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Friction Stir Welding For Al-And Its Alloys

Jammula Praneeth[1], Narraa Naveen[2]
[1, 2] Mechanical Engineering, Anurag Engineering College, Kodad

Abstract: Friction stir welding (FSW) is a solid state joining process that provides many advantages such as microstructure and mechanicalproperties than conventional methods in welding aluminum alloys. When compared with conventional fusion welding methods it gives advantages such as lower residual stresses, especially high joint strength and low distortion because of lower welding temperature and also elimination of porosities and solidification cracking because of no melting occurrence.The FSW process exhibits a number of attractive advantages when compared to other welding processes, perhaps the most significant of which is the ability to weld alloys that are difficult or impossible to weld using fusion welding techniques. In this review the microstructures and mechanical properties of friction stir welding of various Al-alloys.
Key words:FSW,Aluminium, Alloys, Properties

I. INTRODUCTION

Friction stir welding (FSW)is a solid-state process that utilizes localized heat generated between a non-consumable rotating tool and the work piece to create a joint. Seminal investigations have established the feasibility of FSW copper over a range of parameters. In this method, the plates-to-be-welded clamped together rigidly in butt or overlapcondition and a stirring tool with a suitable geometry movesalong them, while the pieces-to-be-joined are moved over eachother in conventional friction welding method. The stirring tool Fig.1 rotating at a high rate is plunged into the clamped plates causing friction. The heat caused by the friction between the tool shoulder and the work piece results in an intense local heating that does not melt the plates to be joined, but plasticizes the material around the tool.The shoulder of the tool also prevents the plasticized material from being expelled from the weld. The friction at the pin surface provides additional frictional heat to the work pieces to a lesser extent.

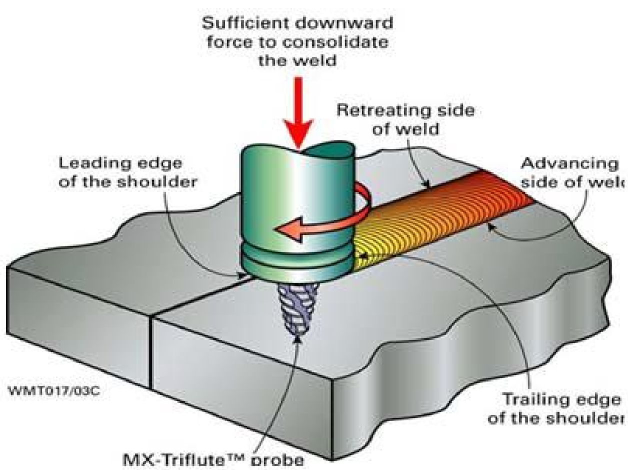

Figure 1: Schematic diagram of Friction stir welding

Friction stir forming (FSF) is a new, environmentally friendly process for joining dissimilar materials. In the process, a modified FSW tool is plunged into the top work-piece, simultaneously creating frictional heat, stirring, and forming the work material into a new shape. The new shape has many possible applications.The FSW process includes three parameters heating, plastic deformation, and forging. Anon-consumable rotating tool, consisting of a probe and shoulder, is plunged into the materials to be joined and thentraverses the joint line. Heat is generated through both friction and plastic deformation of the welded material.

The FSW technique is currently applied to the construction of double skinned railway vehicles made of aluminum hollow extrusions. However, root flaws due to a lack of tool penetration are possible to exist and a high force has to be generated to react against the welding tool pressure load. It is necessary to have a device of high rigidity and profiled backing bar to achieve conventional FSW successfully.

II. WELDING OF ALUMINIUM ALLOYS

A. Aluminium to Cu

Despite the large number of potential industrial applications of aluminium/copper (Al/Cu) hybrid components, in practice, the use of this metallic couple remains limited. The different physical and mechanical properties of both metals, as well as its chemical affinity at temperatures higher than 120 ◦C, which often results in extensive brittle inter metallic phase's formation during welding, make the joining of these two materials very difficult. Although some success in Al/Cu joining has already been achieved by friction and explosion welding, strong restrictions in the thickness of the welded plates and joint geometry limit the wider application of these processes.

Elrefaey et al. [1] were one of the first investigating the feasibility of lap joining of 2 mm-thick AA1100 H24 plates to 1 mm-thick copper plates. They found that the joint strength strongly depended on the penetration depth of the pin tip into the copper surface. The authors observed that the joints showed very weak fracture loads when the pin did not penetrate in the copper surface. On the other hand, slight penetration of the pin tip into the copper surfaceincreased the joint strength significantly. Although the level of bond strength was quite low, it exhibited a general tendency to increase with a rise in the rotation speed. Some years later, Abdollah-Zadeh et al.andSaeid et al[2] in friction stir lap welding of 4 mm-thick AA 1060 to 3 mm thick commercially pure copper, pointed out two factors affecting the welding results, i.e., the amount of brittle and hard intermetallic compounds and the "cold weld" condition. Whereas the welds produced under very high heat input conditions (high rotation speed and low traverse speed) presented formation of brittle intermetallic layers, in which strong micro-cracking takes place, the welds carried out under low heat input conditions (low rotation speedand high traverse speed) displayed incompletely welded interfaces.

