FRICTION STIR WELDING OF AMCs

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Abstract : This paper constitutes the study of friction stir welded material of Al 6061 composites where silicon carbide is used as reinforcement , where silicone content is varied from 3% to 12% . This project is to overcome the problems with the traditional welding methods. To reduce density, increase toughness, build up corrosion resistance property, increase wear resistance property. Test specimens were prepared as per ASTM standards and analysis were performed by SEM analysis , Tensile test and Hardness test.

1 INTRODUCTION

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. Aluminium matrix composites (AMCs) have now replaced traditional unreinforced aluminium alloys as AMCs have excellent mechanical and physical properties. Those properties of AMCs can be tailored to meet the requirements of specific applications. Due to continuous development in production methods of AMCs reinforced with particulate form of ceramics, it is increasingly employed in aerospace, automotive industries, etc., where excellent mechanical properties such as high strength to weight ratio, stiffness and superior wear resistance at room as well as at elevated temperatures are required [1–3].

1.1 Principle 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.

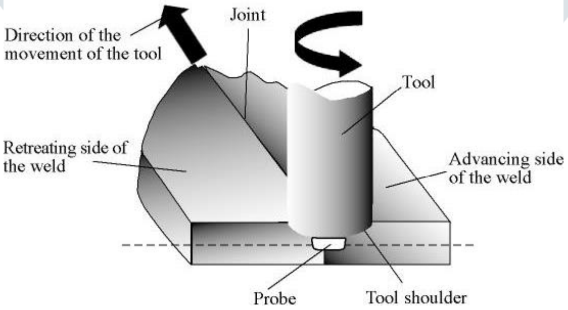


Figure 1 Principle of Operation

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].

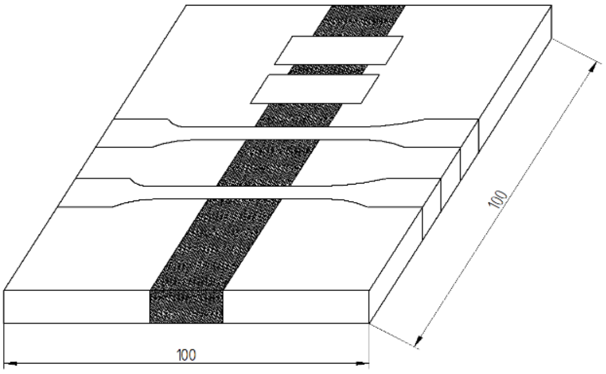
Erica Anna Squeo, Giuseppe Bruno, Alessandro Gugliemotti [11] have selected polyethylene sheet of 3mm thick were friction stir welded with a cylindrical steel pin; two pin diameters and a combination of feed rates and rotational speed of the pin were considered for the experimentation. Moreover, a modification 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

Figure 2 Extraction of Specimens from weld joints



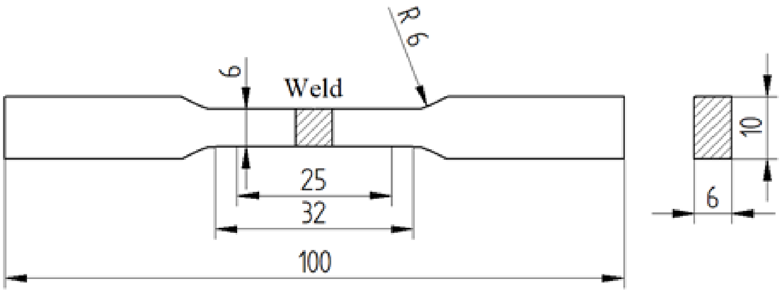


Figure 3 Tensile test specimen dimensions (ASTM E08M)

After friction stir welding the specimens for tensile and hardness testing were extracted from weld joints according to the Figure 2. Specimens for tensile testing were prepared according to the ASTME08M standard shown in Figure 3.

4 RESULTS AND DISCUSSION

4.1 Tensile Properties

Table 1 Tensile Properties Final Results

SI No	Composition	UTS (MPa)	Elongation	Joint Efficiency
01	AA6061	104	9.3	-
02	AA6061 with 3% SiC	70	8	67.30 %
03	AA6061 with 6% SiC	68	8.5	65.38%
04	AA6061 with 9% SiC	74	9.6	71.15%
05	AA6061 with 12%SiC	72	9	69.23%

