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Production and Characterization of Aluminium 7075 – T651 Alloy / B_4C Surface Composite by Friction Stir Processing

R.Ramesh, N.Murugan

Abstract – ***Aluminum-based composites reinforced with hard ceramic particles offers high strength, stiffness, and resistance to wear. That combination of properties produced on the surface makes surface composites attractive to a wide range of applications in automotive and aerospace industries. Several modification techniques, such as high energy laser beam, plasma spraying, cast sinter and electron beam irradiation have been developed over the last two decades to fabricate surface metal matrix composites. Those techniques are based on liquid phase processing at high temperature and various problems such as reaction between reinforcement and matrix are encountered. Those limitations can be overcome if processing of surface composite is carried out in solid state. Friction stir processing is an emerging novel, green and energy efficient processing technique to fabricate surface composites which is based on the basic principles of friction stir welding. The distinct advantages of FSP are microstructural refinement, densification, homogeneity, accurate control and variable depth of the processed zone. Among the various metal matrix composites aluminum 7075 – T651 will find more applications. In this paper, it details about the fabrication of Al 7075-B_4C surface composites by friction stir processing (FSP) to have improved surface hardness and wear resistance. It was found that the average hardness of friction stir processed surface composite was 62% higher than that of the base metal Aluminum 7075 – T651. The increase in hardness was attributed to fine dispersion of B_4C particles and fine grain size of the Aluminum matrix.***

Keywords – ***Friction Stir Processing, Boron Carbide, Brinell hardness, Design of Experiments***

I. INTRODUCTION

Composites [1] represent a combination of at least two chemically distinct materials with a distinct interface separating the constituents. Their high strength to weight ratio, enhanced resistance to environmental hazards, lower density, high fatigue resistance, wear resistance and related properties have widened the range of application leading to a large scale substitution of conventional engineering materials for aerospace and consumer goods. Among various metal matrix composites aluminium is used widely for different applications. Aluminum is a natural candidate for this type of application because of its low density. However, compared to titanium alloys, the strength of conventional commercial aluminum alloys is too low for aluminum to be a better solution. Owing to the many difficulties encountered in the production and use of titanium alloys, the drive to develop stronger aluminum alloys is very high. Especially the surface of aluminium alloy is modified by incorporating various reinforcements to produce surface composites. Among the various processes employed for production of surface composites friction stir processing is a popular method.

Friction Stir Processing [2] is a new, solid state processing technique for microstructure modifications, which was developed based on the principle of friction-stir welding (FSW). A non-consumable rotating tool with a pin and shoulder is inserted into the material and travelled along the desired path. Because of this the frictional heat is generated and the material undergoes severe plastic deformation, resulting in significant microstructure modification in the processed zone. FSP creates a region called the Nugget or Stir zone, where the refinement of microstructure takes place producing equiaxed fine grains with high grain boundaries. Figure 1 shows the step by step procedure of Friction Stir Processing.

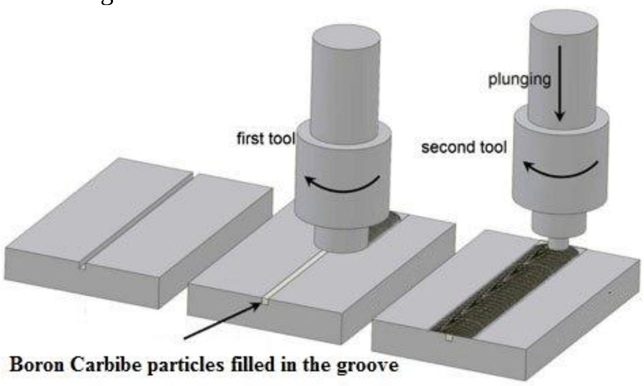

Fig.1 Friction Stir Processing
(a) Plate with groove;
(b) (First Tool) Pinless tool used for closing the groove;
(c) (Second Tool) Tool with pin is used for processing;

S. Soleymani et al [3] investigated a self-lubricating and wear resistant surface hybrid Al-base composite reinforced with a mixture of SiC and MoS_2 particles fabricated by Friction Stir Processing. Microstructure, hardness and dry sliding wear behavior of the hybrid composite were compared with those of base metal. Microstructural analysis [4] of the hybrid composite showed a uniform distribution of reinforcing particles inside the processed zone and a good bonding between surface processed layer and base material. The Tribological studies showed that surface hybrid composite had the highest wear resistance in comparison to the base metal.