Akbari et al[3] analyzed the effect of base materials positioning on friction stir lap welding of 2 mm-thick plates of AA 7070 aluminium alloy to commercially pure copper. Welds produced with the aluminium alloy located on the top of joint and the copper at the bottom, as well as welds carried out with the reverse base materials positioning, were studied by the authors. It was observed that, under similar welding conditions, the strength of the joints produced with the aluminium plate on the top was higher than that of the welds carried out with the reverse materials positioning. According to Akbari et al., the influence of the base materials positioning on the mechanical properties of the joints is closely related with the way how it affects the heat input during welding. Effectively, the authors concluded that the higher strength of the welds produced with the aluminium plate on the top of the joint is mainly influenced by the higher peak temperatures reached during welding with this plates positioning.

B. Aluminium to Mild Steel

High corrosion resistance and exceptional mechanical properties of aluminum alloys has progressed their industrial usage, especially y in car and marine industries s. However, use of aluminum in industries may result in some problems such as the process of joining of aluminum to steel. Joining of aluminum to steel is generally difficult due to differences between their physical and chemical properties [4].Both alloys have incomparable melting point, thermal conductivity, coefficient of linear expansion and heat capacity. Considering the reference phase diagram of Al–Fe system. The low solubility of iron in aluminum promotes s the formation of brittle intermetallic compounds (IMCs) such asFe_2Al_5, $FeAl_3$ and FeAl, in the weld zone. Therefore, it seems that obtaining strong joint between aluminum and steel sounds impossible or very difficult by using common fusion welding techniques. Different techniques such as diffusion bonding [5]. Friction stir welding patented by The Welding Institute (TWI), is widely employed in industry for joining of aluminum alloys [6].Uzun et al. [7] investigated the microstructure, hardness and fatigue properties of friction stir butt welded 4 mm thick aluminum 6013-T4 to X5CrNi18 -10 stainless steel. They successfully obtained sound joints and characterized the microstructure of dissimilar weld such as HAZ and TMAZ in both base metals; how- ever did not investigate the effect of process parameters on tensile propertiess of joints. Watanabe et al. [8] investigated the effect of tool rotation speed and pin position on the tensile strength of 2 mm thick aluminum 5083 alloy and mild steel sheets. The joint exhibited 86% of ultimate tensile strength of aluminum base alloy. investigated the microstructure, hardness and fatigue properties of friction stir butt welded 4 mm thick aluminum 6013-T4 to X5CrNi18 -10 stainless steel. They successfully obtained sound joints and characterized the microstructure of dissimilar weld such as HAZ and TMAZ in both base metals; how- ever did not investigate the effect of process parameters on tensile properties of joints [9]. In dissimilar welds, due to the high tendency of aluminum to react with iron, controlling the formation of IMCs is the matter of concern. According to the experiments the appropriate selection of welding parameters, especially the tool rotation, traverse speed and tool design controls the amount of heat input and therefore the microstructure of the joint [10].

C. Aluminium to Magnesium

Compared to other alloys, Al alloys and Mg alloys have lower density and high specific strength. These are extensively used in automotive, aerospace and ship industries. Owing to the difference in chemical, physical and mechanical properties between components made up of Al, Mg or their alloys, the welding of dissimilar materials is generally more difficult than that of homogeneous materials. It is difficult to produce high quality Al, Mgdissimilar joint by fusion welding technique for the following reasons :the formation of brittle inter metallic's (IMs)and formation of cracks. So dissimilar welding fMg, Al and the iralloysisa challenging technique to be developed. Use of FSW to weld Al alloys [11] and Mg alloys or, to weld Al alloy to Mg alloy has increased substantially in recent years, since these are difficult to weld by fusion welding technique [12]. The side of the tool where linear velocity vector of the rotating tool is same as the welding direction vector is called advancing side (AS) and the side where both of these vectors are opposite to each other is called retreating side (RS). The front portion of the moving tool is called leading edge and the back portion of the tool is called trailing edge.

After welding, metallographic samples and tensile samples were extracted alternatively from weld coupon (Fig. 2). In metallographic samples, Al alloy side was etched by using Kellers Reagent (1 ml HFþ1.5 ml HClþ2.5 ml HNO3þ95 ml distilled water) for 30–50 s and Mg alloy side was etched by solution (14 ml out of '2 g picric acidþ20 ml ethanol'þ2 ml acetic acidþ2 ml water) for 5 s [13].

