JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ADDITIVE FRICTION STIR PROCESSING OF AA(7075)

Dr.H.A. Deore[#1] , T.R. Bhavsar[#2] , M.V.Panjwani[#3] , N.N.Shetewad[#4] , U.V.Khairnar[#5]

Department Of Mechanical, SKNCOE, SPPU, Pune

Abstract:

AA 7075 based surface composites reinforced with two different filler materials that is Silicon Carbide (Sic) , Tungsten Carbide (Wc) were successfully manufactured via processing with uniform of distribution of all the filler particles. The comparative effect of different filler materials and subsequent age hardening on the microstructural evolution of friction stir processed Aluminium matrix surface composites were characterized using optical microscopy and SEM. Hardness, Impact resistance, Wear resistance was studies using micro hardness test, Impact test, Wear test. The enhancement in micro hardness (142 $HV_{0.1}$ for received AA 7075 to 251 HV with Sic filler followed by age Hardening), Impact toughness (15.4 KJ to 27.1 KJ) and wear resistance drooped from 8.51 mg to 5.17 mg) were obtained through the addition filler particles during additive friction stir processing followed by age hardening. The enhancement in mechanical and wear properties was mainly to grain refinement. Sic was found to be best among the two filler for the set of FSP, AFSP and Post AFSP with addition of heat treatment. Nearly double increase in micro hardness, and impact toughness was achieved in age hardened SiC filler surface composites.

Keywords: *-Friction stir processing, Post process age hardening, Surface composite, Impact toughness, Severe Plastic Deformation, Scanning Electron Microscope, Optical Microscope.*

1. Introduction:

Light metal alloys/composites having high strength are very much in demand for aerospace, defence and automotive applications [1]. Grain refinement, compared to other material strengthening techniques can deliver combination of ultrahigh strength as well as ductility which is required for ambient and cryogenic temperature applications [2]. Lately, various severe plastic deformation (SPD) techniques have been established as useful tools to fabricate ultrafine grained (UFG) materials. Broad research is being started to further improve SPD techniques, which can produce UFG metals and alloys commercially. Friction stir processing is basically a local thermo-mechanical metal working method, wherein, a rotating tool having a pin and shoulder is plunged and into work piece that changes the local microstructure. It leads to adjustment of local properties without affecting bulk material properties. Microstructure can be tailored in a single pass or several passes during FSP [3]. Amount of overlap during Multi-pass FSP is very important process parameter which decides contact of tool for given number of times in a specified portion of specimen and by this means obtain the preferred dimension, homogeneous distribution of filler material in the tailored surface. In addition, surface composite on metal substrate has been fabricated using FSP. In this investigation, Tungsten Carbide (WC) and Silicon Carbide (SiC) were selected as a filler material, deliberates since during FSP, formation of Al2W compound takes place by the reaction Al and W, which helps to enhance mechanical and wear properties. among the various Al-Salt systems, SiC was obvious choice outstanding to its high elastic modulus, wear resistance, good high temperature mechanical properties, exceptional oxidation resistance along with low cost [4]. SiC particles also play significant role in grain boundary pinning and usually neither react with the Al matrix and nor produce disadvantageous phases. Present work involves the comparative study of above mentioned two different types of filler material and post process age hardening on Microstructure, Mechanical properties and Wear resistance of FSPed Al7075 surface composites [5]. OM and SEM were used to observe microstructure evolution. Micro hardness and impact toughness measurement analysis was done to evaluate modification in mechanical properties and wear test was carried out to understand wear behaviour.

