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CASE STUDIES AND A CRITICAL ANALYSIS OF THE FRICTION WELDING PROCESS'S PARAMETERS WITH REGARD TO ITS USE IN THE AUTOMOTIVE INDUSTRY

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ABSTRACT

Friction Stir Welding (FSW), being a revolutionary technology and permits welding numerous connections required for several sectors notably aerospace, marine, spacecraft, automotive, etc. It is an attractive solid state material joining technology, different to conventional welding methods, having ability to produce welds with higher integrity and minimum induced distortion, reduced porosity defect, reduced heat affected zone, no requirement of shielding gas, ecofriendly and minimum residual stresses etc. In this research, a critical estimate of major elements of friction stir welding namely process principle, selection of tool and workpiece material, metallurgical and mechanical aspects; influence of process parameters; technique for optimizing the process parameters have been explored. Further different applications of the process are presented along with critical review of literature; finally recognized areas of research work on materials such as AA6061 and Taguchi (L9) orthogonal array used as a methodology to optimize the process parameters for conditions to achieve better quality welds.

Keywords: Aluminum alloy 6061, Friction Stir Welding, L9 Orthogonal array, Review and Taguchi.

INTRODUCTION

Friction stir welding was invented at the welding institute of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminum alloys. Alloys of this class are extensively employed in marine frames, pipelines, and storage tanks and aircraft applications. Compared to many of the fusion welding processes that are normally used for joining structural alloys, FSW is an emerging solid state joining process in which the material that is being welded is not melted and recast. It is also an effective joining technique for a variety of different materials. The metals with low melting temperatures such as copper and aluminum were among the first to be joined by this technique with the help of steel tool. found that joints formed by FSW hold much of the base material strength and have many other advantages over joints produced by conventional welding techniques. found that the maximum temperature in the material being welded is usually less than 80% of its melting temperature of the base metal. Hence, the welding defects like distortion, solidification, cracking, porosity, oxidation, and other defects that result from conventional fusion welding are not observed.

OBJECTIVE

1. To Critical analysis of parameters and case studies of friction welding process with its application in auto industries.
2. To Evaluate the Significance of Cooling Period.

TYPES OF FRICTION WELDING PROCESS

Various variants of friction welding technique are very adaptable and innovative method of solid-state joining process. However, these particular modifications have their own benefits, thus making friction welding more widely used, especially within the car manufacturing industry. This section shall explain in detail the different friction welding processes, their characteristics and application.

Linear Friction Welding (LFW)

Linear Friction Welding plays an important role because it combines tough-to-weld materials which are vital in the aerospace industry. Compared to conventional welding techniques, LFW is a non-fusion process that yields strong and low surface finishing joints. It is used in applications like aero engine manufacturing for joining blades onto discs. There is a trend today focused on developing cheaper linear friction welding machines for auto industry application like in manufacturing brake disc, wheel, as well as engine parts. This process results in a fully reversed motion bringing about frictional heat at and around the weld plane that forces the parts into intimate contact thus generating frictional heat. A small amount of material becomes plasticized and softened by this heat. As the welding process continues, some of the visco-plastic layer is formed on the margins as flash sheets or rippled sheets. The joining times are rapid in a few seconds and are small heats affected zone with minimum process induced deformations. Though it is beneficial, it requires more investigation of tribology, heat generation, and material movement in stable condition LFW.

Spin Welding

Spin welding is characterized by four distinct phases: thermal insulation, solid friction, transient, steady-state, and cooling. This phenomenon applies more specifically to polymers. In the solid friction stage, heat is produced in form of frictional and this leads to heating of the polymer which is done up to the melting point. The following leads to the formation of a thin melted polymer layer that expands due to continued heat production.

In the third phase, stable state, the melting and out flows equal each other. Rotation is ceased once the required melt-down depth is achieved; the molten polymer hardens and solidifies before crystallization and formation of welded joint. This practice can be put to use in other industries where one produces components like air cylinders, munitions, fasteners or some types of equipment. Spin welding is environmentally friendly because it consumes less energy compared to other conventional methods. Secondly, spin welding requires fewer components and therefore incur lower costs. Finally, spin welding can join metals referred to as “unweldable” using any form of traditional fusion.

