial pressures. They concluded the effect of rotational speed as well as axial pressure on the mechanical properties of friction welded steel and found the improvement in mechanical properties with the rise in rotational speeds. According to their investigation, the optimum parameters for achieving best mechanical properties were the combination of 1250 rpm with 120 MPa axial pressure

Alves, et al. [11] did experimentation on friction welding of Aluminum AA 1050 with AISI 304 stainless steel, they friction welded the dissimilar metals and monitored the temperature at the bonding interface during the rotary friction welding process. They have found that the highest rate of heating occurred in the first ten seconds of the first phase of welding. They have also revealed that maximum temperature which was achieved using this combination of materials was 374 degree Celsius. This result confirmed that the temperature during welding coincides with the range of hot forging of AA 1050 aluminum.

Celik and Guns [12] worked on continuous drive friction welding machine by friction welding Al/SiC composite with AISI 1030 low alloy steel. They stated that in conventional welding methods, such as those used in joining ceramic-reinforced aluminum matrix composites, a variety of problems occurs. The part used for strengthening, which rises the viscosity in the melting phase, marks the mixing of matrix and reinforcement material hard, and this causes lower joining quality and makes the formation of welding tough. Also, chemical reactions and undesirable phases are observed due to difference between the chemical potential of the matrix and reinforcement material. The same has been joined by continuous drive friction welding machine and found that there was much improvement in the mechanical properties and the joint integrity was also found to be excellent. The results of the study indicated that an aluminum matrix composite and AISI 1030 steel can be optimally joined by the friction welding process.

Dissimilar weldments were produced by Handa and Chawla [13] using friction welding technique. The joints were produced at five different axial pressures. The fractography analysis were conducted to evaluate the mode of failure. The SEM fractographs indicate that with the increase in axial pressure, the joint strength increases. With rise in axial pressure the river like pattern firstly converts into cleavage type and with the further increase in pressure dimples were apparent, indicating ductility (Fig 2).

