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INVESTIGATION AND OPTIMIZATION OF TENSILE STRENGTH OF FRICTION STIR WELDING JOINT: AN OVERVIEW

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ABSTRACT

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding,the work pieces to be joined are melted at the joining interface and usually a filler material is added to forma weld pool of molten material that solidifies to become a strong joint. In contrast, Soldering and Brazing do not involve melting the work piece but rather a lower melting point material is melted between the work pieces to bond them together. Friction Stir Welding (FSW) was invented by Wayne Thomas at TWI (The Welding Institute), and the first patent applications were filed in the UK in December1991. Initially, the process was regarded as a "laboratory" curiosity, but it soon became clear that FSW offers numerous benefits in the fabrication of aluminum products. Friction Stir Welding is a solid-state process, which means that the objects are joined without reaching melting point. This opens up whole new areas in welding technology.

KEYWORDS: Friction; Welding; fabrication.

INTRODUCTION

A constantly rotated non-consumable cylindrical tool with a profiled probe is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. Frictional heat is generated between the wear resistant welding components and work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the pin is moved forward, a special profile on its leading face force plasticized material to the rear where clamping force assists in a forged consolidation of the weld. This process of the tool traversing along the weld line in aplasticized tubular shaft of metal results in severe solid state deformation involving dynamic re-crystallization of the base material.

The joining, does not involve any use of filler metal and therefore any aluminium alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding. When desirable, dissimilar aluminium alloys and composites can be joined with equal ease.

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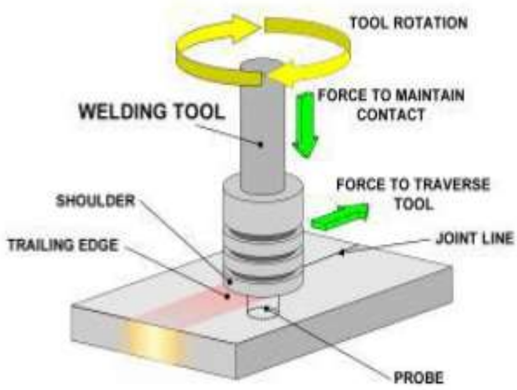

Figure 1: Working principle of friction sitr welding[1]

LITRETURE WORKS

VALIDATION OF MARKER MATERIAL FLOW IN 4MM THICK FRICTION STIR WELDED AL 2024-T351 AS REPORTED BY COMPUTED MICROTOMOGREPHY USING STANDERED METALLOGRAPHY TECHNIQUES

The process is referred to as a solid state joining process where no bulk melting of the base material occurs. In comparison to fusion welds there is no evidence of an as cast structure in the weld nugget. The process essentially relies on frictional heating and plastic deformation brought about by a rotating and non-consumable tool that is plunged into and then traversed along the join line between typically two abutting work pieces. The FSW tool in conjunction with the processing parameters; axial load or down force, rotation and travel speed provide the necessary energy input required to thermally soften the work piece material.

The joining tool comprises essentially of two parts: a shoulder and a pin. The tool shoulder not only helps to produce heat by means of friction induced rubbing with the surface of the work piece but also acts as a barrier preventing expulsion of locally plasticized material from the immediate weld zone. The FSW pin then forces this thermally softened material, contained at the underside of the work pieces by a backing bar or anvil, to flow in the direction of rotation where it is transferred from in front of and then to the back of the pin where it cools and consolidates. The residue of this interaction between the welding tool, the work pieces and the clamping system can be evidenced in the microstructure and flow induced patterns of the weld nugget. These flow patterns appear like the layers of an onion prompting the term onion ring structure for the weld nugget, 4mm thick Al 2024 T351 is using identical tool shoulders but dissimilar tool pins, demonstrating very different Flow patterns.

FRICTION STIR WELDING OF ALUMINIUM ALLOY TO STEEL.

The authors tried to butt joint weld an aluminum alloy plate to a mild steel plate using friction stir welding .This study investigated the effects of pin rotation speed, position of the pin axis, and pin diameter on the tensile strength and microstructure of the joint. The main results obtained are as follows: Butt-joint welding of an aluminum alloy plate to a steel plate was easily and successfully achieved. The maximum tensile strength of the joint was about 86% of that of the aluminum alloy base metal. Many fragments of the steel were scattered in the aluminum alloy matrix, and fracture tended to occur along the interface between the fragment and the aluminum matrix. A small amount of intermetallic compounds was formed at the upper part of the steel/aluminum interface, while no intermetallic compounds were observed in the middle and bottom regions of the interface.

