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PARAMETERS AFFECTING STRENGTH OF FRICTION STIR WELDING JOINT ON ALUMINIUM ALLOY: A REVIEW

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ABSTRACT

Friction Stir Welding is a solid-state process, which means that the objects are joined before reaching the melting point and is a newly developed welding technique utilized to weld lightweight alloys, such as aluminum alloys. Aluminum alloys are broadly used in the aerospace industry, automotive industry, railways, and the marine industry due to their resistance to corrosion, lightweight, and high strength to weight ratio. In this paper review of parameters affected parameters on friction welding strength has been identified.

REVIEW ARTICLE

1. INTRODUCTION

Conventional friction welding is done by moving the parts to be joined relative to each other along with a common interface also applying compressive forces across the joint [1]. The frictional heat generated at the interface due to rubbing softens the metal and the soft metal gets extruded due to the compressive forces and the joint forms in the clear material, the relative motion is stopped and compressive forces are increased to form a sound weld before the weld is allowed to cool [3]. As a joining technique, FSW is quite robust. It can be used to weld dissimilar metals and has successfully been used to weld steels, aluminum alloys, titanium, copper, and magnesium alloys. Different variations of joints can be performed using FSW such as butt, lap, and spot welds among others. Butt welding aluminum alloys has received much of the focus. Butt welding materials of different thicknesses as well as tapered sections can also be performed [5]. FSW can be used in some applications to reduce weight by replacing fasteners and reducing part count, which can reduce costs. It is necessary first to discuss the convention used for referring to locations within friction stir welds. Since friction stir welds are asymmetrical, it is necessary to accurately convey which side is intended when referring to specific locations within a weld concerning the tool rotation and feed directions.

2. LITERATURE REVIEW ON PROCESS PARAMETERS

Aditya et.al [1] studied Friction stir welding (FSW) which combines two plates by frictional heating which is a plastic deformation state within the material. In this heat is generated due to the frictional process between the rotating tool shoulder and the plates to be welded. The frictional heat thus

generated results in thermal softening of the material which is a plastic deformation of the two materials. Arab and Zemri [2] analyzed the Friction Stir Welding (FSW) which was done on Aluminum Alloy 6082-T6 plates having dimensions of 200 x 70 x 2 mm. The Design of Experiment (DOE) was applied to apply the most important factors which play a major role in Ultimate Tensile Strength (UTS) and the Hardness (HV) of AA 6082-T6 joints which is created by Friction Stir Welding (FSW). Two factors tool rotational speed and welding speed on (UTS, HV) were taken as process parameters and investigated by Taguchi method using L9 orthogonal array to find the optimum process parameters in minitab. An analysis of variance (ANOVA) was applied for determining the selected factors are more significant or not. The output responses and the optimum process parameters for getting the higher UTS are obtained by using a combination of parameters of rotational speed at 1400 rpm and 125 mm/min and the welding speed at1400 rpm and 160 mm/min to maximize Hardness (HV).

Bidgolia et.al projected about the application of thermoplastic materials which has been increased in recent few decades because of its properties recyclability, low density, and resistance to chemical changes. The friction stir welding process is one of the latest methods of solid-phase welding, which has been recently increased with a significant improvement in terms of weldability. On increasing the inlet temperature the formation and growth of cavities are seen which converts them into tunnel cavities. According to the results of scanning electron microscopy (SEM), the increase in rotational speed shows improvement in the grinding of continuous carbon fibers and thus increased the tensile strength of the material. The results of the tensile test indicate that the failure of the taken samples of polymer is because of microstructural changes in the HAZ. Chandu et.al [4] studied the mechanical properties of aluminum welds and their alloy which are obtained by using the frictional stir welding technique. These provide various industrial applications and increases the opportunity for complex structure, steel welding. Chiteka [5] analyzed the tool material used for FSW, The most important factor is the selection of friction stir welding/processing (FSW/P) tool material which is an important task which results in the quality of the weld produced at the end.