2. Experimental Description

AA7075-T6 condition sheet with elemental composition was used in this study, whose composition was determined by ICP OES. Samples of dimension 200 mm × 150 mm × 6 mm were cut using low speed cutting diamond saw. Super-saturated solid solution was achieved in these sheets by solutionizing heat treatment at 480 °C for 2 h in argon atmosphere using tubular furnace with subsequent rapid quenching up to room temperature. An array of 360 cylindrical holes having diameter of 2 mm and depth of 3 mm was drilled on the surface area measuring of 180 mm × 52.5 mm as reservoir for the filler materials. Degreasing and drying of plates was carried out before usage. SiC and Cparticles with size of diameter 15- 25 μm and 10–20 μm respectively and (WC) with average diameter and length of 15–20 nm and 5 μm respectively were used as filler material. SiC filler particles and WC were filled manually in the cavities and a 1.8 mm flat head punch was used for compaction. Calculated volume percentage of filler material was 5.31 with respect to total matrix of AA 7075. A fixture was employed to fix the specimens tightly to eliminate misalignment. FSP was performed on specially designed CNC FSW machine having capacity of producing maximum download force of 10 kN and 3000 rpm. Non consumable, conical probe, rotating tool made of W-1% La2O (Tungsten-Lanthanum Oxide) alloy having 3 mm pin length and 20 mm shoulder diameter was employed to carry out experimentation. In order to achieve defect free processing, at the onset, tool was plunged slowly into the specimen at higher rpm (1200 rpm) until the shoulder surface penetrates 0.3 mm into the work piece surface and 15 s dwell time was maintained to facilitate required preheating. Tool rotation speed of 800 rpm with traverse speed of 60 mm/min was used throughout processing with tool tilt angle of 3°. FSP was performed using 60% overlap (overlapping ratio of 0.6) between two consecutive passes to assist uniform distribution of filler material. Post FSP, artificial age hardening was performed at 120 °C for 24 h with subsequent air cooling up to room temperature. Samples for metallography were taken out from the FSPed zone using abrasive cut off machine. The specimens were rough and fine polished to obtain mirror finish. Rinsing and cleaning of mirror polished specimens was carried out using water and acetone respectively. Keller reagent (2 ml HF + 3mlHCl + 5 ml HNO3 + 190 ml H2O) was used for etching specimens. This sample preparation was carried to facilitate the inspection of microstructural features such as filler distribution in Al matrix, grain size and grain morphology using OM and SEM. To examine degree of hardening, micro hardness readings (minimum eight readings per specimen) were taken by applying load of 100 g for 10 s. Impact toughness of the selected specimens was evaluated at room temperature by determining energy absorbed by the material up to fracture using Charpy impact test (ASTM E23). The samples with the dimensions of 55 mm × 10 mm × 5 mm having 45° Vnotch (2 mm depth and 0.25 mm radius) was machined from the FSPed plate using Vertical Machining Centre (VMC).

3.Result and discussion

3.1 Optical and SEM microstructure

Fundamentally, the microstructure of FSP shows three distinct regions such as stir zone (SZ), thermo-mechanically affected zone (TMAZ), and heat affected zone (HAZ). Fig. (1) shows the macrostructure of the FSPed specimen revealing size of the SZ and TMAZ [6]. In present investigation, microstructural study was focused on the stir zone (SZ). Fig (1). shows optical microstructures of the base material encompassed of elongated grains, having mean diameter of 50–80 μm. Few large irregular-shaped particles of size 5–10 μm, consisting primarily of AlW compounds including other alloying elements, can be observed [7]. These particles are frequently referred as "constituent" particles and are very resistant to closure. In contrast, the microstructure of FSPed stir zone, without including any filler, (Fig. 1(c)) portrayed dynamically recrystallized fine, equiaxed grains attributable to collective effect of frictional heating and intense plastic deformation.) shows grain structure of SZ and TMAZ in the FSPed specimen. Difference in grain structure is clearly visible between these regions [8]. As overlapping ratio of 0.6 was used during FSP, in this investigation, HAZ is almost missing. The rotating and traversing motion of tool, during FSP, stirs and mixes the base material as well as filler particles together. By increasing overlap ratio and no. of passes filler particles disperse more uniformly. Wc particles have more formability compared to SiC particles, which led to formation of partial rings in the microstructure of Wc filler surface composites. In the regions having lower stress concentration, Wc particles could be deformed along the shear stress direction and in the regions having higher stress concentration, Wc particles could be fragmented into smaller particles forming partial onion ring [9]. Incomplete rings were observed in the microstructure of SiC filler surface composites. Owing to low formability of SiC particles, they could not be deformed and large sized SiC filler particles did not separate in onion rings.

Wc filler particle distribution and microstructural modification in the SZ of FSPed specimens with Wc filler addition are revealed in Fig. 1(c) and (d). Defect free specimen without agglomeration of Wc filler particles can be seen. Initially the Wc particles are fragmented and then agglomerated in few areas of SZ. Fig. 1(e) and (f) show the SEM micrographs of the SZ in the FSP-treated Al-SiC composite specimen. Homogenous SiC particles dispersion in the Al matrix without any particle cluster formation is clearly evident [10]. Besides, few fragments of some broken down SiC filler particles are indicated in Fig. 1(e), which may the result of the extreme stirring action of the pin during FSP leading to generation of severe plastic strain [11]. Presence of 300–400 nm SiC particle, confirms that intense plastic strain generated during FSP lead to breaking of SiC particles into several rubbles and as a result of material flow, which is a feature of FSP, these particles spread homogeneously into the Al matrix.