TRANSFER ANALYSIS DURING FRICTION STIR WELDING OF AL6061-T6 ALLOYS.

The accurate 3D finite element simulation of the Friction Stir Welding (FSW) process requires a proper knowledge of both material and interface behaviors, but friction, the key phenomenon of this process, is quite difficult to model and identify. Friction stir welding is a relatively new welding process that has significant advantages compared to the fusion process such as joining conventionally non-fusion wieldable alloys. Being a solid-state joining process it produces weld with reduced distortion and improved mechanical properties. The aluminum alloys are widely used in different industrial applications such as ship building, aerospace and automobile industries due to their light weight, good mechanical strength and high corrosion resistance. A three dimensional finite element model is developed to study the thermal history in the butt welding of 6061 aluminum alloy using

ANSYS package. Solid 70 elements are used to develop the model. The heat source incorporated in the model involves the friction among the material, probe and shoulder. In this work, a moving co-ordinate has been introduced to model the three-dimensional heat transfer process because it reduces the difficulty of modeling the moving tool. In this model the main parameter considered is the heat input from the tool shoulder and tool pin. The temperature distributions of the weld at various welding speeds are obtained. The friction stir welding experiments are carried out at a transverse speed of 0.75 mm/sec of tool. Brinell's Hardness test, tensile test and micro structure analysis are performed on the welded material.

THERMOMECHANICAL MOLDING AND FORCE ANALYSIS OF FRICTION STIR WELDING BY THE INFINITE ELEMENT METHOD.

Friction stir welding (FSW) is a solid-state jointing technology, in which the butted plates are heated, plasticized and jointed locally by the plunged probe and shoulder moving along the joint line. The residual stresses due to the thermo mechanical performance of the material and the constraint of the welded plates by the true are one of main concerns for this process. A prediction of the clamping force applied on the plates during FSW is expected to be helpful in controlling the residual stresses and weld quality. Furthermore, the prediction of the force history in FSW will be biennial to understand the mechanics of the process and to provide valid models for controlling the process, especially in the case of robotic FSW. In this paper, a three-dimensional model based on an infinite element method is proposed to study the thermal history and stress distribution in the weld and, subsequently, to compute mechanical forces in the longitudinal, lateral and vertical directions. The proposed model includes a coupled thermo mechanical modelling. The parametric investigation of the effects of the tool rotational and longitudinal speed on the longitudinal, lateral and vertical forces is also conducted in order to compute the appropriate clamping force applied on the plates. Measurements by the load cells in the longitudinal, lateral and vertical directions are presented and reveal a reasonable agreement between the experimental results and the numerical calculations.

EXPERIMENT AND EVALUTATION OF FRICTION STIR WELDS OF AA6061-T6 ALUMINIUM ALLOY.

Friction stir welding is a relatively new joining process, which involves the joining of metals without fusion or filler materials. The amount of the heat conducted into the work piece dictates a successful process which is defined by the quality, shape and microstructure of the processed zone, as well as the residual stress and the distortion of the work piece. The amount of the heat gone to the tool dictates the life of the tool and the capability of the tool to produce a good processed zone. Hence, understanding the heat transfer aspect of the friction stir welding is extremely important for improving the process.

Many research works were carried out to simulate the friction stir welding using various soft wares to determine the temperature distribution for a given set of welding conditions. Very few attempted to determine the maximum temperature by varying the input parameters using ANSYS. The objective of this research is to develop a finite element simulation of friction stir welding of AA6061-T6 Aluminum alloy. Trend line equations are developed for thermal conductivity, specific heat and density to know the relationship of these factors with peak temperature. Tensile and hardness values for the welded specimens are found for different rotational speed and feed. Variation of temperature with input parameters is also observed. The simulation model is tested with experimental results. The results of the simulation are in good agreement with that of experimental results.

OPTIMIZATION OF PROCESS PARAMETER OF FRICTION STIR WELDING OF DISSIMILAR ALUMINUM ALLOYS USING TAGUCHI TECHNIQUE.