3. REVIEW ON STRENGTH

Das et.al [6] studied the Friction Stir Welding (FSW) method for metal joining of both similar and dissimilar metals without using the filler material. It delivers better mechanical and metallurgical characteristics. The optimum tensile strength gained after optimization is considered to be a better joining strength of FSW samples. Devaiah et.al [7] investigate the Fusion welding process of aluminum and its alloys, which tends to degrade its mechanical strength near the welding zone due to its high thermal diffusivity and high melting point. The microstructure and the mechanical characters of dissimilar friction stir welded AA5083-H321 and AA6061-T6 aluminum alloys were studied and analyzed. The effect of the welding speed on the metallurgical and mechanical properties was studied and analyzed. It is found that the welding speed of 80 mm/min produces the good mechanical and metallurgical properties than the other welding speeds which are considered as parameters. The observed results were analyzed with the fracture features and the microstructure. The fracture mode was observed to be a ductile fibrous fracture at the end.

Doos and Wahab [8] analyzed the Friction Stir Welding method which is relatively the latest joining process having numerous advantages over the traditional arc welding processes by reducing distortion and eliminating the solidification. Mechanical properties of welded joints are analyzed which includes nondestructive tests like visual inspection, X-ray, and destructive tests like tensile tests, microhardness, and microstructure. According to FSW experiments, the outcomes obtain as aluminum pipe (AA 6061-T6) with a maximum welding efficiency of 61.7% in terms of ultimate tensile strength, by taking rotational speed as 630rpm and traveling speed as1 mm/sec. Elangovan et.al [9] investigated A6061

aluminum alloy (Al-Mg-Si alloy) which is widely accepted in the fabrication of lightweight structures with a high strength to weight ratio and has good corrosion resistance properties. The tool rotational speed, welding speed, axial force, etc. are used as its working parameters. tool pin profile plays a major role in deciding the joint properties as it revolves over the surface of the two joining materials. To study the effect in the work tool pin of AA6061 aluminum alloy is considered. Having Five varying tool pin profiles (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular, and square) have been used to create the fsw weld joints with having five varying tool rotational speeds (800–1600RPM) of the pin. Tensile strength properties, microhardness, and microstructure of the weld joints have been studied with the data obtained by it and found that the joints created using square pin profiled tool with a tool rotational speed of 1200RPM shows superior mechanical properties compared to other weld joints.

El-Keran et.al [10] work on Friction Stir Welding which is a solid-state welding process with a special rotating tool design. Heat is generated by the friction between the workpiece and the tool. The benefit of FSW weld is to weld the material without achieving the fusion temperature so it becomes easy to join almost all types of aluminum alloys, even which are non-weld able alloy by traditional welding process such as fusion welding because of hot cracking and unfortunate solidification microstructure in the welding zone area. FSW is widely and mainly used in aerospace, automotive, marine industries, electronics, etc. The effect of the welding parameters such as tool rotation speed, welding speed, tool tilt angle, and tool design are taken which provides reviews of the FSW of similar and dissimilar aluminum alloys, FSW benefits, and their applications.

Elnabia et.al [11] compared the outcome with parameters of efficiency and strength using their S/N ratio with the help of Minitab. Friction Stir Welding (FSW) is a solid-phase welding process used for welding similar and dissimilar materials mainly aluminum and its alloys. Dissimilar weld joints between aluminum alloy grade (AA5454) and aluminum alloy grade (AA7075) created by using friction stir welding and to properly optimize these selected parameters which of then utilized by using Taguchi L16 optimization method in minitab. Seven different parameters of two levels are taken in this work. The seven selected process parameters used in minitab are tool rotational speed, traverse speed, pin profile (based on taper angle), the ratio between shoulder diameter (D) and pin diameter (d) (D/d ratio), tool tilt angle, plunge depth, and the location of weld material (weld location)). After selection, mathematical models are created for ultimate tensile strength and ductility various parameters show the output response surface. The final results of this work obtained by using parameters like the rotational speed, traverse speed, D/d ratio, and plunge depth in determining UTS (mean, signal to noise ratio (S/N)) at different levels, but pin profile, base metal location and tool tilt angle are not considered to be valid parameters at any levels. The accuracy of the output result attained is based upon UTS which is 97.6% and 99.5% for mean and S/N ratio, respectively. Lastly the maximum joint efficiency and the strength of the grade AA5454, is to be 85.3%.

