International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.4 Issue No.2, pp : 88-90 01 Feb2015

Microstructure and Mechanical properties of Multipass Friction Stir Processed Aluminum Silicon Carbide Metal Matrix

V V Murali Krishna G*, Prof K.Satyanarayana
Venkatamurali.g@gmail.com
SRKR Engineering College Bhimavaram

Abstrct :In this study, SiC particles were incorporated by using Friction Stir Processing (FSP) into the 6351 aluminium alloy to form particulate composite materials. Sampels were subjected to constant rotational and traverse speeds of the FSP tool with and without SiC reinforcements. Microstructural observations were carried out by employing optical microscopy of the modifiedsurfaces. Mechanical properties were evaluated by tensile test on UTM. For the 100% overlapping, No.of passes caused grain modification in the processed zone. The tensile test results indicate an improvement of strength and Microhardness for Single Pass FSP samples and a reduction in the strength of FSP samples with increasing the No.of passes due to the dissolution of the hardening precipitates.

1. I**ntroduction**

Al alloys of the 6000 series are known to have good formability, corrosion resistence, weldability, and high strength-to-weight ratio. They have constituted the heighest volume of Al extruded product and been widely used for automobile and aerospace industries, architectural applications, bicycle frames, transportation equipment, bridge railings and welded structures. The major alloying elements in the heat-treatable 6000 series are silicon and magnesium. Both elements are required for precipitation strengthening, which is commonly acquired by solutionizing and artificial aging. Strengthening can be enhanced further by refining the grain size to a few micrometers and lower. This can be achived by Friction Stir Processing(FSP), which is a soild state processing technique developed from the principles of Friction Stir Welding(FSW) and used for microstructural modification by grain reinnforcement. In Fsp, a non-consumable rotating tool consisting of pin and shoulder is inserted into a plate of metal and traversed along a line to process the region of intrest. Friction between the tool shoulder and the workpiece results in localizing heating that softens and plasticizes the processed zone. The stirring action of the rotating pin causes intense plastic deformation of the locally heated material. The combination of the plastic deformation, mixing and thermal exposure results in a modified microstructure in the stirring zone (SZ), which is commenly charactrerized by fine and equiaxed grain structure with predominate high -angle boundarys. The modification is generally attributed to dynamic recrystallization and break-up of constituent particles. Next to the SZ, a narrow transistion region known as thermomechanically affected zone (TMAZ) is formed, follwed by the heat affected zone(HAZ), and finnaly the uneffected base metal(BM).

FSP was devoloped by Mishra et.al [1] microstructural modification and fabrication of metal matrix composites are based on the basic principles of the FSW. Several FSW and FSP works have been devoted to study the microstructural and mechanical propertys of 6000 series Al alloy's. General remarks indicate that frictional heat and intensive plastic deformation during FSW cause dissolution and /or coarsening of strengthening precipitates. Woo et al.[2] investigated the influence of stirring pin and pressing tool shoulder on the microstructural devolepment in FSP of 6061 Al. It was found that microstructural softening occured due to frictional heating by the tool shoulder.The effect of multiple passes on microstructural development during FSP has been investigated on different aluminium alloys [3,4]. Johannes and Mishra[5] demonstrated the effectiveness of multiple passes in creating large areas of superplastics material of 7075 Al with insignificant microstructural difference , having grain size in the range of 3.6-5.4. Ma et al .[6] also showed similar grain refinement in the microstructure of 7075 Al produced by multi-pass FSP and indicated that two-pass FSP samples of 50% overlap have greater superplasticity then single-pass FSP samples. A resent study by El Rayes and El Danaf [7] on multi-pass FSP of 6082 Al indicated that the increase the number of passes from one to three with 100% overlaping reselted in large SZ size but more dissoletion of the harding phase.this was found to soften the SZ and reduce its strength.

