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# Synthesis and Characterisation of Boron Carbide Reinforced 7075 Aluminium Alloy using Friction Stir Processing

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**Abstract—***Steel is globally accepted as primarily used material for the construction of military and non military vehicles because of its high energy absorbing properties, high strength, greater notch toughness and high hardness. Earlier investigations revealed that 5083 aluminium alloy can successfully used as armour material and compatible to standards imposed by US Army Research Laboratory (ARL) with an intention to reduce weight, ease mobility and enhance fuel economy. It leads to need of heavy rolling mills to process AA 5083 aluminium alloy which can derive its strength from strain hardening. This paves a way to develop supplement materials. Among aluminium alloys 2xxx, 6xxx and 7xxx series of aluminum alloys are heat treatable while as 7xxx series aluminium alloys can compete with steels. Therefore, determining the material with the lowest possible areal density that resists the predefined threat successfully is required in armor design studies. In this present investigation AA 7075 aluminium alloy was selected as substrate for fabricating surface composite. Layering of monolithic material with ceramic material results in improvement of ballistic performance. Most of investigations werebased on enhancing wear characteristics by fabricating composites using stir casting and powder metallurgy on various aluminium alloys as substrate. The present investigation has its significance as synthesis of surface composite was done using friction stir processing by incorporating boron carbide particles. It also emphasizes the details pertaining to synthesis of surface composite. Surface metal matrix composite has exhibited considerable improvement in hardness compared to substrate while as marginal improvement in hardness was observed in friction stir processed AA 7075 aluminium alloy.*

**Keywords:** *Friction stir processing, boron carbide, surface composite, AA 7075 aluminium alloy /substrate, synthesis.*

## 1. INTRODUCTION

There is an evasion of higher density materials in the field of automobile, transport and air craft industries in order to achieve both easiness in mobility and fuel economy. Among lighter alloys, aluminium, titanium and magnesium alloys are considered as the frontier materials to substitute ferrous materials. Magnesium of self explosive nature and titanium is of high incurring cost paving the way to focus number of investigations based on aluminium and its alloys as the potential material for aforesaid [1-4]. High energy absorbing, high strength, greater notch toughness and high hardness which are the essential requisite properties for ballistic applications makes steels to accept as primary material in defense [5-10]. Even though aluminium and its alloys possesses all the necessary mechanical properties to become potential armour material, its lower melting point , less sensitivity to strain rate and poor tribological property forbids it's usage[11-12]. Earlier investigation revealed that surface layering of monolithic materials with harder material and subsequent existence of tougher material to dissipate the kinetic energy of projectile is an effective measure towards enhancing ballistic performance [13-14]. Several methods like plasma spray, chemical vapour deposition (CVD),physical vapor deposition (PVD),electron beam welding(EBM) , plasma transferred arc welding (PTAW), laser surfacing are usually used to produce surface composite [15-16] by changing the surface morphology of substrate. These surface modification techniques are based on fusion technique and not free from limitations like poor interfacial bond integrity, casting defects such as pores, shrinkages voids.Recently developed friction stir processing (FSP) which is based on solid state [17-18] resulted in causing free form all cited defects was chosen for fabricating targets. Hence the present investigation deals with synthesis of surface composite using AA 7075 aluminium alloy as substrate by incorporating boron carbide.In addition to it, an attempt was made to establish processing parameters of FSP, evaluation of mechanical properties on the evidence of micrographs.

## 2. EXPERIMENTAL DETAILS

The base material used in this study is wrought AA7075-T651aluminium alloy having chemical composition of magnesium 2.5%, zinc 5.8 %, copper 1.4% and aluminium (rest) based on weight percentage. Commercial available $B_4C$ was received in the form of powder having average size of 30µm to form surface metal matrix composite (SMMC) using friction stir welding machine. AA7075 was subjected to friction stir processing to understand the influence of friction stir processing on mechanical property. While as two different tools i.e. flat tool (shoulder Ø 20 mm) and threaded tool (pin length 3 mm, pin Ø 6mm, shoulder Ø 20 mm) made of H-13 were used during synthesis of SMMC to fabricate SMMC.Initially flat tool was used for the purpose of compacting powder inside the previously drilled holes on the surface of clamped workpiece. Successive run was done using threaded tool to undergo plastic deformation and resulting in fabricating SMMC.Trial runs were made by varying rotational speeds and feed to obtain defect free surface composites on the substrate using friction stir processing. Vicker micro hardness test was done to evaluate surface hardness under 0.3 kgf of load. Metallurgical specimens were prepared from the sections of substrate, friction stir processed AA 7075, SMMC by following standard metallographic practices. Polished surfaces were etched with Kellar reagent (95% $H_2O$, 2.5% $HNO_3$, 1.5% HCl and 1% HF).