Ethiraj et.al [12] studied about Friction stir welding which is a relatively a latest solid-phase joining process, which is suitable for welding similar and dissimilar materials especially aluminum and its alloy. It is clear from the outcome of tensile testing that the joint made at the tool rotational speed of 1320 rpm has the maximum weld strength among all the varying rotational speeds. The amount measured for microhardness values at heat affected zone and base metal zone have higher hardness as compared to the weld zone. These outcomes have vast impact on the development of welding procedures for various dissimilar stainless steel materials by using the friction stir welding process. Fratini and Pasta [13] studied frictional stir welding, which is widely in use nowadays. Before friction stir welding (FSW) was introduced welding of the aluminum alloys were bit difficult with traditional methods. This work

has been done for studying the influence of FSW process parameters on the tensile strength which would develop on the joints. in respect of improvement of the strength of the weld joint, the post welding treatment has been done and various parameters, and attained more surface finish by removing the stress concentration caused by welding process on the surface of the weld joints. Lastly, the fracture locations on the workpiece have been seen.

4. REVIEW ON ROTATION SPEED

Ghazvinloo and Shadfar [14] investigated the welding process, which is a pure solid phase joining method for metals and alloy materials. There are numerous types of welding processes available in various manufacturing industries. Friction stir welding (fsw) was first tested and used for aluminum and its alloys. In this heat is created by using friction between a rotating tool and the base material used for the weld. The weld defects plays important role in welding as it results in the quality degradation and the strength of welding joints which may lead to premature failure in the joints. In the present work, investigation of the effect of Al-6%Si aluminum alloy is taken with having various tool travel speed and tool rotation speed with friction stir welding. For this purpose, a butt joint was created having parameters as tool travel speed of 50, 75, and 125 mm/min and tool rotation speed of 800, 1000, and 1200 rpm respectively. Heidarzadeh et.al [15] observed to achieve a defect-free butt joint of dissimilar metals by friction stir welding technique with having various parameters, like tool material, geometry, tool rotational speed, feed rate, and tilt angle. Lastly, Optimum values of tool rotation speed and feed rate are optimized for the best quality of the butt joint. Jayabalakrishnan et.al [16] analyzed Friction stir welding which is a solid phase joining process where the parent metal properties remain constant while joining takes place in a plastic phase without melting of the metals. For these Finite Elements, the Analysis process is done with Friction Stir Welding for the joining of two dissimilar materials grade AA6061 and pure copper (cu) by using different parameters. For this work, CREO software is used along with ANSYS Software for stress analysis.

Küçükrendeci and Küçük [17] studied about the behavior of aluminum plates having a thickness of 5mm grade ENAW-6060 which was butt welded from one side using friction stir welding (FSW), which is a solid phase bonding method, by using 3 different rotating speeds and feed rates as its process parameters. Results obtained from tensile tests show that the rotating speed and the feed rate create variation in tensile strength results of EN AW-6060 aluminum plates bonded by using FSW. Kumar [18] studied the various process parameters used in Friction Stir Welding (FSW), which is the newest innovation in the market today and the most complex process for welding of light-weighted alloys, such as aluminum and magnesium alloys for aircraft and ship manufacturing. Kumar et.al [19] analyzed the Taguchi technique for getting optimum mechanical properties with varying parameters. For getting the best mechanical properties like higher tensile strength and hardness for aluminum grade AA 7075 plates, it is welded using FSW. To optimize the weld different parameters like tool rotation speed, weld travel velocity are taken into consideration. The best-predicted values for ultimate tensile strength and hardness of the friction stir welded for aluminum grade 7075 are 197 Mpa and 93 HRB respectively. Kumar et.al [20] observed the Frictional Stir Welding technique as it works by fusing two or more metal pieces to improve its mechanical properties. Based on varying parameters like the tool rotational speed, Transverse speed, Axial Force the properties of the weld joint change according to its properties such as yield strength, tensile strength, and corrosion resistance of the base material. Kumar et.al [21] presented the benefits in welding of aluminum and its alloys. Friction Stir Welding (FSW) plays a vital role in the joining process in the aerospace, railway, and shipbuilding industries especially in the welding of aluminum and its alloys. The process uses a non-consumable spinning tool that generates frictional heat in the workpiece zone. Heat is generated between the tool and material then both the pieces of metal

combines using mechanical pressure. The output results in the conclusion that Friction stir welding is the most suitable joining technique for similar and dissimilar aluminum and its alloy. It is seen that weld quality of FSW joint is superior to another joining process available for joining aluminum alloys.