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Z.Y. Ma et al [5] investigated the effect of overlapping passes on the microstructure and superplastic behavior of friction stir processing. Overlapping passes exerted no obvious effect on the size of recrystallized grains. Both single and two-pass FSP 7075Al exhibited similar grain sizes of 5.4–5.7_m. Compared to single-pass FSP, two-pass FSP resulted in an enhancement in superplastic elongation and a change in superplastic response. A shift to higher optimum temperature was observed in the two-pass FSP 7075Al. Furthermore, overlapping passes led to a shift to higher optimum strain rate in the center region of second pass in the two-pass FSP 7075Al.

In this paper, Al / B_4C surface composite layers were achieved on commercial 7075 – T651 Aluminium by employing friction stir processing technique. Agglomeration of B_4C particles was occurred after a single pass. The dispersion of B_4C particles was found to be affected by the number of FSP passes. Moreover, the increasing in number of FSP passes causes a decreasing in matrix grain size of the surface composite layer.

II. EXPERIMENTAL PROCEDURE

Aluminium Alloy 7075-T651 plates of size 50 mm x 100 mm x 6.35 mm were used as base material. The chemical composition of AA7075-T651 is given in Table 1. A groove of 0.5 mm width and 2.5 mm depth and 100 mm length was made on the plate and filled with boron carbide powder of 5 micro meters. With the help of the pin less tool the grooves are closed. Then the tool with pin is used for processing. The tool is made of high carbon high chromium steel, oil hardened to 62 HRC, having cylindrical profile surface was used for friction stir processing. Response Surface Methodology (RSM) was used for developing mathematical model to predict maximum hardness achieved in friction stir processed surface composite. The FSP process variables are identified as rotational speed (N), traverse speed (V) and number of passes (P). An axial force of 8 KN is kept constant for all the runs. The experiment was designed based on a three factor 3-level factorial technique. In Response surface methodology, the natural variables are transformed into dimensionless coded variables. The decided levels of the selected process parameters are given in Table 2 and developed design matrix is shown in Table 3. FSP was carried out as per the design matrix at random. Figure 2 shows the Friction Stir Processed plates. Specimens were prepared from the Friction Stir Processed plates. After preparing specimens the specimens are subjected to Brinell hardness test. Hardness is measured on the top of the processed surface. Three readings are taken for each sample and then the average has been calculated. General metallurgical procedure is followed to prepare specimens for metallographic studies. The strength of the base metal aluminium was 41 BHN (B Scale). Microstructure has been viewed perpendicular to the work piece.

Table 1 Chemical composition of the employed alloy

Elements	**Al**	**Zn**	**Mg**	**Cu**	**Cr**
Weight %	90.07	5.6	2.5	1.6	0.23

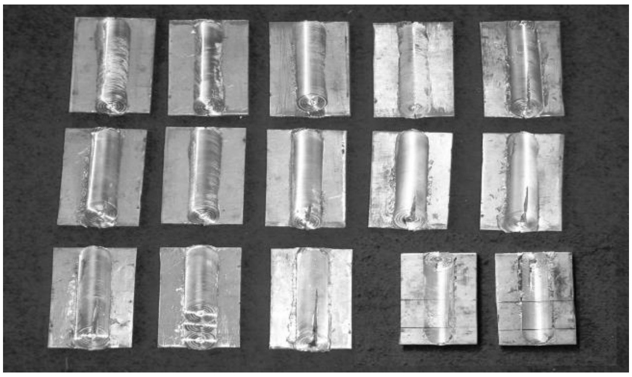

Fig 2 Processed work pieces

Table 2 Process Control factors and its levels (three factors – three levels)

Factors	**Units**	**Notation**	**Factor levels**		
			-1	**0**	**1**
Rotational speed	rpm	N	425	500	575
Traverse speed	mm/s	V	40	50	60
Number of Passes		NP	1	2	3

Table 3 Design Matrix and the estimated values of hardness (BHN)

Experiment trial	Design Matrix			Hardness (BHN)
	RS (rpm)	TS (mm/min)	NP	
1	575	60	2	64
2	575	40	2	37
3	425	60	2	41
4	425	40	2	56
5	575	50	3	53
6	575	50	1	63
7	425	50	3	45
8	425	50	1	52
9	500	60	3	60
10	500	60	1	50
11	500	40	3	38
12	500	40	1	35
13	500	50	2	57
14	500	50	2	50
15	500	50	2	34

III. DEVELOPMENT OF REGRESSION MODEL

BHN is a function of these parameters. Coefficients are calculated using SYSTAT software and model has been developed using the coefficients Y = f (RS, TS, NP). The developed mathematical equation is BHN = 349.208 – 0.662 * RS – 6.387 * TS + 0.014 (TS * PS).