## 3. RESULTS AND DISCUSSION

### 3.1 Comprehensive details on fabrication of surface composite using friction stir processing:

During FSP, tool movement from right to left about horizontal axis was maintained during surfacing to obtain defect free surface composite.Higher rotational speed (greater than 1200 rpm) of tool resulted in intense plastic deformation causing surface cracks and voids in the transverse section of processed surface composite as shown in Fig 1.Similarly, rotational speed less than 750 rpm during friction stir processing has led to improper mixing of $B_4C$ particles and yield similar type of results. Higher transitional feed rate as wells as larger plunging speed during fabrication of surface composite using friction stir processing resulted in tool breakage.It was observed that the threaded portion of tool used for mixing hard boron carbide particles during second stage of friction stir processing undergone tool wear.

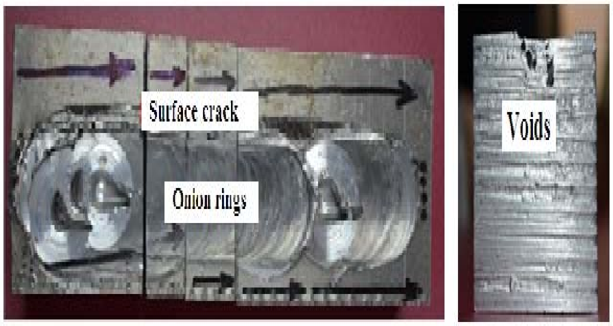


**Fig. 1: Depicts the surface crack along the tool travel and presence of voids along the transverse section.**

Tool wear may be attributed due to presence of harder boron carbide particles which is responsible for wearing out the threaded portion of pin. The breakage portion of tool embedded inside the surface of base was shown in Figure 2.

**Fig. 2: Represents the breakage portion of tool embedded inside the surface of base.**

After number of trials for fabrication of surface composite, friction stir processing parameters such as tool rotational speed in the range of 925- 1000rpm yielded suitable plastic flow of material to form surface metal matrix composite. Hence, different tool feed rates of 20, 50 and 70 mm/ min was trialed to optimize longitudinal feed of processing with tool rotation speed of 960 rpm. Higher tool feed rates causes micro and macro defects in the structure or on the surface. Increased tool feed led to deficiency in filling up and formation of surface cracks and voids. It is also witnessed that voids or holes generated around the lower part of tool's pin as shown in macrograph Fig.3. These defects are attributed due to lack of penetration of heat during higher tool feed ( above 60mm/ min) and causing the material not to become soft while undergoing plastic deformation and results in improper filling the material. It is also observed that increase in feed rate and higher tool rotational speed causes reinforcement particles to escape from the predrilled hole and decreases the rate of reinforcement.

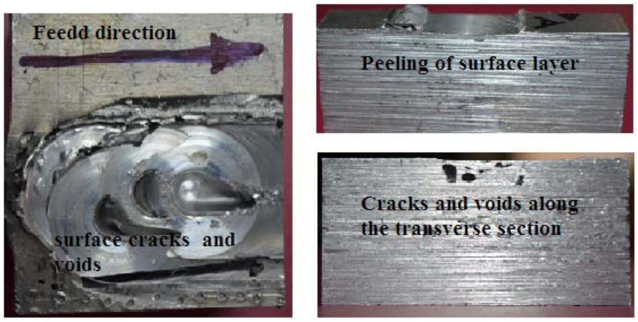


**Fig. 3: Shows the macrograph the friction stir processed failed SMMC during higher feed rates above 60mm/min.**

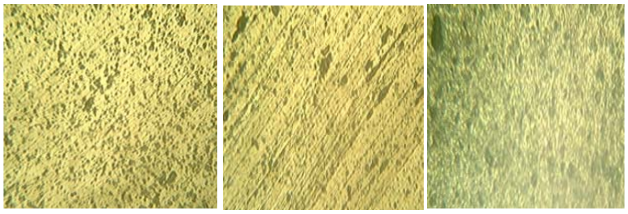
While as lower tool feed rate lead to accumulation of the reinforced particles (boron carbide) on the upper portion of substrate or area closer to the surface and resulting in variation in reinforcement density from one point to other inside the base.