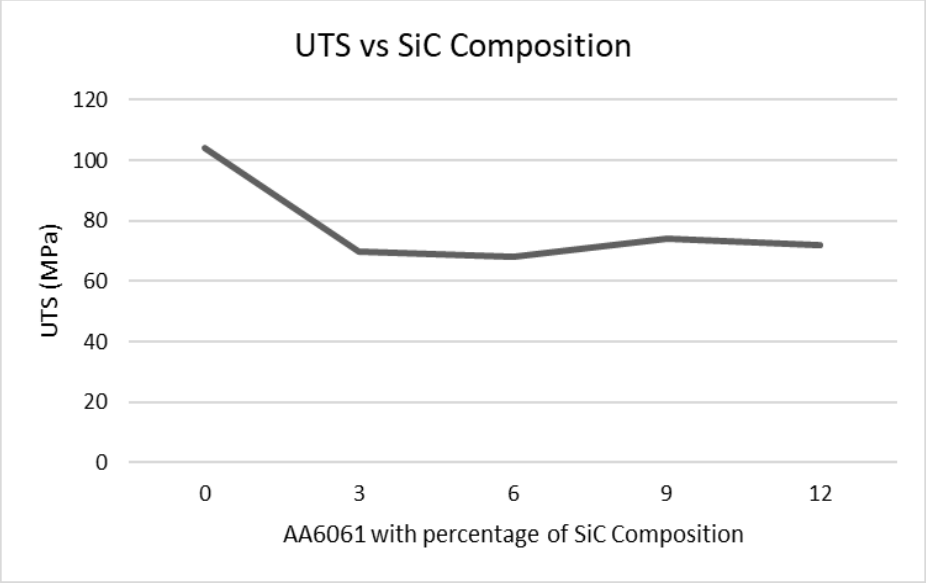


Figure 4 Tensile Strength vs SiC Composition

We compared our results with the Tensile property of AA6061 .We have analysed the tensile property by varying the composition of the reinforcement which is Silicon Carbide . We have varied the composition of Silicon Carbide in AA6061 by 3% , 6% , 9% , 12%. In our analysis we have found that the Joint efficiency of the AA6061 with a Silicon Carbide composition of 9% is higher as show in Table 1 and Figure 4 .So we have come to the conclusion that we get better tensile strength when composition is 9%.

4.2 Hardness Properties Results

Table 2 Hardness Properties Final Results

SI No	Composition	Vicker's Hardness Number	Elongation	Joint Efficiency
01	AA6061	55.8623	9.3	100 %
02	AA6061 with 3% SiC	51.62501	8	92.41 %
03	AA6061 with 6% SiC	52.20022	8.5	93.444%
04	AA6061 with 9% SiC	54.44	9.6	97.45%
05	AA6061 with 12%SiC	47.59864	9	85.207%

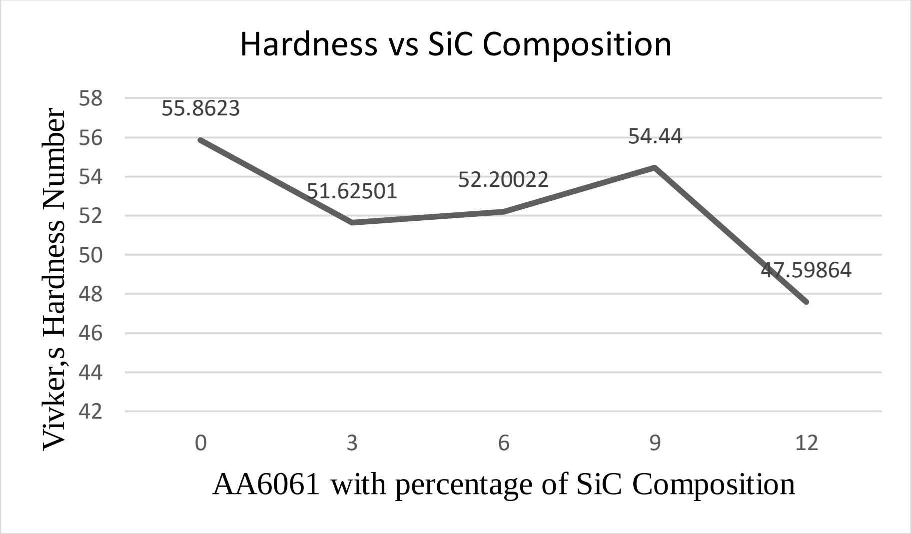


Figure 5 Hardness vs SiC Compositions

We compared our results with the Hardness property of AA6061 .We have analysed the Hardness property by varying the composition of the reinforcement which is Silicon Carbide . We have varied the composition of Silicon Carbide in AA6061 by 3% , 6% , 9% , 12%. In our analysis we have found that the joint efficiency with respect to hardness of the AA6061 with a Silicon Carbide composition of 9% is higher as show in Table 2 and Figure 5 .So we have come to the conclusion that we get better hardness results when composition is 9%.