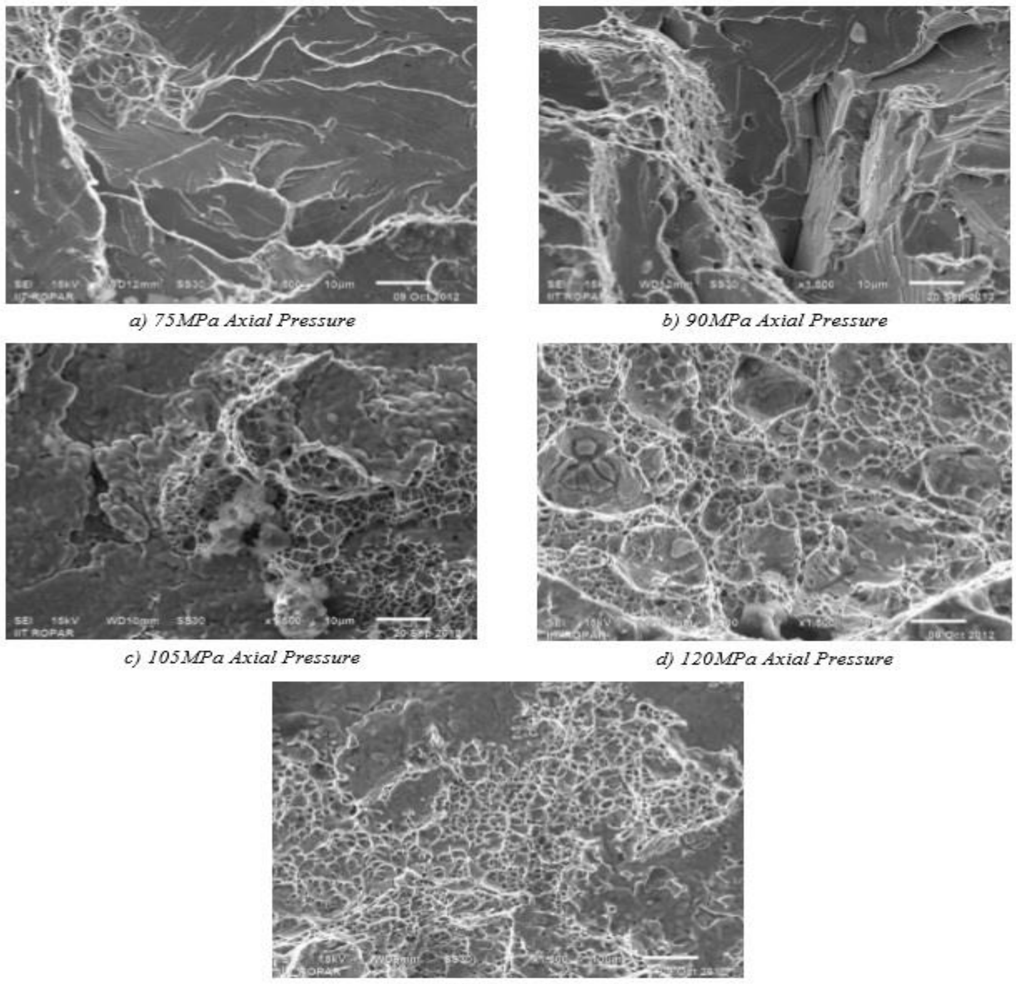

Fig-2. SEM micrograph taken at the fractured surfaces during tensile testing of the friction welded specimen welded at 1000 rpm and at different axial pressures

Ozdemir [14] reported that microstructural evaluation of friction welded joints of AISI 304L to AISI 4340 steel revealed four distinct zones across specimens which were identified as PM (Parent Metal), PDZ (Partial Deformed Zone), DZ (Deformed Zone) and FPDZ (Full Plasticized Deformed Zone) as shown in Fig 3. Also the author concluded that the higher microstructural changes took place in the FPDZ and DZ region. The width of FPDZ region is mainly affected by rotational speed. The use of higher rotational speed and shorter friction time increases the tensile strength of friction weld. It can be inferred that the width and formation of FPDZ which occurred as a result of the reactions taking place at welding interface have a detrimental effect on the mechanical strength and consequently the quality of the friction welded AISI 304L with AISI 4340 steel couple may be optimized by optimizing the suitable parameters.

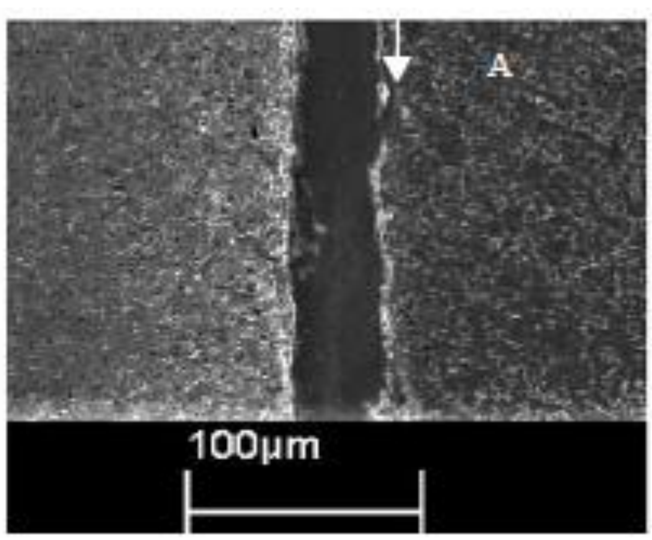

Fig-3. SEM micrograph taken from the welding interface of the friction welded specimen welded at 1500 rpm Ozdemir [14]

In this investigation Handa and Chawla [2] made an attempt to join austenitic stainless steel with low alloy steel at different combinations of speeds and axial pressures. Furthermore, the torsional, impact strength and hardness values were observed by the authors. The authors revealed that the torsional strength increases with the increase in rotational speeds, the torsional strength increases with the increase in axial pressure as well. Maximum hardness was observed at the center of the weld interface and if one proceeds away from the joint vicinity, hardness starts decreasing.

4. Conclusions

It has been concluded from the above study that friction welding is the alternative method which can be effectively used for joining of dissimilar methods. The joint strength available with friction welding is four times greater than available with the conventional welding processes. It was also evident from the literature that with the increase in rotational speed, the mechanical properties gets improved. The mechanical properties also gets enhanced with the rise in axial pressure as well. This might be attributed that with the rise in either the rotational speed or the axial pressure, more heat was generated at the vicinity of the joint, resulting in migration of elements from one metal to another. It was also concluded from the study that flash was generated during the friction welding process and the amount of flash is more towards the low alloy steel than that of austenitic stainless steel side. The amount of hardness available was found to be more than available on the parent materials and the maximum hardness was found to be on the weld interface.

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