The results were analyzed with the help of analysis of variance (ANOVA) and concluded that optimum levels of tool rotational speed is 700 rpm, traverse speed is 15mm/min, ratio between tool shoulder diameter and pin diameter is 3, pin tool profile is cylindrical threaded and finally friction stir welding produces satisfactory butt welds. Yahya Bozkurt (2012) has done work on optimization of friction stir welding process parameters to achieve maximum tensile strength in the polyethylene slab. Three process parameters, tool rotational speeds, tool traverse speed, and tilt angle of the tool were identified for optimization. The material taken for study is high density polyethylene sheet which is a thermoplastic to determine welding process parameters on ultimate tensile strength of the weld for good joint efficiency. The optimization technique applied is Taguch's L9 orthogonal array, signal to noise ratio and ANOVA. The results depicted are tool rotational speed of 3000rpm contributes 73.85% to the overall welding parameters for the weld strength and the tool tilt angle has least contribution .Elatharasan et al (2013) in their

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research study, experimental analysis of process parameters of friction stir welding and its optimization. The outcomes of the experimentation are ultimate tensile strength, yield strength increased with increase in tool rotational speed, welding speed and tool axial force. The percentage of total elongation increased with increase in rotational speeds and axial force but decreased when there is increase in welding speed continuously. The results documented as maximum tensile strength is 197.50MPa, yield strength is 175.25MPa, percentage of total elongation is 6.96 was exhibited by the friction stir welding joints fabricated with optimized parameters of 1199rpm rotational speed, 30mm/min welding speed and 9 KN axial force.

STUDY OF PROCESS PARAMETERS IN FRICTION STIR WELDING OF DISSIMILAR ALUMINIUM ALLOYS.

Friction stir welding was performed for four different tool rotation Speeds namely 600, 800, 1000 and 1200.Defects were analyzed using radiography. It was found that defect concentration was maximum for the 600 RPM tool rotation. It was a little lesser for the 800 RPM parameter and even lesser for the 1000 RPM speed rotation. Minimum defects were observed for the highest tool rotation speed, namely 1200 RPM. An analysis of defects is given in this paper. Tensile Test values and bend test values were also reported. A method of solid phase welding, which permits a wide range of parts and geometries to be welded and called Friction Stir Welding (FSW), was invented by W. Thomas and his colleagues at The Welding Institute (TWI), UK, in 1991. Friction stir welding has a wide application potential in ship building, aerospace, automobile and other manufacturing industries. The process proves predominance for welding non-heat treatable or powder metallurgy aluminum alloys, to which the fusion welding cannot be applied. Thus fundamental studies both on the weld mechanism and on the relation between microstructure with mechanical properties and process parameters have recently been started. A great advantage is, in particular the possibility of joining dissimilar materials, which are not, or only with great difficulties wieldable by classic fusion welding techniques.

One of the possible applications is for example the welding of high performance materials, such as particle reinforced aluminum alloy, to larger structures made from a lower performance, but less expensive alloy. Friction stir welding is a relatively simple process as shown in Figure. A specially shaped tool, made from material that have a hard and wear resistant relative to the material being welded, is rotated and plunged into the abutting edges of the aluminum parts to be joined. After entry of the tool probe to almost the thickness of the material and to allow the tool shoulder to just penetrate into the aluminum plate, the rotating tool is transitioned along the joint line. The rotating tool develops frictional heating of the material, causing it to plasticize and flow from the front of the tool to the back where it cools and consolidates to produce a high integrity weld, in the solid phase.

FRICTION STIR WELDING OF AL ALLOY THIN PLATE BY ROTATIONAL TOOL WITHOUT PIN.

For friction stir welding (FSW), a new idea is put forward in this paper to weld the thin plate of Al alloy by using the rotational tool without pin. The experiments of FSW are carried out by using the tools with inner-concavity shoulder, concentric-circles shoulder and three-spiral shoulder, respectively. The experimental results show that the grain size in weld nugget zone attained by the tool with three-spiral shoulder is nearly the same while the grain sizes decrease with the decrease of welding velocity. The displacement of material in the heat-mechanical affected zone by the tool with three-spiral shoulder is much larger than that by the tool with inner-concave shoulder or concentric-circles shoulder.