Figure 2: Surface morphology of the FSW coupon of Al alloy to Mg alloy

III. CONCLUSION

Friction stir welding of aluminium is now a mature and robust process, which is becoming increasingly well established in the fabrication of critical components. It is true to say that FSW has extended the use of welding in certain materials and applications, in particular in the welding of alloys for the aerospace industry. The qualities making the process attractive include reduced cost, minimal repair requirement, good properties and total automation leading to a high level of consistency.

As with fusion welding, FSW is basically a thermal process. Temperatures reached (typically around 500°C) are sufficient to cause major microstructural changes in precipitation hardened or work hardened alloys. Unlike fusion processes, FSW also involves extremely high shear strains and strain rates, which will have a profound influence on the development of microstructures. The debate on the relative importance of recovery and recrystallisation continues to be lively, and further work is required in this area to gain a full understanding of the complex processes and their interactions which determine microstructures.

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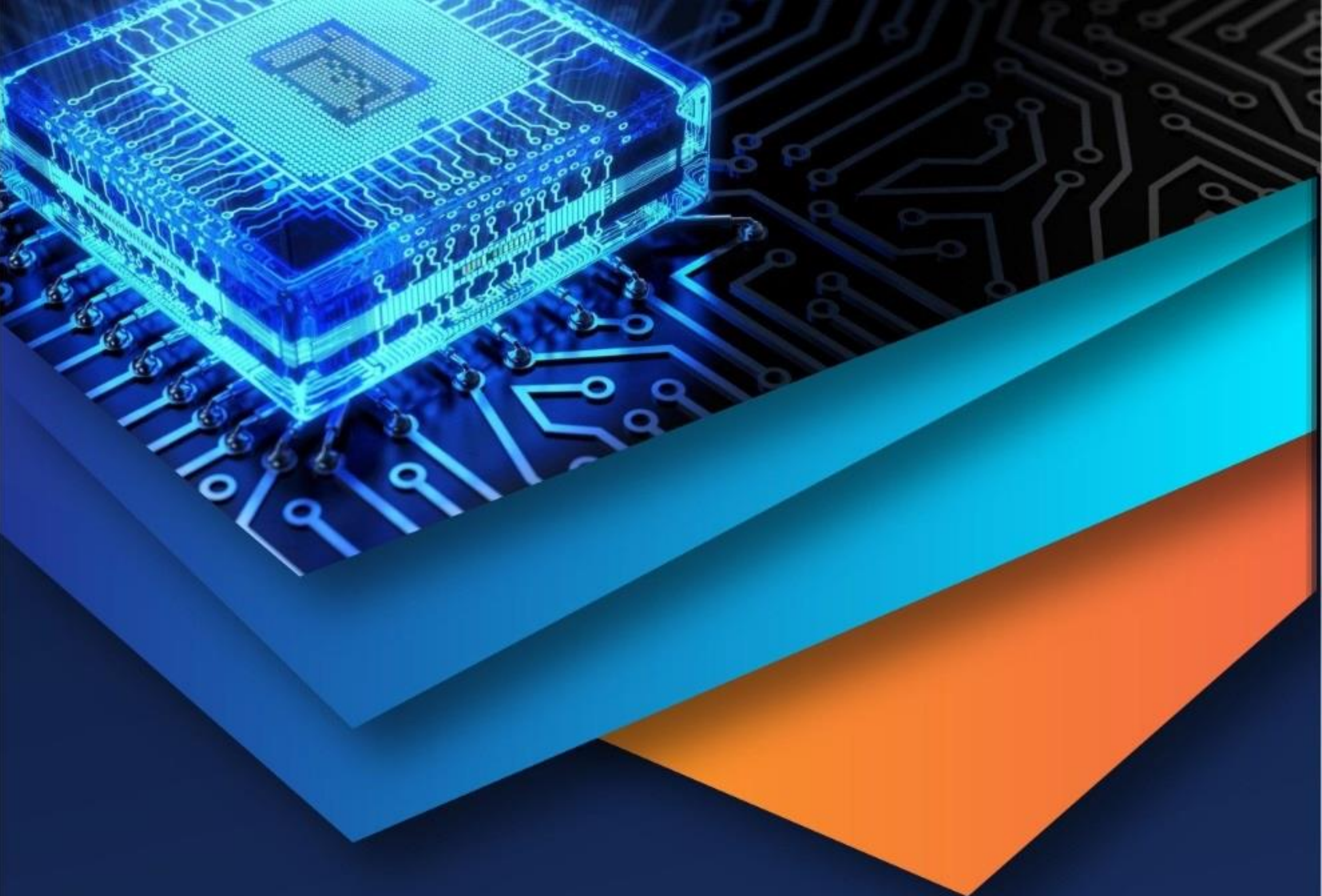

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