Rotary Friction Welding

One of these processes is the rotary friction welding in which one part of a component rubs another one. Carbon steel vehicle axles, suspension rods, steering columns, gearboxes, and driveshaft's are widely used components of this technology in cars. The system can also be used in making engine valves with some sections of the component constructed out of different materials. This procedure involves the rapid rotation of a single part while another one is kept in position. Sufficient heat is generated over the interface and further axial load that stops the rotation and forms solid state bonds in its place. Therefore, rotary friction welding enables one to join diverse metallic parts and thus customizes components according to their functions in service.

Inertia Friction Welding

Inertia Friction Welding is a variation that uses the bulk kinetic energy stored in an inertial welder. One work piece is attached to a flywheel, while the second is held stationary in this operation. The required energy is stored in form of kinetic energy at the required rotational speed of the flywheel. Subsequently, when the drive motor is disengaged, the work pieces are pushed together which forces the mating surfaces to rub against each other under pressure. Heat is generated which absorbs the kinetic energy stored in the rotating flywheel, at the weld interface due to friction. Wide ranging is this technique and is employed mostly on welding a diverse of component even in the automobile business. It is more energy efficient, and it allows the forge force be maintained for a certain time after rotation stops which ensures strong weld.

Friction Surfacing

As a result, Friction Surfacing is a surfacing procedure developed from friction welding for coating materials. This process involves applying the Mechtrode TM, which is a material coating of rod shape and under pressure rotation. This results in formation of a plasticised layer at the interface between the rod and the substrate. A plasticized layer with thickness ranging from 0.2 mm to 2.5 mm will be formed by moving a substrate over the rotating rod's surface depending on the Mechtrode diameter and the coating material employed. These create one type of composite material with features suited for a particular application. Friction surfacing differs significantly from traditional techniques such as welding and spraying. However, it produces a 'hot forging' action with respect to coating, increasing material integrity.

Friction Stud Welding

Friction Stud Welding is one type of friction welding that can take place in difficult settings, like it might happen under water. It is commercially performed down to a depth of 1,300 ft and used in underwater rescue work. This entails attaching a pattern of studs onto a wrecked submarine's hull, serving as fittings for cabling and life-support gear. In 2001, Oceaneering International successfully showed that underwater friction stud welding was possible for submarine rescue. Similar explorations took place in a commercial sense in relation the process to repair offshore platforms. Initial research though pointed to an elaborate mechanical, corrosion, and fatigue testing analysis prior to deployment of this process in offshore repairs.

Friction Stir Welding (FSW)

FSW, known also as an innovative method of welding, patented by the Welding Institute in 1991. Solid-state welding (FSW) is fusion welding without melting that incorporates extrusion and forging, unlike traditional weld fusion. The technique, however, functions at submerging temperature point's way below those at which the components melts, thus presenting numerous benefits over fusion welding. It provides lower cost of energy and consumption materials like Fusion welding process. Also, it produces sound material properties in both weld and the heat affected zone leading to FSW is energy efficient, requires small amount of consumable materials like Fusion welding process. Also, it produces sound material It has the ability to weld materials that would be termed as "unsellable" by the fusion welding method and is a lower-distorting technique than fusion welding.