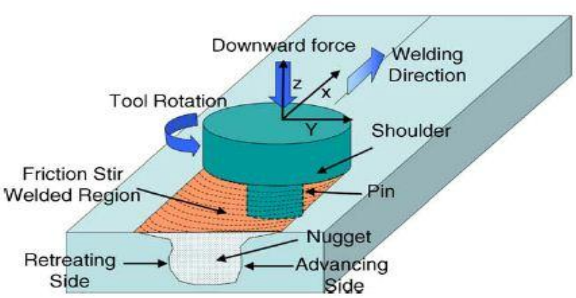
The influence of the overlapping(OL) percentages of multi-pass FSP on the microstructural and mechanical characteristics of the alloy surface has received less attention.The intersection between consecutive passes creates an overlapped region between the processed zoneand thus further alters the microstructres. Also,there is a possibility of additional dissolution and/or coarsening of strengthenting precipitates of Al 6351 at the overlapped region due to thermal cycle of subsiquent pass.This can progress to further weakening of the mechanical properties of the processed zone. Therefore, the aim of the study is to investigate the affect of the OL percentages produced by multi-pass FSP on the microstructure and mechanical properties of Al 6351.By running Multi-pass FSP with one overlapping percentages it is also possible to examine the comparitive analysis of single-pass and multi-pass FSP of Al 6351.

The objective of this paper was to investigate the possibility of incorporation of reignforcement particles into surface layer of commercially Al 6351 to form metal matrix composites by means of FSP technique.Also, the influence of no.of passes on the mechanical properties were experimentally investigated.

2. Experimental procedure:

Four millimetre thick plates of Alluminium alloy 6351 plates were used in this study.The dimensions of the FSP plates were 100mm x 50mm . The FSP tool material is made of HSS steel ; it has a shoulder of 16mm dia and 2mm long pin with a (2*3)mm tapper dia. FSP was conducted using a vertical milling machine with constant tool rotating rate 1000rpm and travel speed of 20mm per minute. It should be note that WD,TD and ND denotes the processing ,transfers and normal directions of the plate respectively.Single pass & multi pass FSP were carried out with and with out SiC. The surface plates was cleaned with grinding paper before processing. The average size of the SiC particles was about 10μm. In a small group cut on the work piece and filled with SiC particles then FSP was carried out.In the case of multi pass processing, three passes were made with 100% overlapping .

To asses microstructure refinement in the SZ, metallographic samples were prepared for examination by using optical microscopy. The metallographic samples were cut from the cross section of FSP plates, then ground and polished using standard metallo graphy techniques.The optical microscopy(OM) studies were carried out the samples were chemically etched at ambient temperature for about 6 min with kellers reagent to distinguish the grein boundaries, identify precipitates and difference in composition. Further examination in SZ was also made by X-ray diffraction. The mechanical properties of FSP samples were measured at ambient temperature by tensile testing, TD tensile specimens of 4-mm thick were cut from the FSP plates a guage length of 50mm was used to ensure that the guage section is entirely made from the processed zone. For each processing condition, the tensile specimens were made and tested by using the computerized UTM. The tensile strength was then computed and compared to the tensile strength of the base metal.

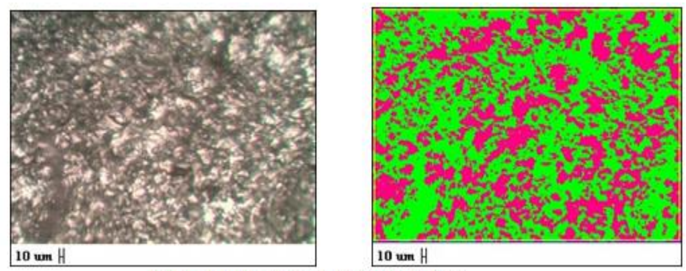


3. Result and Discussion:

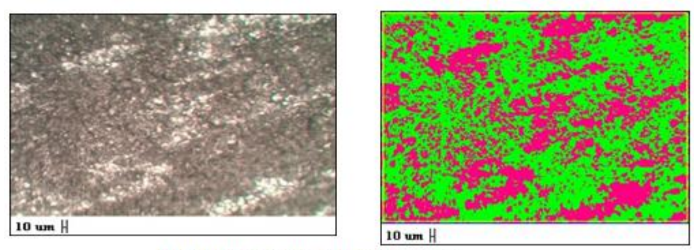
3.1. Microstructure:

After the Aluminium 6351 Alloy-SiC composite was fabricated by Friction Stir Processing, microstructure at cross-section of stir zone was observed using optical microscope. The prcessing parameters are 1000rpm rotational speed of tool and 20mm/min transverse speed. The average size of the SiC particles is 10μm. The microstructure of base materaal 6351 Alloy after conducting friction stir processing in single, two and three passes are shown in fig. Respectively. As it is already observed from the literature, that rotational speed and travelling speed variations varies the microstructure significantly, In the presant study all the experiments are conducted at 1000rpm rotational speed and 20mm/min traverse speed. From fig(a) for single pass it is observed that around 43.6% by volume Silicon flakes are present in α-Al matrix. As the no.of passes increased, with 100% overlap a refinement of Silicon flakes is observed and volume % of silicon incfreased to 44.81%. In the third pass, the Silicon flakes are futher refined and vollume % of Silicon is found to be 42.8%. It is noticed that the grain size is reduced for 100% overlapping specimens compared to specimens with single pass(without overlapping).

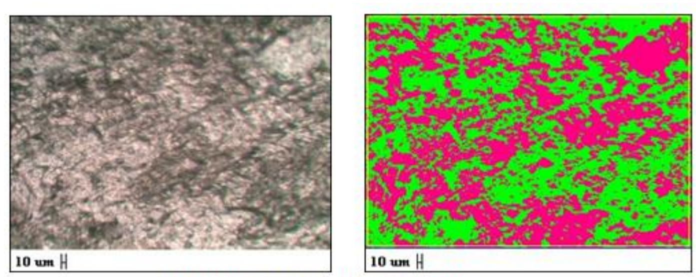
Fig. Shows the micrographs of Al 6351+ SiC composite specimens in the stirring zone. The addition of SiC particles into Al 6351 matrix using the Al 6351 matrix. With multipass friction stir processing with 100% overlap resulted in more heat input and so grain growth increased and SiC is distributed non-homogeneously in Al matrix.



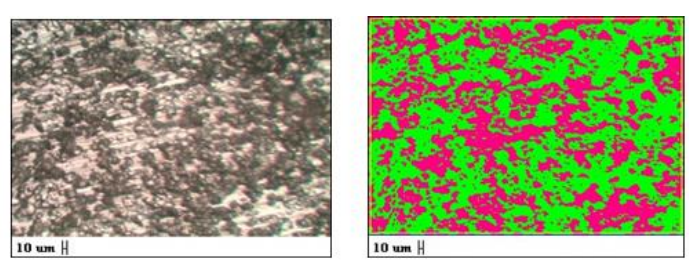
Fig(1) Microstructure of Al6351 Single pass



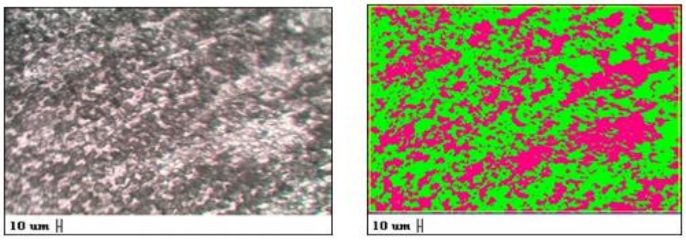
Fig(2) Microstructure of Al6351 Two pass



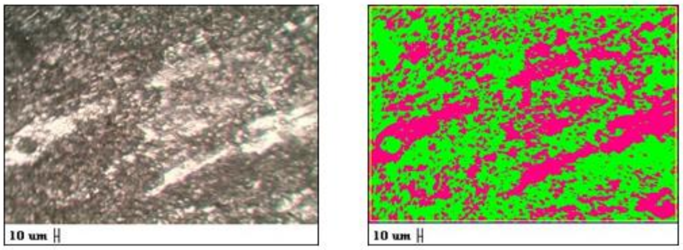
Fig(3) Microstructure of Al6351 Three pass



Fig(4) Microstructure of Al6351+SiC single pass



Fig(5) Microstructure of Al6351+SiC double pass



Fig(6) Microstructure of Al6351+SiC three pass

3.2. Mechanical properites:

3.2.1. Tensile Properites:

Table shows the results of tensile properties obtained after experimentation. It is observed that the UTS, yeild strength increases with single pass friction stir processing for base material Al 6351 alloy. However, with multipass using 100% overlapping the same prperties showed a decreasing trend. This may be due to refinement of grain size with single pass FSP and sofening of grains due to excessive heat input during multipass leading to decrease in tensile properties for multipass FSP specimens.

