Friction Stir Welding of AMC

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Abstract *:* This work constitutes the study of friction stir welded material of Al 6061 composites where fly ash is used as reinforcement. FSW was conducted for different tool rotational speed varied from 700 rpm to 1100 rpm. This project is to overcome the problems with the traditional welding methods. Microstructure analysis was performed by optical microscopy, and Hardness test were also conducted using Vickers micro hardness tester. Effect of different tool rotational speed was checked on joint characteristics. Sound joints were obtained using FSW without any defects. After FSW uniform and fine grain formation was observed in the weld nugget. Compared to all rotational speeds joints exhibited higher hardness at 1000 rpm, where uniform and fine grain structure was obtained. FSW was used successfully for joining the aluminum matrix composites

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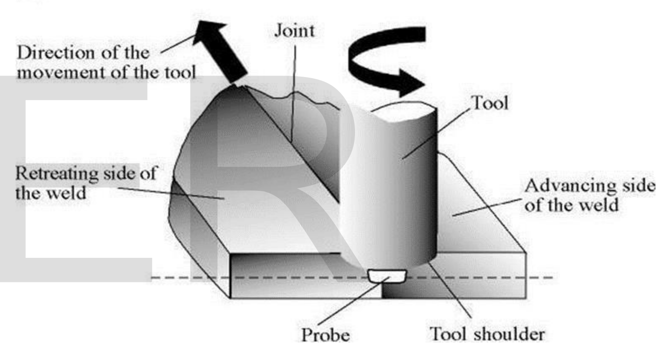
1 INTRODUCTION TO FSW

Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two facing work pieces without melting the work piece material. Heat is generated by friction between the rotating tool and the work piece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool, much like joining clay, or dough. It is primarily used on wrought or extruded aluminium and particularly for structures which need very high weld strength. FSW is also found in modern shipbuilding, trains, and aerospace applications. It was invented and experimentally proven at The Welding Institute(TWI) in the UK in December 1991. TWI held patents on the process, the first being the most descriptive.



1.1 PRICIPLE OF OPERATION

A rotating cylindrical tool with a profiled probe is fed into a butt joint between two clamped workpieces, until the shoulder, which has a larger diameter than the pin, touches the surface of the workpieces as shown in Figure 1. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. After a short dwell time, the tool is moved forward along the joint line at the pre-set welding speed.

Frictional heat is generated between the wear-resistant tool and the 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 tool is moved forward, a special profile on the probe forces plasticised material from the leading face to the rear, where the high forces assist in a forged consolidation of the weld.

2 LITERATURE REVIEW

This section consists of brief information about the various work related to friction welding of High density polyethylene sheet conducted by various researchers and their experimental details.

Welding of composite materials is almost unavoidable in many applications. Also, welding of composites should not deteriorate its mechanical properties. Welding of AMCs by traditional fusion welding processes such as shielded metal arc welding (SMAW), gas tungsten arc welding(GTAW) and gas metal arc welding (GMAW) leads to defects in welded joints [4,5]. Some of the problems associated with fusion welding of AMCs are high solubility of gases in the molten state, solidification shrinkage, presence of oxide inclusions, thermal stresses due to high variation in coefficient of thermal expansion between the Al matrix and ceramic reinforcement particles, formation of intermetallic compounds due to interfacial chemical reactions between reinforcement particles and matrix in the molten state and segregation of reinforcement particles during solidification of composite [6,7]. Aluminium matrix getting heated to its melting point during the fusion welding process is the main reason for the above said problems. If AMCs are welded by solid state welding process the above problems can be avoided. In the solid state welding, AMCs are heated till Al matrix just reaches its plastic state and hence AMCs can be successfully welded without defects caused due to overheating. Consequently, AMCs can be effectively utilized for a variety of critical applications .Friction stir welding (FSW) is a solid state joining process which was invented by The Welding Institute (TWI), UK, in 1991 [8]. FSW is a continuous, hot shear, autogenous process involving a non-consumable rotating tool of harder material than the material to be welded. The frictional heat generated by the relative motion between the rotating tool and the material to be welded, softens the material and coalescence is achieved at the retreating side of the tool. A detailed description of the FSW process is presented in literatures [9,10].