After number of trials for fabrication of surface composite, friction stir processing parameters such as tool rotational speed in the range of 925-1000rpm, a longitudinal feed speed about 50 mm/minute and plunging speed of 30 mm/minute resulted in the formation of surface metal matrix composites without voids along the transverse section and free from surface cracks as shown in Fig.4. It was also found the tracks of rotational tool having specific lay in the form of onion rings as shown in Fig.5.Tool movement from right to left about horizontal axis was maintained during surfacing to obtain defect free surface composite.

**Fig. 4: Defect free SMMC (surface metal matrix composite)fabricated using FSP.**

### 3.2Metallographic Study

Base metal consists of elongated grains along the rolling direction as evident from optical micrograph shown in Fig. 5(a). Presence of dispersoids and elongated grains in AA 7075 aluminium alloy can be witnessed from above figure Fig. 5(a), while as Fig. 5(b) shows the effect of friction stir processing on AA 7075 aluminium alloy.



**5(a)** **5(b)** **5(c)**

**Fig. 5: (a) representing microstructure of base (b) shows friction stir processed AA7075 (c) SMMC.**

It can be witnessed that there is a microstructural refinement caused by thermal effect during FSP in friction stir processed AA 7075 aluminium alloy.

Fig. 5(c) shows the effective incorporation of boron carbide particles in to substrate.Incorporation of carbide particles is caused due to stirring action of pin which rotates with high rotational speed. During rotation, frictional heat is generated due to rubbing between the tool and work piece and helps in the distribution of reinforcement particles to form surface metal matrix composite. In addition to it, heat generated due to plastic deformation during second stage of processing softens the material and leading further mixing of carbide particles.

### 3.3 Microhardness test:

The results of Vicker hardness testing is presented graphically as Fig. 6 for better illustration.

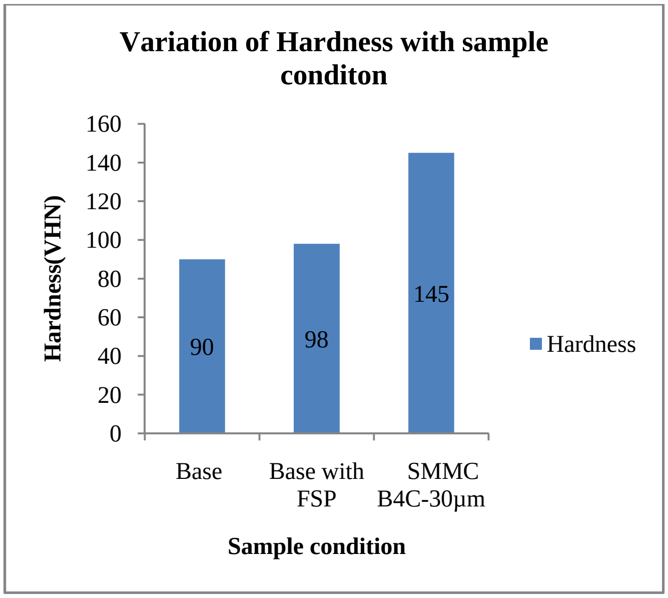


**Fig. 6: Showing hardness of sample under different condition.**

From the Fig. 6, the substrate/ base selected for surface modification is inT-651 condition and the inherent hardness is attributed due to the phenomena of precipitation hardening. Dispersion of dispersoids phases like Mg( $Zn_2AICu$) , $Mg_{32}$( AI $Zn)_{49}$ and $MgZn_2$ in the aluminium matrix is responsible for obtained hardness in substrate. During friction stir processing temperature increases in the stir zone of the substrate and this heat causes in relieving residual stresses and favors growth in the precipitated grains and led to marginal improvement in hardness.