The above-mentioned results are varied by numerical simulation. For the tool with three-spiral shoulder, the tensile strength of FSW joint increases with the decrease of welding velocity while the value of tensile strength attained by the welding velocity of 20 mm/min and the rotation speed of 1800 r/min is about 398 MPa, which is 80% more than that of parent mental tensile strength. Those verify that the tool with three-spiral-Shoulder can be used to join the thin plate of Al alloy.

As a new solid-state joining technology, friction stir welding (FSW) owns many advantages, such as low stress, small distortion, no fusion welding defects, etc. Because the metal of well-meant isn't melted during FSW, the material in weld of FSW is the key factor to incense the quality of weld. In order to thoroughly understand the mechanism of FSW, many researchers have made lots of scientist work on the metal plastic of weld in FSW. Several methods on material have been published, including the steel ball tracing technology, the stop-action technology, the metallography method, the marker material method and the numerical simulation method.

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ANALYSIS AND COMPERISON OF FRICTION STIR WELDING AND LASER ASSISTED FRICTION STIR WELDING OF ALUMINIUM ALLOY.

Friction Stir Welding (FSW) is a solid-state joining process; i.e., no melting occurs. The welding process is promoted by the rotation and translation of an axis-symmetric non-consumable tool along the weld centerline. Thus, the FSW process is performed at much lower temperatures than conventional fusion welding, nevertheless it has some disadvantages. Laser Assisted Friction Stir Welding (LAFSW) is a combination in which the FSW is the dominant welding process and the laser pre-heats the weld. In this work FSW and LAFSW tests were conducted on 6 mm thick 5754H111 aluminum alloy plates in butt joint configuration. LAFSW is studied firstly to demonstrate the weld ability of aluminum alloy using that technique. Secondly, process parameters, such as laser power and temperature gradient are investigated in order to evaluate changes in microstructure, micro-hardness, residual stress, and tensile properties. Once the possibility to achieve sound weld using LAFSW is demonstrated, it will be possible to explore the benefits for tool wear, higher welding speeds, and lower clamping force. FSW offers significant benefits over conventional joining processes so it has attracted attention as a solid state bonding method with low heat input and has become widespread as a lap joint technique to weld together aluminum alloy sheets. A rotating tool with a shoulder and terminating in a pin moves along the butting surfaces of two rigidly clamped plates placed on a backing plate. Heat generated by friction at the shoulder and to a lesser extent at the pin surface softens the material being welded. Severe plastic deformation and flow of this plasticized metal occurs as the tool is translated along the welding direction. Extensive research has been carried out to improve the applications of this process. Researchers have explored different aspects of this process namely, tool design, microstructural and mechanical properties, residual stress, and mathematical modeling. Fuji studied the effect of tool design on mechanical properties and microstructure of friction stir welded aluminum alloys.

Determined the optimum tool pin geometry from its load bearing capacity for a given set of welding variables and tool and work-piece materials. Pin and painless tool configurations were used for thin sheets in AZ31 magnesium alloy friction stir welding. A different metal flow was observed depending on the presence or absence of the pin. An attempt has been made to study the effect of tool pin profiles and welding speed on the formation of friction stir processing zone in AA2219 aluminum alloy. The square pin profiled tool and 0.76 mm/s speed produced mechanically sound and metallurgical-defect-free welds. As an alternative tool design there is a class of FSW tools called bobbin tools (sometimes referred to as self-reacting tools). The name refers to the shape of these tools, which consist of two shoulders connected by the tool pin. When using a bobbin type tool there is no need for a backing plate. Hilbert studied thermal models for bobbin tool friction stir welding. Cerri and Leo proposed a heat treatment of 2 h at 535 °C to improve the weld ductility of medium strength aluminum alloy, while the tensile strengths remained comparable to those of as-friction stir welded samples.

MATERIAL FLOW BEHAVIOUR IN FRICTION STIR WELDING PROCESS-A CRITICAL REVIEW ON PROCESS PARAMETER AND MOLDING METHODOLOGIE.

