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Latest Developments in Friction Welding- A Review

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***Abstract:** Friction welding has been used for joining the two metal or alloys by the force of friction and it is having numerous benefits over the other conventional methods of joining the alloys. Some of the benefits obtained by this welding are better tensile strength, refine grain hardness, microstructure improvement and metallurgical properties over the parent metal. So, the prime intention of this study is to review the latest trends in the field of friction welding and throwing the light on some aspects which have not realised the potential yet. Therefore, in this research article some stories of the friction welding are collected and analysed on the basis of the parameters, testing and type of materials used for the welding purposes. From most of the articles quoted, it has been found that rotational speed was found to be the dominating parameter among them but the parameter of heat input and stress analysis through latest methods have not used upto that level. On the basis of this review, some recommendations for the manufacturing sectors are highlighted here which may prove to be useful for the industrial applications in the forthcoming times.*
***Keywords:** Friction welding, alloy; welding; hardness; strength, literature review*

I. INTRODUCTION

Friction welding is a variation of pressure welding method, in which the welded connection is formed without melting the metal, by joint plastic deformation of the pieces to be welded with the help of heat resulting from friction [1]. Here we generate large amount of localised intense heat generation and deformation results in less energy consumption and highly strong weld [2]. As it is a solid state welding process, the process does not form molten pool thereby eliminating the solidification errors. Friction Welding can join two different materials having different thermal and mechanical properties without compromising the strength of the weld. Friction Welding is preferred over conventional processes because of low cost, highly precise operations, repeatability and reliability [3]. During welding, one part rotates at a high speed while the other remains stationary, and an axial force is used to bring the two parts together [4, 5]. It can be used to tie solid and tubular sections together. A flash occurs at the interface region due to the combination of heat and pressure.

As a general rule, every forgeable metal can be friction welded. This gives more freedom to the engineers as they can create bimetallic structure. Some of the common bimetallic friction joints are:

1) Aluminum to steel
2) Copper to aluminium
3) Titanium to copper
4) Nickel alloy to steel

Copper to aluminum joints are commonly considered unweldable, but with friction welding, it is possible. Friction welding does not require any external heat or flux, keeping the process easy and less messy [6, 7]. Moreover, it contains minimal or no defects when compared to fusion welding. Friction welding is considered one among the fastest welding methods, clocking up to twice or even 100x faster than normal fusion welds. In the present research, the literature review has been done on friction welding in order to determine the different process variables while welding of different substrate materials.

II. LITERATURE REVIEW

Paventhan et al. [8] An attempt was made to develop an empirical relationship to predict the tensile strength of friction welded aisi 1040 grade medium carbon steel and AISI 304 austenitic stainless steel, incorporating the process parameters such as friction pressure, forging pressure, friction time and forging time, which have great influence on strength of the joints. response surface methodology was applied to optimize the friction welding process parameters to attain maximum tensile strength of the joint.

The maximum tensile strength of 543 MPa could be obtained for the joints fabricated under the welding conditions of friction pressure of 90 mpa, forging pressure of 90 MPa, friction time of 6 s and forging time of 6 s. Winizenko and Kaczorowski [9] The authors investigated the mechanical properties and microstructure of friction welded coupe of ductile iron with stainless steel. Scanning electron microscopy (SEM) was used for investigation of the fracture morphology and phase transformations taking place during friction welding process. Friction welding is accompanied by a transport of atoms in both directions across the ductile iron-stainless steel interface. This results in the enrichment of stainless steel with carbon and ductile iron with chromium and nickel atoms. Stainless steel carbon enrichment results in the formation of chromium carbides that are distributed mostly at the grain boundaries. Iron enrichment in Cr and Ni resulted in the creation of an alloy ferrite. Cr was found also in a carbide eutectic. The range of Cr and Ni diffusion in iron generally does not exceed 50 m. The depth of the diffusion of carbon in the case of a joint subjected to a double thermal effect is 150 m and higher than for a sample subjected to one step friction welding. The intensity of diffusion processes during friction welding of bainitic ductile iron is larger than for ferritic ductile iron.

Selvamani and Palanikumar [10] In this work, 12mm diameter AISI1035 grade steel rods are friction welded with an aim to optimize the process parameters. The joints are made with various process parameter combinations (incorporating ANOVA methods) subjected to tensile test. A maximum tensile strength of 548.439MPa could be attained in friction welded AISI 1035 grade medium carbon steel rods under the welding conditions of 28.8 MPa/s of Friction pressure/time, 29.4MPa/s of Forging pressure/time and 24.41rps of rotational speed. Rotational speed was found to have greater influence on tensile strength of the joints followed by Forging pressure and Friction pressure. Prasanthi et al. [11] The investigation deals with the efforts to form a defect free bonded interface between mild steel (MS) and titanium (Ti) using the rotation friction welding process. The conditions were optimized based on several trials by varying friction welding parameters like frictional force, upset force, burn-off length and rotational speed. Friction welds of mild steel and grade-2 Ti have been successfully fabricated using optimized values of frictional force, upset force, burn-off length and rotational speed (0.8 tonnes, 1.6 tonnes, 3 mm and 1000 rpm respectively).