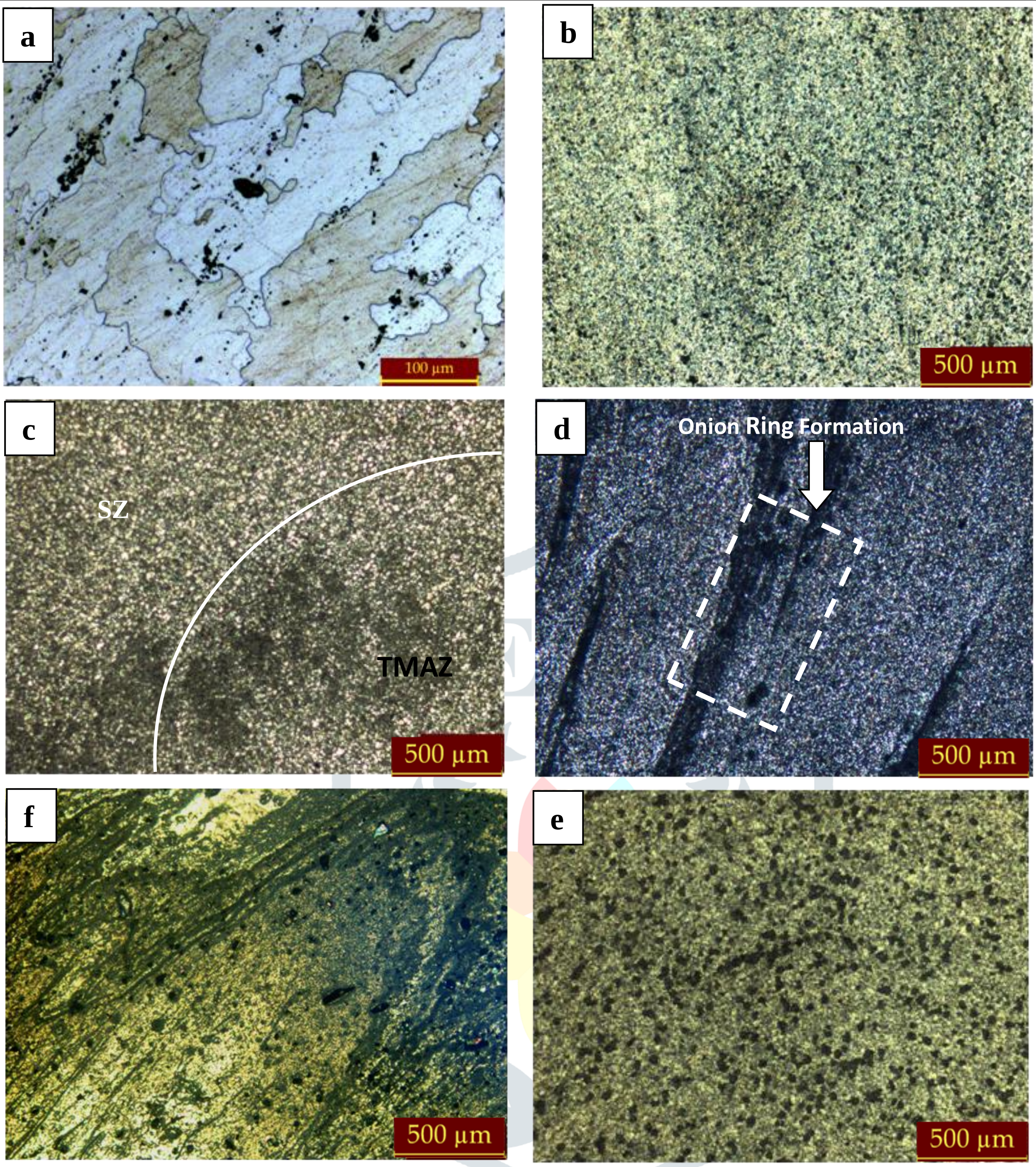

Fig.1 : Optical Microstructures showing (a) Base Metal AA7075 T6, (b) Stir Zone of FSPed AA7075 without filler, (c) Transition between FSPed stir zone and Thermomechanically affected zone, (d) Stir Zone of FSPed AA7075 with SiC filler showing onion rings (e) Stir Zone of FSPed AA7075 with SiC filler, (e) Stir Zone of FSPed AA7075 with WC filler [12]