Friction Stir welding (FSW) is an energy efficient, environment friendly, and versatile technique used to join high-strength aerospace aluminum alloys and other metallic alloys that are hard to weld by conventional fusion welding. More than a decade, FSW is considered to be the most noteworthy development in metal joining area and was developed for micro structural modification of metallic materials. Material flow during friction stir welding is very complex and can be understood with very critical investigation only. Most of studies in literature used threaded pins since most industrial applications currently use threaded pins. However, initially threaded tools may become unthreaded because of the tool wear when used for high melting point alloys or reinforced aluminum alloys. Material flow with unthreaded pin was found to have the same features as material flow using classical threaded pins. The material flow is also influenced by the process parameters that directly influence the micro structural refinement. In the present article, the current state of understanding and development of the FSW with emphasis on material flow behavior with various modeling techniques and the influence of process parameters like tool rotation and traverse speeds, tool tilt and plunge depth etc on the resultant microstructure are critically reviewed.

STUDY OF TOOL GEOMETRY ON FRICTION STIRS WELDING OF AA 6061 AND AZ61.

Making a choice in selection of friction stir welding/processing (FSW/P) tool material has become an important task which determines the quality of the weld produced. The tool material selection depends on the tool material operational characteristics such as operational temperature, wear resistance and fracture toughness which therefore determine the type of materials which can be joined. In this research, several tool materials have been analyzed and the materials which they could be used to join have also been outlined. Soft materials can be easily

welded using tool steels while harder materials need harder tool materials such as carbide based materials and polycrystalline cubic boron nitride (PCBN).
Friction stir welding (FSW) is a solid state welding process that does not involve the actual melting of the work material. The heat generated from the friction between the tool and the work material is enough to soften the work material at a temperature below the melting point of the base metal. The process of FSW involves the welding and processing of a wide range of materials from soft materials such as aluminum to hard materials such as titanium. In such a situation, the FSW tool is often subjected to severe stresses and high temperatures. Zhang et al. indicated that material characteristics can be critical for FSW. The tool material choice is dependent on the work-piece and the required tool life and also it depends on the user experience and preferences.

STEADY STATE THERMAL ANALYSIS OF FRICTION STIR WELDED STRINGER PANEL OF AN AIRCRAFT WING.
Welding is a wide range multistate permanent fastening method of fabrication. Globally welding technology has numerous applications. The present project deals with the calculation of the steady state thermal analysis and fatigue life of the friction stir welded stringer panel. The stringer panel is a device used for supporting the upper and the lower skin of the aircraft wing. The equivalent stresses and life cycles are calculated theoretically referring to many journals, the theoretical inputs are given to the analysis software ANSYS Workbench i.e. heat flux, temperature, and speed of rotation of the friction stir tool. The resultant equivalent stress and the total deformation apart from that the life cycles are also generated. The theoretical values of stress and fatigue life are computed. The best welding conditions are predicted by suitable analysis in ANSYS Work bench software by providing suitable working conditions as inputs.

Aircraft Structural weight has always been important in aircraft manufacturing industry. Aircraft structural design is a subset of structural design in general, including ships, land vehicles, bridges, towers, and buildings. All structures must be designed with care because human life often depends on their performance.

Metal structures are subject to corrosion, and some kinds of corrosion are accelerated in the presence of stress. Aircraft structures are designed with particular attention to weight, for obvious reasons. If we could see beneath the interior fittings of passenger aircraft, we would see numerous lightening holes in the frames as well as regions where the skins have been thinned by chemical milling.

PARAMETERIC ANALYSIS OF FRICTION STIR WELDING.
Friction stir welding (FSW) uses a non-consumable tool to produce frictional heat in the adjoining surfaces. The welding parameters like rotational speed, welding speed, tool pin length, and tool shoulder diameter play a major role in deciding the joint properties. In this work, an attempt has been made to analyze the effect of various tool profiles on mechanical properties of aluminum alloy. Various tool profiles have been used to fabricate joints by using constant thickness (3mm) work piece of aluminum alloy. The mechanical properties of welded materials are measured in-terms of tensile strength and Brinell hardness number (BHN). By using Design of Experiment (DOE) concept, experiments were carried out to predict tensile strength and BHN of the welded joint. In this work, heat generated during the process is utilized to improve the quality of welded joint by using backing plate (low thermal conductivity or insulating material) between work piece and fixture. By varying the welding parameters, effect on joining efficiency in terms of gap between two mating surfaces on the back side of the welded plate has been analyzed. From this investigation, it has been found that tool profile (shoulder dia. 18 mm, pin length 2.8 mm) produces good tensile strength.

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