5. REVIEW ON OPTIMIZATION

Leon and Jayakumar [22] investigated Aluminum grade 6061 alloys for its tensile properties and impact strength for higher hardness and fine microstructure. Aluminum and its alloys are commonly used for the construction of aircraft structures or military aircraft. Aluminium grade 6061 alloy generally sows low weldability strength by normal fusion welding process these leds to the development of Friction Stir Welding (FSW), which provides a new and different improved way of creating weld joint in aluminium and its alloy. After the weld changes of mechanical properties are compared and analysed with the parental metal with having various process parameters like tool rotational speed and welding speed which decides the joint quality and then the parameters are optimized for best joint strength and quality welded from the FSW. Mall and Panchal [23] analyzed Friction Stir Welding (FSW) where various parameters such as the tensile strength of weld are affected by varying welding speed as well as the shoulder diameter and welding speed strongly affect the percentage elongation of the weld joint. Mishra [24] studied Image processing which can be a breakthrough in the aerospace and manufacturing industries. Friction Stir Welding of 6060 T5 Alloy is carried out in these studies. Mishra and Dixit [25] Studied Friction Stir Welding (FSW) which is a solid state joining process, which gives high potential to the aerospace industries. More and Raut [26] analyzed Friction stir welding (FSW), which was invented by Wayne Thomas in The Welding Institute (TWI) in London in 1991. Friction stir welding (FSW) is a solid-phase joining process which means the joining of metal plates without reaching the melting point (its plastic deformation state) of the material. This technique is energy efficient, environmentally friendly and can be used to join high-strength aluminum alloys. Simulation is performed using Ansys software for joining 304L stainless steel plates and to obtain the superior quality of welds by using different input parameters.

Motalleb-nejad et.al [27] studied Friction stir welding (FSW), which is a promising welding technology from the same moment of its existence because of its easy use, low energy costs, being ecology friendly process, and no need for filler metal. Muruganandama et.al [28] investigated friction stir welding (FSW) which is a solid-state welding process used for joining two dissimilar metals using non-consumable tools. This paper shows the experimental investigation on the effect of the post-weld heat treatment on its mechanical properties of the butt joint using aluminium alloys 2024 T6 (as soft metal) and 7075 T6 (as hard metal). The butt joint after the post welding heat treatment at lower temperatures (200°C) have the tensile properties which is comparable to the FSW joints and the fracture which comes in the base metal 7075 T6. In most of FSW joints around 50%, deformation is seen after the heat treatment is done at low temperature and also the failure can be seen inside stir zone. Pandey et.al [29] analyzed about Friction stir welding, which is a solid-phase joining process. It is widely used for aluminum and its alloys. In this work, it was analyzed that how the tensile strength, as well as microstructural behavior of AA7075, varies if the process parameter like axial pressure force, It can be widely used in aircraft, marine, automotive as well as railways industry because of eco-friendly. Paramaguru et.al [30] investigated, underwater Friction Stir Welding (UFSW) which works in solid phases joining techniques which uses a non-consumable tool for welding the metals. In this investigation, it is evaluated about the mechanical properties of the AA5052 Aluminium alloy ufsw joints and different effects based on the type of welding tools and welding process parameters on the weld joint properties are studied and analyzed. The Tensile strength, micro-hardness distribution, fracture features, micro-and macrostructure of the fabricated weld joints

have been studied and analyzed for getting different mechanical properties and fracture characterization of the joints. Patel et.al [31] gives highlight know high strength aluminum alloys are used in aircraft and the marine industries. The mechanical properties of the fusion-welded aluminum joints are very poor as compared to fsw. In this the process parameters and its effects on the mechanical properties, microstructure and macrostructure specific aluminum alloys are studied and reviwed.