IV. RESULTS AND DISCUSSION

It is found that the average hardness of friction stir processed surface composite was 1.5 higher than that of the base metal Aluminum 7075 – T651. Figure 3 shows the microstructure of base metal and figure 4 shows the processed surface composite.

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The increase in hardness was attributed to fine dispersion of B_4C particles and fine grain size of the Aluminum matrix. Microstructure of the surface composite has higher hardness because of fine dispersion of B_4C particles and fine grain size of the Aluminum matrix. The effect of traverse speed and the rotational speed on BHN was calculated and presented in figures 5 and 6. By using the mathematical equation graph has been plotted between Traverse speed Vs Brinell hardness and Rotational speed Vs Brinell hardness. From figure 5 it has been observed that when the traverse speed increases hardness increases due to the reduction in heat input. From the Figure 6 it has been observed that when the rotational speed increases, the hardness increases due to fine dispersion of B_4C particles. It has been observed that the maximum harness value of 64 BHN occurs when the processing speed 575 rpm and traverse speed 60 mm/min respectively.

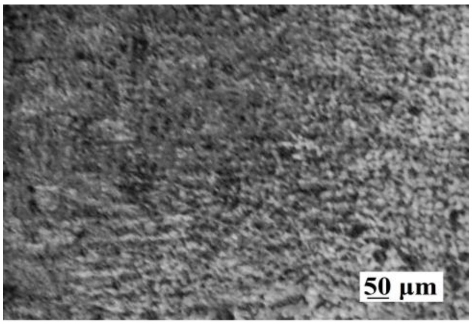

Fig 3 Microstructure of Base Metal Aluminium 7075 – T651

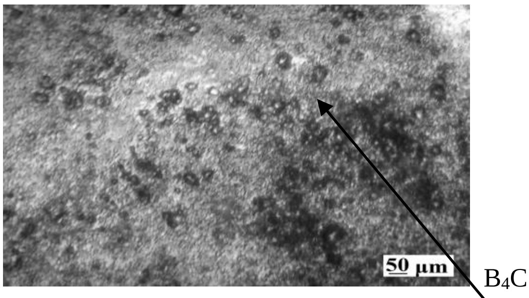

Fig 4 Aluminium 7075 – T651 / B_4C surface composite (RS – 500 rpm, TS – 50 mm/minute) (Nugget Zone)

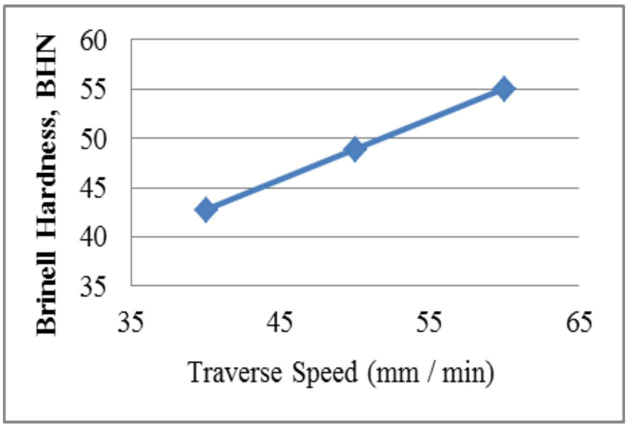

Fig 5 Traverse Speed Vs Brinell hardness, BHN (B-Scale)

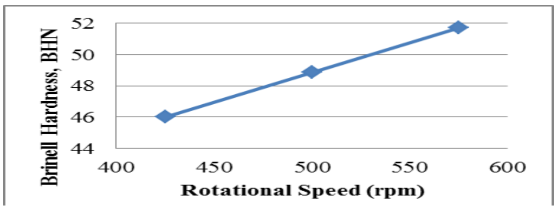

Fig 6 Rotational Speed Vs Brinell hardness, BHN (B-Scale)

V. CONCLUSION

Thus the surface composite has been fabricated using FSP and hardness of the processed top surfaces has been carried out. Surface composite has higher hardness than that of the base metal. The results show that the rotational speed of 575 rpm and the traverse speed of 60 mm/min can be employed to produce a good surface composite. Microstructural observations have been carried out. Processed surface at nugget zone has higher hardness due to the fine dispersion of B_4C particles.

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