Kimura et al [12] The authors found the joining phenomena and the tensile strength of friction welded joint between titanium alloy (Ti–6Al–4V) and low carbon steel (LCS). The joining phenomena during the friction process such as joining behavior, friction torque, and temperature changes at the weld interface were measured. The effects of friction pressure, friction time and forge pressure on the joint strength were also investigated, and the metallurgical characteristics of joints were observed and analysed. Reddy [13] The purpose of this work was to assess friction welding of AA1100 and Zr705 alloy. Finite element analysis was adopted to analyze the friction welding process. The process parameters were frictional time, frictional pressure, rotational speed and forging pressure. The joints were evaluated for their strength, bulk deformation, penetration and flange formation. For friction welding of AA1100 and Zr705 alloy, the forging pressure should be 1.25 times of the frictional pressure. The author revealed that the friction welding of AA1100 and Zr705alloy is satisfactory if the operating conditions: frictional pressure of 25 MPa, frictional time of 4 sec, rotational speed of 2000 rpm and forging pressure of 31.25 MPa.

McAndrew et al. [14] did their investigation on friction welding of Ti-6Al-4v using for the manufacturing of bladed disks in aero engines. This research threw light on the important aspects of linear friction welding and its limitations. And this article also contributed to the analytical and numerical modelling and finally the research implications for the manufacturing sector are depicted in this research. Wang et al. [15] An extensive investigation on the effect of linear friction welding parameters on the microstructure, texture distribution and mechanical properties of Ti-6.5Al-3.5Mo-1.5Zr-0.3Si titanium alloy joints was performed. The authors found that a critical shear velocity is necessary to be reached to obtain a sound joint. The width of the thermo mechanically-affected zone (TMAZ) was reduced with friction pressure or/and shear velocity, while the width of the weld centre zone (WCZ) remained constant. Kimura et al [16] The authors investigated the effects of tensile strength on friction welding condition and weld faying surface properties of friction welded joints between pure copper and austenitic stainless steel (AISI 304). The joining phenomena and the joint tensile strength at various friction welding conditions were investigated. The maximum temperature of the joint at a friction pressure of 90 MPa was lower than that of 30 MPa. Also, the central portion of the weld interface of the joint with high friction pressure was not joined completely. Hence, it was showed that the joint should be made with a low friction pressure. As a conclusion, the good joint with the fracture in the OFC side should be made with a low friction pressure such as 30 MPa, a friction time after the friction torque reached the initial peak such as 3.6 s, and a high forge pressure such as 270 MPa. Furthermore, the weld faying surface of the OFC side should be polished just before welding, and it was suggested.

Balasubramanian et al. [17] The authors did experiment on dissimilar joining of Ti and SS using copper in the form of the rod using method 1 and copper coin using method 2 successfully. The oxygen-free copper did prove as a very good interlayer material in the joining Ti and Stainless Steel, resulting in a defect-free joint with great strength. Maximum tensile strength of 303 MPa and 270 MPa was achieved using methods 1 and 2 respectively.

Banerjee et al. [18] Defect-free welds between A-516 ferritic and 316L austenitic stainless steel were achieved using inertia friction welding (IFW) under varying friction and forge pressures. The microstructural evolution and the associated mechanical properties were characterised across different weld regimes. The welds were free from microcracks and demonstrated higher strength and hardness than the parent metal (PM), indicating enhanced properties. Carbide precipitates were not observed at the weld interface, implying no occurrence of sensitisation in the stainless steel. The presence of refined grains coupled with low grain orientation spread (GOS) values was the indication of continuous dynamic recrystallisation (CDRX) occurring during IFW. Sundaraselvan et al [19] The authors evaluated the improvement of solid state joints made of different materials, Al6082 Aluminum and Mild Steel. Rotary friction welding was used to create the joints (RFW). The process parameters of friction welding machine were optimised using response surface methodology (RSM) to achieve the maximum tensile strength of the joint. Friction pressure, forging pressure, friction time and forging time have influence on effect of parameters. Among them, forging time has greater influence over Tensile strength by the formation of intermetallics. The maximum tensile strength is 613 MPa, obtained from sample which is prepared by friction (6 MPa) and forging (7 MPa) pressures for 4 s. Raj and Biswas [20] The authors stated that using an external heat source during friction stir welding (FSW) of high melting point materials is a promising approach to enhance the material flow and reduce the axial load, improving the tool life. The welding was performed at a constant rotational speed of 300 rpm with welding speeds of 70 and 140 mm/min and 300 °C preheating temperature in the assisted FSW. The results show that the application of friction stir welding resulted in highly refined grains with deformed carbide particles in the stir zone of both materials, which increased mechanical properties. An increase in temperature during the I-FSW process led to a slight increase in the size of the particles and high atomic diffusion of Cr and Mo elements at the interface of the SS316L and Inconel 718 joint, which showed enhancement of the weld strength.