Erica Anna Squeo, Giuseppe Bruno, Alessandro Gugliemotti [11] have selected polyethylene sheet of 3mm thick were friction stir welded with a cylindrical steel pin; two pin diameters and a combination of feed rates and rotational speed of the pin were considered for the experimentation. Moreover, a modification of the traditional friction stir welding process was investigated by adding a heating step of the pin and the samples to join. The quality of the joint was evaluated by means of tensile tests and thermal analysis. For each joining test, two samples were fixed in a metal frame in a butt joint configuration, in contact along the smaller edge. Steel flat pins with a shoulder 6mm in diameter were used for joining. In the process set-up a minimum distance about 0.2mm was left between the pin flat surface and the bottom surface of the samples. The pin rotational speed was changed between 3,000 and 20,000 rpm, the feed rate between 10 and 44mm/min, the pin diameter between 1 and 3mm. Also the sheet and the pin temperature was changed in two different ways: by means of hot air gun and by a heating plate. The temperature changed between the room value and 150^0C. The joint strength was measured by means of tensile strength. Thermal tests were also carried out with a differential scanning calorimeter(DSC).

From their work we obtained conclusions i.e. a very high strength may be obtained(close to the strength of base material) Amir Mostafapour and Ehasan Azarsa[12] was investigated the weldability of high density polyethylene sheets via heat assisted friction stir welding and effect of process parameters on microstructure and mechanical properties of welded plates. Tensile and bend tests were done in order to evaluate mechanical behavior of material. The tool used in the study is designed based on the tooling system that has been developed. It consist of shoe, a rotating pin, and a heater, which is located at the back of the pin. The designed tool provides the mixing and joining of plastic parts together in the presence of heat. Additionally, a specially designed fixture was utilized to assure that the tool works in its best performance. The shoulder is stationery relative to pin, whereas in FSW of metals, the shoulder rotates with the pin. The main objective of this research is to investigate the effect of process parameters , such as rotational speed of pin, tool transverse speed and adjusted heater temperature , on mechanical behavior-ultimate tensile and flexural strength and micro structure of high density polyethylene sheets. The process parameters was investigated under multiple levels. Pin rotational speeds were 1000, 1250, and 1600 rpm. Shoulder temperature of 80, 110 and 1400^0C were examined. Welding speeds had values of 10, 25 and 40mm/min. Optimum value of 0.5mm was achieved for plunge depth through experimental tests. Tensile tests were performed by Zwick/Roll device with autograph capability and samples were extracted from each welded part in accordance with ASTM D638 standard. Three point bend test was done according to ASTM 790 standard with GT-7010A2 device manufactured by Gotech company.

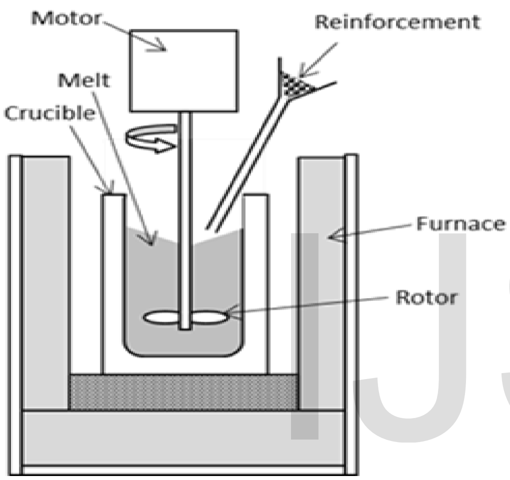
It can be examined that a rotational speed of 1600rpm and welding speed of 20mm/min with an increase in heater temperature , ultimate tensile and flexural strength raise up to base material strength. From microstructure observation that were obtained from photolastic device. This device utilizes polarized light in which each parts of the weld section appeared in different color s, because process left different effect on various regions of it.