Prakash et.al, [32] presented the newly work on Friction stir welding (FSW) which is a relatively solid phase joining technique. FSW is very energy efficient, environment friendly, and versatile. The main advantage of FSW is its low distortion tendency, absence of melt related defects and superior joint strength. Prashanthi et.al [33] observed about the friction stir welding which is mainly used in automobile and aerospace sectors for getting the smooth finish and high strength of the materials. it discusses the hardness and the tensile strength of two dissimilar materials after the friction stir welding is performed on two different aluminium plates placed adjacent to each other. Rao and Rao [34] studied about joining of two similar 6061 aluminium plates of 4mm thickness and was carried out by friction stir welding process. FSW uses welding head pin which usually rotates at high rpm, travels down the length of contacting metal plates, creating a highly deformation zone through the force and the frictional heating. FSW has gained the important attention by manufacturing industries, such as Ship building, Automotive, Railway and the Aircraft production. Reddy and Reddy [35] present FSW Technique which is a solid phase welding procedure mainly used for part manufacture in aerospace, automotive and other industrial establishments for welding or joining alloys like aluminum, magnesium and copper with various parameters like Rotational speed, welding speed and the angle of attack are taken in consideration for analyzing the weld quality. Reddy et.al [36] investigated the Friction stir welding technique, which is a new solid phase joining process having high energy efficient, versatile and environment friendly in nature. Widely it is used to join high-strength aerospace aluminum alloys and other metallic alloys that are complex and finds bit difficult to weld by using conventional fusion welding.

Shaik et.al [37] projected about Friction stir welding process which is an advanced welding technique that offers various advantages when compared with the other conventional welding techniques. Keeping its advantages and considering its involvement increase in the usage of FSW process in various automobile and aerospace industries. Aluminum alloys of different grades using the Friction Stir Welding Process. In these, Taguchi L9 array is used for carrying out the research. Based on these ranges are also taken for each input parameter. After measuring its output responses, main effects are studied between the input process parameters and the output responses in minitab. This analysis can be further used for predicting the empirical equations. Shrivas et. al [38] found the strength effected by temperature in Friction stir welding (FSW) join by high speed rotation of FSW tool which develops high temperature on tool. In his work concerned with the effect of temperature in the FSW process and heat generation by the high speed of rotation on the FSW apparatus. The other parameter has also studied to show the effect on FSW tool in stir welding process. Shrivas et. al [39] presented the work on same grade of aluminium material would be welded by friction stir welding on low speed of rotation by using H13 tool. The Low-speed rotation of tool reduces the installation cost of heavy motor machine which saves high power. Minimized rotational speed of FSW tool will give the optimum welding strength under preheated water-cooled work piece. From the result it is clear that increasing the Temperature of work-piece with water cooled medium increases the strength. Shrivas et. al [40] focusing on dissimilar alloys (AA4018 - AA8011) joining by friction stir welding have improved the mechanical strength of the welded joint. The work investigated the effect of heat addition on the mechanical properties of a dissimilar aluminum alloy welded joint. The heat treatment hardening effect revolution is found in aluminum alloys, which helps in

producing friction heat so that the mechanical strength of the joint can increase. Sharma et.al [41] analyzed about the Friction Stir Welding (FSW),which is a relatively new solid phase welding technique for similar and dissimilar materials, especially with aluminum and its alloys. The Friction Stir Welding is continuous process which involves plunging a rotating tool that is specially placed between the joining sides of a joint. The relative motion between the plate and the tool produces frictional heat forming a plastic deformation zone around the portion of the tool that has been used. Outcome shows that FSW of aluminum alloy is becoming an important technology with higher commercial applications.

Singh et.al [42] Reviewed about the work done on friction stir welding process using different varying parameters, weld speed, tool rotation speed, tool inclination and design of tool profile are its some parameters used in the work. FSW is an new technique widely used for manufacturing of aerospace, cryogenic tanks, railway, military aircrafts and especially utilized in manufacturing of aluminium and its alloys. FSW goes for plastic deformation in welding portion, metal mixing and thermal occurrence influence the microstructural refinement which shows vast enhancement in its mechanical properties by using correct selection of input parameters. Sivaraj et.al [43] projected the knowledge that has been built up with respect to the friction stir welding (FSW) of aluminum and its alloys since the technique was invented in 1991 is on this paper. The fundamental principles of FSW are described in this, which includes metal flow and thermal history with varying process parameters which would affect the weld microstructure and likelihood of the defects. Finally, the mechanical properties came out is discussed and reviewed.

6. Conclusions

While the welding process typically produces welds which are as strong and ductile as the parent material, certain welding parameters have been found to produce a sharp decrease in strength and ductility in the welds. Welding Parameters for two similar grades aluminum plate are not passed from heat treatment with variation to rotating tool parameter. With this information it should be done work on input parameter which reduce the defects and increase the strength.

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