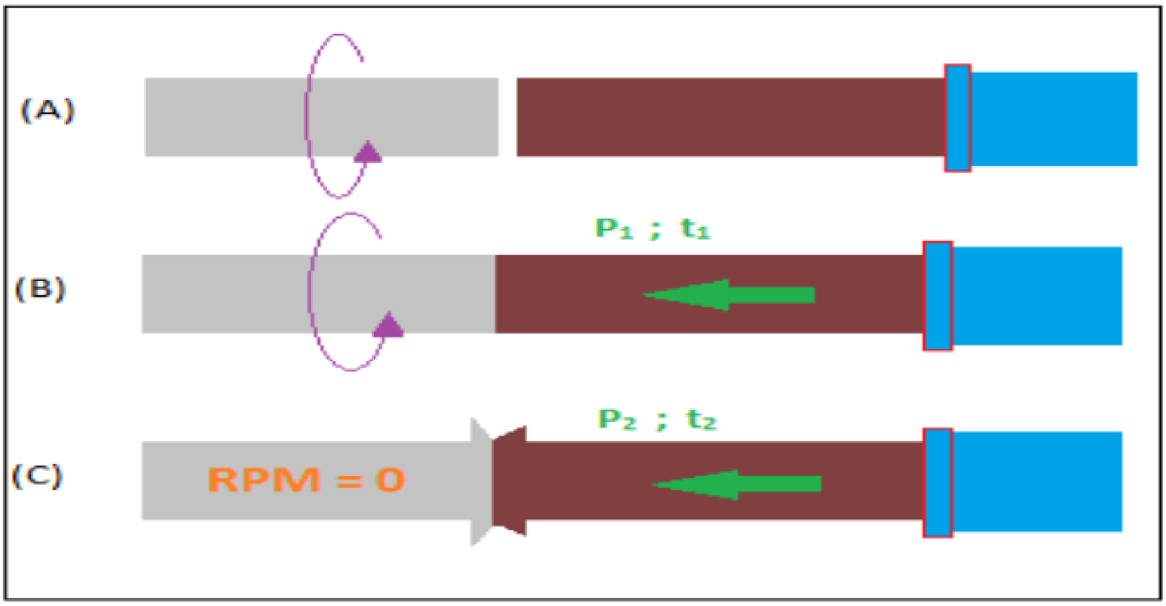
Applications and Considerations

The friction welding processes are used in different sectors. Linear Friction Welding is highly important in aerospace and automotive industries, and Spin Welding is common for plastic parts. A lot of components joining within the automotive sector usually use this rotary friction welding method. Inertia Friction Welding is flexible and can be applied to different parts of automobiles. It consists of a special coating technique called Friction Surfacing and Friction Stud Welding which is used in underwater applications. For this reason, friction stir welding is an innovative method which has been used in aerospace, automotive, and other sectors. Each type of friction welding comes with its benefits and drawbacks. These procedures have distinct advantages such as lower energy consumption, good quality bonds, and ease of automatable process. However, such techniques involve special machinery and issues regarding configuration possibilities. Subsequent chapters will provide additional explanation about specific processes in the car industry and their application.

PRINCIPLE OF FRICTION WELDING PROCESS

The sequence of stages occurring in the friction welding process has been transformed into the conversion of mechanical energy to heat energy then solid state joining of materials. There appears relative motion of one body and its movement leads to rapid rotation around its axis as it carries energy originating of motion. At the same time, the other element stays still to be pushed along the axis in order for it to make contacts with a rotating one. The friction that arises between the two converging moving elements and rotating and stationary ones gives rise to heat generation. The conversion of mechanical energy into localized frictional heat at the interface is critical for this process which is important in various other stages that follow it. Plasticization occurs as a result of the increase in temperature without the actual melting of the materials. This "plasticised" region takes center stage for the next phase. Once the plastic stage has been optimized, rotation stops, a second compressive force called forging pressure.

As a result, material is extruded from the joint edges creating a clean solid state weld. Lastly, allow the joint to cool and fasten up with a solid welded connection similar to cost quality. Basically, the process overview covers the complexities related to friction welding, underscoring how it produces solid-state bonding with no melting material and results in strong quality joints.



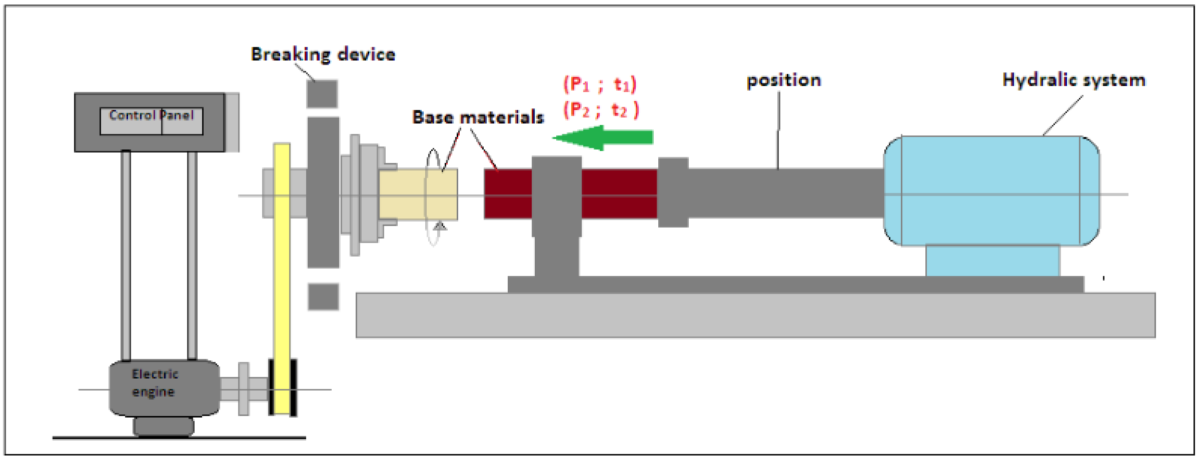
Physics of Friction Welding:

Friction welding is a kind of process where mechanical energy transforms into thermal or high temperature energy, and later on it leads to material deformation that is plastic in nature. At the joint interface between the rotating and stationary components, kinetic energy gets converted into rubbing heat as they get in contact. Localized heat generation is important as it helps in the commencement of the plasticization process without causing the materials to melt. It softens the materials making them to reach their plastic states in which necessary deformations take place as the heat is concentrated. Plasticization is crucial and results in strong solid-state fusion welding. Visco plastic material flow created during the extrusion of material at the joint edges facilitates removal of contaminants from interface, thereby assuring cleanliness and strength of weld. The physical basis of friction welding involves no melting; it takes place completely in the solid state.

Hence, this peculiarity eliminates typical difficulties in fusion welding, for example, rough heat affected zone. Hot work is applied by controlling the forging force leading to refined microstructure and the formation of fine grain hot worked microstructure at the joint. The physic behind friction welding is carefully managed to produce strong and clear weld in solids without the need for melting.

Detailed Process Description:

Friction welding is a complicated process that takes place using very many intricately managed stages which are essential for ensuring that there will be an effective and strong solid state bond between all the jointed parts. Kinetic energy is the initial form of power that initiates a reaction as it results from the rapid rotation of one component. The concentrated heat results from friction at the interface between a rotating part and a static object. The heat causes plasticisation and produces a softened zone essential for adhesion, but melting point is not reached. This is followed by material extrusion from the joints perimeter creating a characteristic feature called a flash. Forging rotation stops and extra hot pressure is applied to make sure tight joint and removal of interface contaminates. This process allows cooling of the joint as well as solidifying of the plasticized material for strong fusion of the weld. These controlled parameters like the rotational speed, axial force, and forging pressure govern the conditions necessary for plasticization, extrusion, and solid-state welding. The delicate nature of this process emphasizes on the importance of precision that goes with it thus makes it a unique way of creating solids state bond and there is no need of using molten material.



Importance of Controlled Parameters:

A number of essential parameters have to be tightly controlled during the actual friction welding procedure in order to ensure the satisfactory nature of the produced weld seam. Essential parameters include rotational speed, axial force, forging pressure and material properties. The number of revolutions per unit time (rotational speed) is related to how much kinetic energy is imparted on the material system.

Exact control of this speed provides an adequate temperature and appropriate plasticity for the bonded joint without overheating and tension.

The intimate contact of the surface should be established by introducing an axial force that will bring together the rotating and static elements. In order to obtain desired material interaction and enable further stages of plasticization and extrusion, proper axial force is applied. The amount of material extrusion and consolidation at the joint is determined by a pressure called forging pressure, which is the final compressive force applied after rotation stops. Clean, solid-stat welding depends on controlled forging pressure which ejects contaminants and creates strong bonds. The materials' properties such as makeup and thermal properties affect their response to the generated frictional heat. Knowledge and mastery of these properties result in accurate management of the plasticization and solidification processes hence the molding of a preferred mechanical weld. Essentially, the control of these parameters is required to achieve an optimal state for plasticization, material flow, and joint forming so as to ensure the excellence nature of friction welding on autos and many others industries.

CONCLUSION

In general terms, the present invention is dependent on relative motion where both faces of the weld joint are in motion during the heating phase of the operation, which motions are brought into phase when the conditions of the joint are appropriate. While both will continue in motion, at least for a brief period, the relative motion between the parts is stopped by virtue of synchronizing the motions so they are in phase and identical. The change of phase of the motions of the mating parts can be accomplished with far greater precision and speed than are possible when alignment of the parts is dependent on stopping the motion of one or both the parts. In general terms, the present invention is applicable to all weldable materials, and includes a few materials not ordinarily joined by welding techniques. These materials include aluminum and a broad variety of aluminum alloys, brass, bronze, metallic carbides, such as tungsten and titanium carbides, cobalt based alloys, columbium, copper, cupronickel alloys, lead, magnesium alloys, molybdenum, nickel alloys, mild steel, carbon steel, free-machining steel, maraging steel, stainless steel, tool steel, sintered steel, tantalum, titanium and titanium alloys, tungsten and zirconium, as well as more complex alloys of many of the foregoing elements and metals. In our experiment, we could not perform the friction welding properly because of low heat production, less time of contact for both the parts, improper rpm and inappropriate pressure which is required to produce the desired weld. So, we have to increase rpm, apply pressure effectively and increase the time of contact between the plates to have the friction welding effectively.

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