III. CONCLUSIONS AND RESEARCH IMPLICATIONS

Friction welding is a solid-state joining process used extensively currently owing to its advantages such as low heat input, high production efficiency, ease of manufacture, and environment friendliness. materials difficult to be welded by fusion welding processes can be successfully welded by friction welding. From above discussions which were limited to only the last decade, some conclusions may be drawn which are summarised as follow; efficient method of joining the ferrous and non ferrous alloys, superior properties than parent metal and better bonding other methods of joining. But for most of the studies were pinpointed were focused on the rotational speed, forging pressure, forging time and diameter involved of the material. This created a gap on analysis the stress analysis for the most of the welding joints which may prove a better exercise in nearby times for realising the potential of the friction welding yet.

IV. LIMITATIONS

The literature review was limited to the last decade to explore the significant effects of the friction welding in application.

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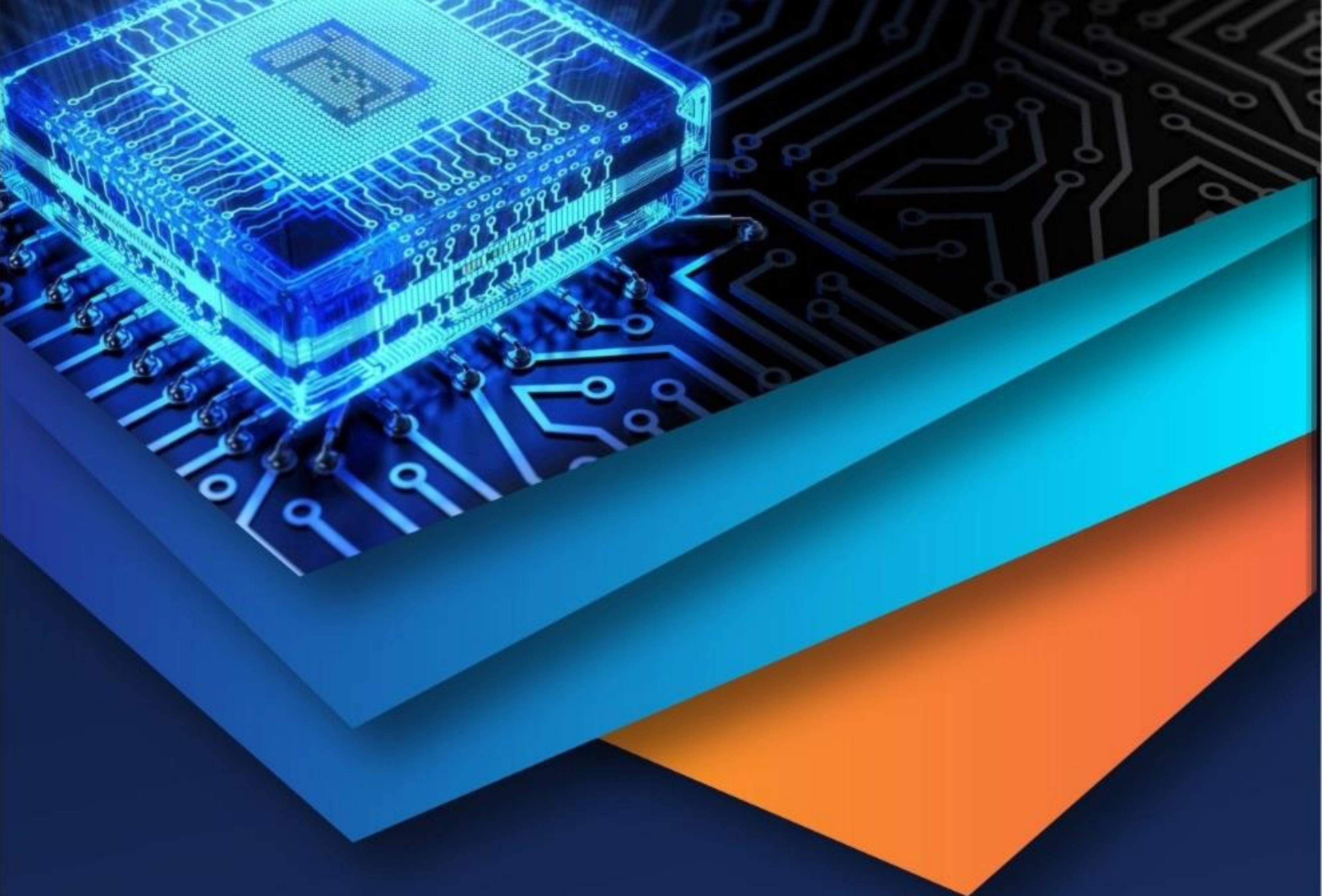

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