3 Experimental details

3.1 Stir casting

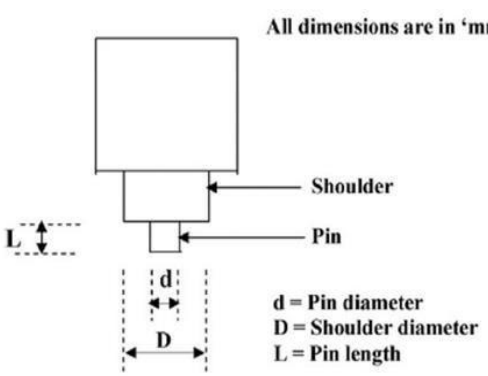
Composites were produced by stir casting process. The experimental set up is shown It consisted of an electrical resistance holding furnace and a stirrer assembly. The stirrer consisted of a three blade impeller attached to a variable speed D.C. motor whose speed could be varied between 0 - 1500 rpm. The stirrer along with the motor had provisions that it could be clamped at any desired height from the vertical. During the process, the molten metal was well agitated by a mechanical impeller to create vortex motion. The depth of the immersed impeller was approximately one third of the height of the molten metal from the bottom of the crucible and the speed of the impeller was maintained at 760 rpm as shown After degassing the molten metal with Nitrogen, preheated SiC particles and fly ash particles

at 840ºC were added into the vortex created by the impeller. Vortex produces uniform suspension of solid particles in the melt due to centrifugal acceleration. Composites were produced by stir casting process with three different Weight% of Fly Ash i.e., 2%, 4% and 6% and constant weight % of SiC particles(10%). The size of the particles dispersed was 25 µm. The melt was held at 840ºC for 15 minutes and then stirring was continued to achieve uniform distribution of SiC and Fly Ash particles in the molten 6061. Then the mixed molten metal is poured in to the mould cavity.Cast composites were solidified.



3.2 Welding Tool

FSW process involving the butt joining of pure aluminium is carried out using the H-13 Tool steel as tool material



Pin length (mm)	5.7
Tool shoulder diameter, D (mm)	18
Pin diameter, d (mm)	6
D/d ratio of tool	3

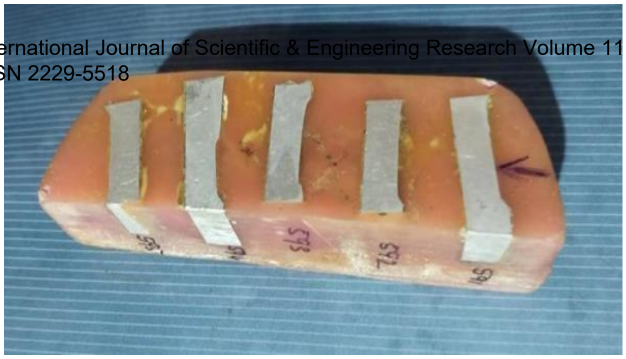
4 Results and discussion

4.1 Hardness test

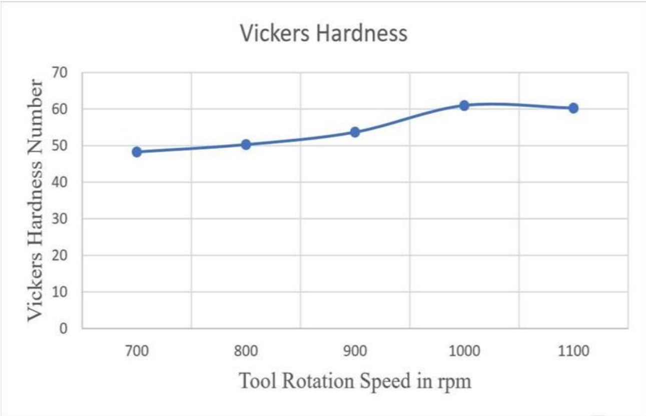
Vickers Hardness Test is similar to the Brinell hardness testing method. The principle in this test is that a defined shaped indenter is pressed into the material. The indenting force is applied for a certain decided amount of time[11]. The resulting indentation diagonals are measured and recorded. The hardness number is calculated by dividing the force by the surface area of the indentation. As mentioned previously, the principle of the Vickers test is similar to the Brinell test, but the Vickers test is performed with different forces and indenters. The square base pyramidal diamond indenter is forced under a predetermined load ranging from 1 to 129kgf into the material to be tested. After the forces have attained static or equilibrium conditions, further penetration cease, the force remains applied for a specific time (10 to 15s for normal test times) and is then removed. The resulting unrecovered indentation diagonals are measured and averaged to give the value in millimeter. These length measurements are used to calculate the Vickers hardness number(HV).