The addition of SiC reinforcement in Al 6351 base alloy resulted in improvement of tensile properties like UTS and yeild strength. This is due to homogeneous distribution of SiC particles in Al base alloy and good bonding between SiC particulers and base Al. The multi-pass FSP with SiC reinforcement reduced the tensile properties of specimens, probably due to grain sofeting and non-uniform distribution of SiC in the base alloy matrix.

Tensile properties of Aluminium Alloy 6351-SiC surface composite				
Material	Type of specimen	UTS(mpa)	Yield strength(mpa)	% Elongation
Al 6351 alloy (base maetal)	Single pass	239.16	232.4	9.2
	Two pass	151.24	147.55	22.6
	Three pass	142.87	139.66	17.6
Al 6351 alloy +SiC	Single pass	158.49	137	15.8
	Two pass	146.25	127.97	14
	Three pass	120.87	104.27	6.6

Table 1: Tensile properties of Friction Stir processed specimens

3.2.2. Hardness:

The results of the vickers microhardness values for all the test samples are shown in table. The hardness of Al 6351 base alloy with single pass has increased compared to Al 6351 base alloy without FSP. For the multi-pass test specimens the hardness is found to be decreased due to grain softening caused by excussive heat input and non-uniform distribution of silicon. For Al 6351-SiC composite with single pass, the hardness is found to increase compared to Al 6351 base Alloy with single pass, this is due to the inclusion of hard SiC particles into tje Al matrix. However the effect of multi-pass FSP on hardness of both Al6351 base alloy and Al 6351-SiC compsite is found to be decreasing due to heat input and grain softening during multipass FSP.

Material	No.of passes	Center	Left to Right			
Al 6351	1	135.9	136.6	135	138.9	136
	2	120.6	121	120.3	119.8	120.9
	3	105.5	104.9	104	105.3	103.8
Al6351+SiC	1	138.7	138.2	137.4	137.9	138.1
	2	126.2	126.8	126	126.3	125.8
	3	119`	118.7	119.1	119.4	118.9

Table 2 : Hardness values

4. Conclusions:

1. It has been demonstrated that FSP was an appropriate method to modify the microstructure and mechanical properties of 6351 Al-alloy.
2. FSP resulted in fine and equiaxed grains in the stirring zone and overlapping area.
3. Increasing the percentage of overlapping resulted in limited change in the grain size, but provided more subgrain formation.
4. A reduction in the strength and microhardness of muti-pass FSP samples occured due to the precipitate dissolution and the limited reprecipitation by the thermal cycle of FSP.
5. The highest microhardness of Al 6351/SiCp composite can be attributed to the presence of reinforcement particles.
6. With further research efforts, FSP cuold be conducted for mechanical behaviour of these composites, like fatigue,wearand creep, response etc...

References

i. Mishra, R.S., Ma, Z.Y., Charit, i., 2003. Friction stir processing: a noval technique for fabrication of surface composite. Mater.lett. A341, 307-310.

ii. Woo W, Choo H, Brown DW, Feng z. Influence of the tool pin and shoulder on microstructure and natural aging kinetics in a friction-stir-processed 6061-T6 aluminum alloy. Metall MaterTrans A 2007;38:69-76.

iii. K.Nakata,"IMPROVEMENT OF MECHANICAL PROPERTIES OF ALUMINIUM DIE CASTING ALLOY BY MULTI-PASS FRICTION STIR PROCESSING", Matr. Sci.and Eng,A 437(2006), 274-280.

iv. Khaled J.Al-Fadhalah,"MICROSTRUCTURE AND MECHANICAL PROPERTIES OFMULTI-PASS FRICTION STIR PROCESSED ALUMINIUM ALLOY 6063",Mater. & design,53(2014), 550-560.

v. Johannes LB, Mishra RS. Multiple passes of friction stir processing for the creation of superplastic 7075 aluminum. Mater Sci Eng A 2007;464:255-60.

vi. Ma ZY, Mishra RS, Lic FC. Superplastic behaviour of micro-regions in two-pass friction stirprocessed 7075Al alloy. Mater Sci Eng A 2009;505:70-8.

vii. El Rayes MM, El Danaf EA. The influence of multi-pass friction stir processing on the microstructural and mechanical properties of aluminum alloy 6082. J Mater Process Technol 2012;212:1157-68.