4.3 Microstructure characteristics

The microstructure of the AA6061 Silicon Carbide composite at an magnification of 50 micrometres (Figure 6) was fabricated with the friction-stir welding method. It can be seen that the Silicon-carbide particles are distributed uniformly, bonding well with the aluminium matrix. The interface between the Al-matrix and Silicon particles is clean allowing a strong interfacial bonding. No agglomeration of the particles was observed in the composite. It is also clear from the Figure 6 that, coarse SiC particles present in the base metal is successfully broken in to smaller size by the stirring action of FSW tool. As a result better mechanical properties of the joints have been obtained in the friction stir welded joints. There is no evidence of any major defects in the welds. Indicating that the heat supplied is optimal for the welding process.

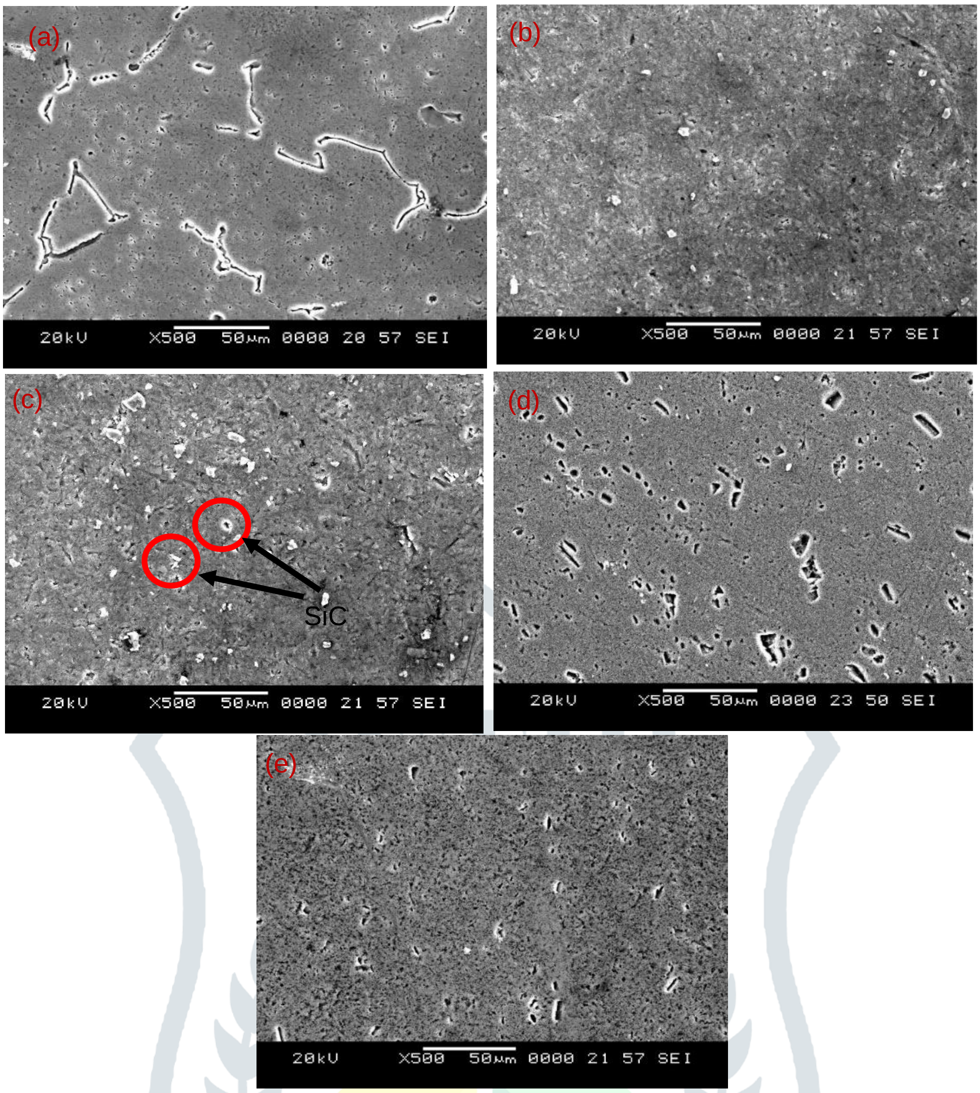


Figure 6 Microstructure Study 50 micrometres

CONCLUSIONS

Based on the results obtained form the present research work following conclusions have been drawn

1. Sound FSW joints have been obtained without any defects
2. Microstructure of joints reveals the homogeneous distribution of SiC particles in the nugget zone
3. Joint efficiency of maximum 71.5% and minimum of 65.38% is obtained for AA6061 with 9% SiC and AA6061 with 6% SiC with respect to UTS
4. Joint efficiency of maximum 97.45% and minimum of 85.207% is obtained for AA6061 with 9% SiC and AA6061 with 12% SiC with respect to hardness

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