The test was performed according to ASTM E92-82 [28]. The Vickers Hardness Number (HV) is obtained by the following formula.

$$HV = \frac{2P\sin\left(\frac{136}{2}\right)}{d^2} = \frac{1.8544\,P}{d^2}$$



Test specimen



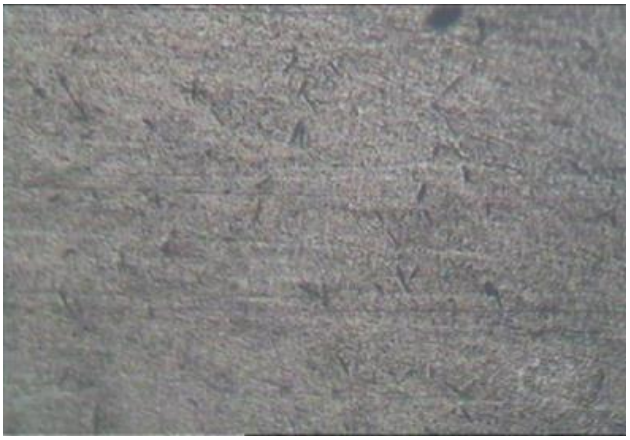
We compared our results with the Hardness property of AA6061. We have analyzed the Hardness property by varying the rotation speed of the tool. We have varied the rotation speed of the tool in AA6061 from 700rpm to 1100rpm. In our analysis we have found that the joint efficiency with respect to hardness of the AA6061 with a fly ash composition of is higher at 1000rpm as show in Graph (figure 5.7) .So we have come to the conclusion that we get hardness results when the tool rotation speed is at 1000 rpm

4.2 Micro structure

The specimens cut from the welded plates perpendicular to welding direction were prepared for microstructural observation. They were polished using different grades of emery from coarse to fine grades. Final polishing was done with diamond paste of 2 microns size. for etchant we are used (methanol 25ml, hydrochloric acid 25ml, nitric acid 25ml,hydro fluoric acid 1ml) called as kellers etchant.

In fusion welding of aluminium alloys, the defects like porosity, slag inclusion, solidification cracks, etc. deteriorates the weld quality and joint properties. Usually, friction stir welded joints are free from these defects since there is no melting takes

place during welding and the metals are joined in the solid state itself due to the heat generated by the friction and flow metal by the stirring action. However, FSW joints are prone to other defects like pinhole, tunnel defects, piping defects, kissing bond, cracks, etc. shown in Table 1.2 due to improper flow of metal and insufficient consolidation of metal in the region.



1000rpm

6 Conclusion

- The study demonstrates that, friction stir welding can be successfully adapted for joining aluminum matrix composite. The microstructure at the nugget zone was characterized by fine and equiaxed grain. The weld zone can display homogeneous distribution of grains. The clusters present in the parent composite were fragmented by stirring action of the tool. The weld zone can exhibit higher hardness due to homogeneous distribution of grains. Highest hardness value was obtained for a rotational speed of 1000 rpm.
- For various tool rotations conditions, the micro-hardness values along the cross section of the FS welds were found to vary between 55 and 65 HV.
- Increased rotational speed of the tool at the intermediate level resulted in a weld nugget of smaller sized grains. Particulate agglomerations were broken up to a greater extent compared with the low roational speed case. A higher tool rotational speed resulted in a highly fine and homogeneous distribution of grains in the weld nugget

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