While as in SMMC $B_4C$-30µm, fine distribution of second phase particles (boron carbide) suppress the grain growth and addition of boron carbide particles decrease the grain size as seen from Fig.5. Dynamic recrystallization causes grain refinement in the stirred region is attributed due to and presence of $B_4C$ particles in the composite layer. In addition to these, grain refinement in stirred region can be accounted due to the restricted grain growth as result of grain boundary pinning by the $B_4C$ particles. In addition to above, significant morphological modification like microstructural refinement, homogenization and densification achieved during friction stir processing led to yield higher hardness in SMMC $B_4C$-30µm.During deformation i.e. second stage of processing , regardless of carbide particles, grains break into smaller size and a large number of high angle boundaries are produced. Mechanical rupture of inherent grain boundaries are also attributed due to the stirring action of rotating tool which results in the formation of high angle boundaries. These high angle boundaries will impede the free movement of dislocations and enhances strength and hardness. Hence, these afore mentioned led to impart considerable improvement in hardness compared to base/ AA 7075 aluminium alloy as seen from Fig. 6.

## 4. CONCLUSION

1. With the tool feed rate of 50mm/ min rotational speed 960 rpm and plunging speed of the order of 30 mm/minute resulted in synthesis of defect free metallurgical SMMC.

2. Marginal improvement in hardness was witnessed in friction stir processed base and it was attributed due to elimination of residual stresses.

3. SMMC exhibited significant improvement in hardness compared to base and it is attributed due to Orowan mechanism and fine dispersion of boron carbide particles in the AA7075 matrix.

## 5. ACKNOWLEDGENENTS

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## REFERENCES

[1] Kiyoshi Funatami, Emerging Technology in Surface Modification of Light Metals.Surface and coating Technology. 2000; Vol.133:264-272.

[2] Statistical data of Automotive Materials committee, Japanese Society of Automobile Industry, May 1997.

[3] North American Passenger Car and Light Truck Aluminum Content Report1999, Ducker Research Co., Southfield.

[4] K. Takeuchi, Y. Isobe, T. Toyama, Journal of Japanese Institute of Light metals. 1998 Issue (48) Vol.9: 446-457.

[5] Ade F. Ballistic qualification of armour steel weldments. Weld J1991; 70:53-54.

[6] Madhusudhan Reddy G, Mohandas T. Ballistic performance of high strength low-alloy steel weldments. Journal of Material Processing Technology 1996;57: 23-30.

[7] Madhusudhan Reddy G, Mohandas T, Tagore GRN. Weldability studies of high strength low- alloy steel using austenitic fillers. Journal Mater Processing Technology 1995;49: 213-228.

[8] Borvika Tore, ClausenaArild H, Hopperstada Odd Sture,Langsetha Magnus. Perforation of AA5083-H116 aluminium plates with conical-nose steel projectiles d experimental study. International Journal of Impact Engineering.2004;30:367-84.

[9] Backman EM, Goldsmith W. The mechanics of penetration of projectiles into targets.International Journal of Engineering Science.1978; 161:99-103.

[10] W. A. Gooch, M. S. Burkins and R. J. Squillacioti.Ballistic testing of commercial aluminum alloys and alternate processing techniques to increase the availability of aluminum armor.23rd international symposium on ballistics. Tarragona, Spain 16-20 April 2007.

[11] Backman EM, Goldsmith W. The mechanics of penetration of projectiles into targets.International Journal Engineering Science. 1978 ; Volume 16: 1–9.

[12] Corbett GG, Reid SR, Johnson W. Impact loading of plates and shells by free-flying projectiles: A review. International Journal of Impact Engineering.1996; Volume 18:141–149.

[13] Johnson W. Impact strength of materials. London: Edward Arnold; 1972.

[14] EvrenOzsahin ,SuleymanTolun .On the comparison of the ballistic response of coated aluminum plates. Materials and Design 2010; Volume 31: 3188–3193.

[15] Abboud J H and West D R F. Microstructure of Titanium injected with SiC particles by laser processing. Journal of Materials Science Letters .1991; 10: 1149.

[16] Pei Y T, Ocelik V and Hosson J T. Futuristic Materials, editors B.B.Jha ,R.K.Galgai , Vibhuti N Misra. Allied Publishers, Indian Institute of Minerals Engineers, Bhubaneswar Chapter 2004.

[17] Friction Stir Processing Technology: A Review. Z.Y.Ma. Volume: 39A, March 2008 Metallurgical and Materials Transactions A .642—648.

[18] R.S. Mishra, Z.Y. Ma, I. Charit. Friction stir processing: A novel technique for fabrication of surface composite. Materials Science and Engineering A (2003) 341:307-/310