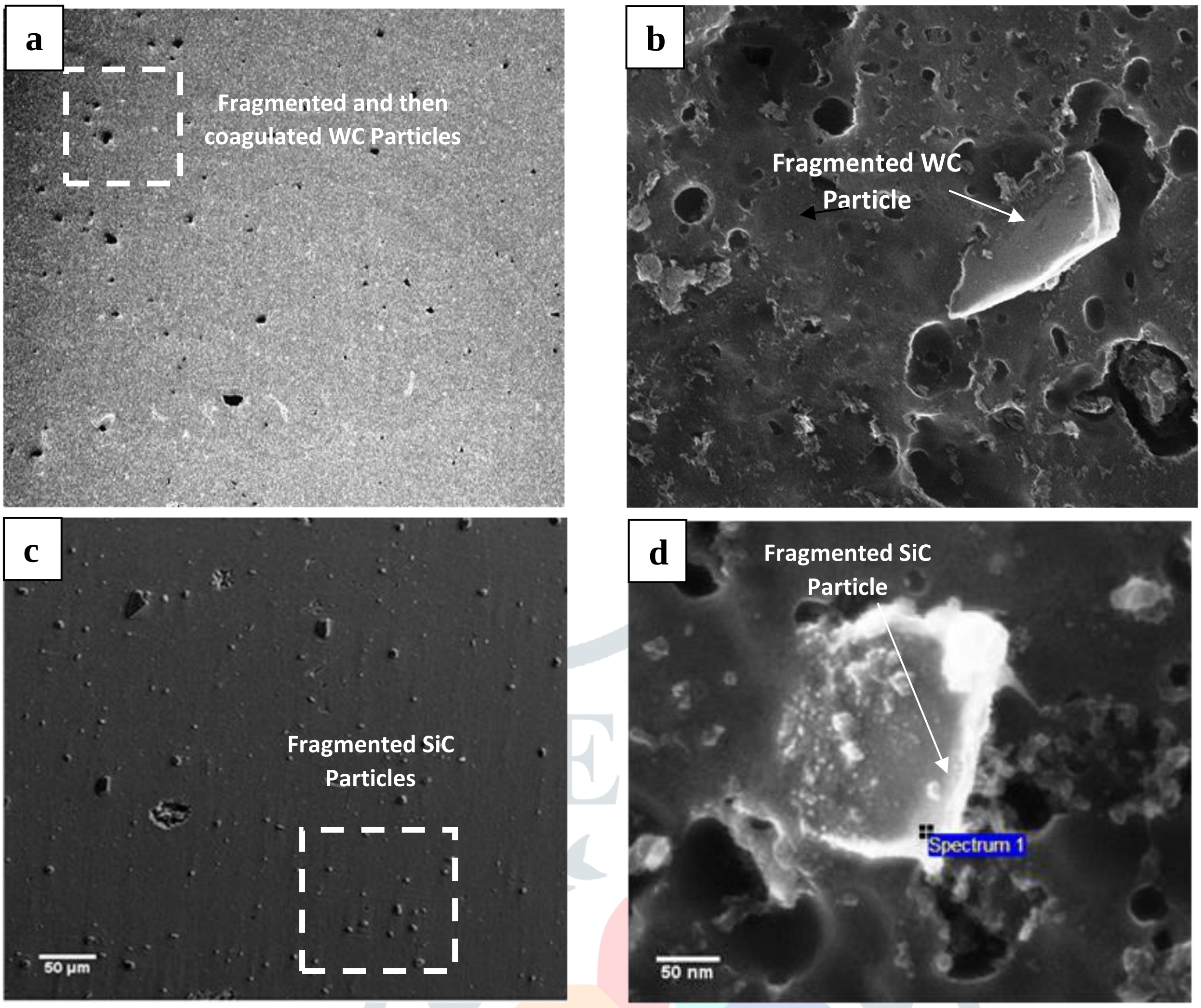

Fig.2 : SEM Micrographs showing (a) uniform WC distribution in the Al matrix, (b) Magnified view of WC particle in Al matrix showing interfacial bonding, (c) uniform SiC particle distribution in the Al matrix (d) Magnified view of fragmented SiC particle [12]

3.2 Mechanical Properties

Contact between aluminium matrix and filler particles along with size and distribution of precipitates formed during subsequent age hardening are some of the features that play a vital role in influencing the mechanical properties of composite layer formed using FSP.

3.2.1 Hardness:

The average hardness results of base metal AA7075 and surface composites formed via FSP using different fillers. Solutionizing treatment leads to significant decrease in hardness, whereas, noteworthy improvement in hardness which due to grain refinement. In consequence of stirring action during FSP, mechanical separation of native grain boundaries take place leading to formation of HABs, which sequentially delay dislocation motion and improve hardness and strength of surface composites. SiC particles addition leads to more local deformation and grain fragmentation compared to (WC) particles. Grain boundary pinning by SiC particles and allied dispersion hardening may be the reason for higher hardness of composite layer formed by FSP with SiC filler compared with (WC) fillers. Surface composite with SiC filler was found to have highest average hardness, and WC have less hardness as compared to the Sic. Nearly two times improvement in the average surface hardness of base metal was observed after FSP using SiC filler and subsequent age hardening by combined effect of grain refinement (FSP), dispersion hardening (incorporation of filler particles) and precipitation hardening (subsequent age hardening).

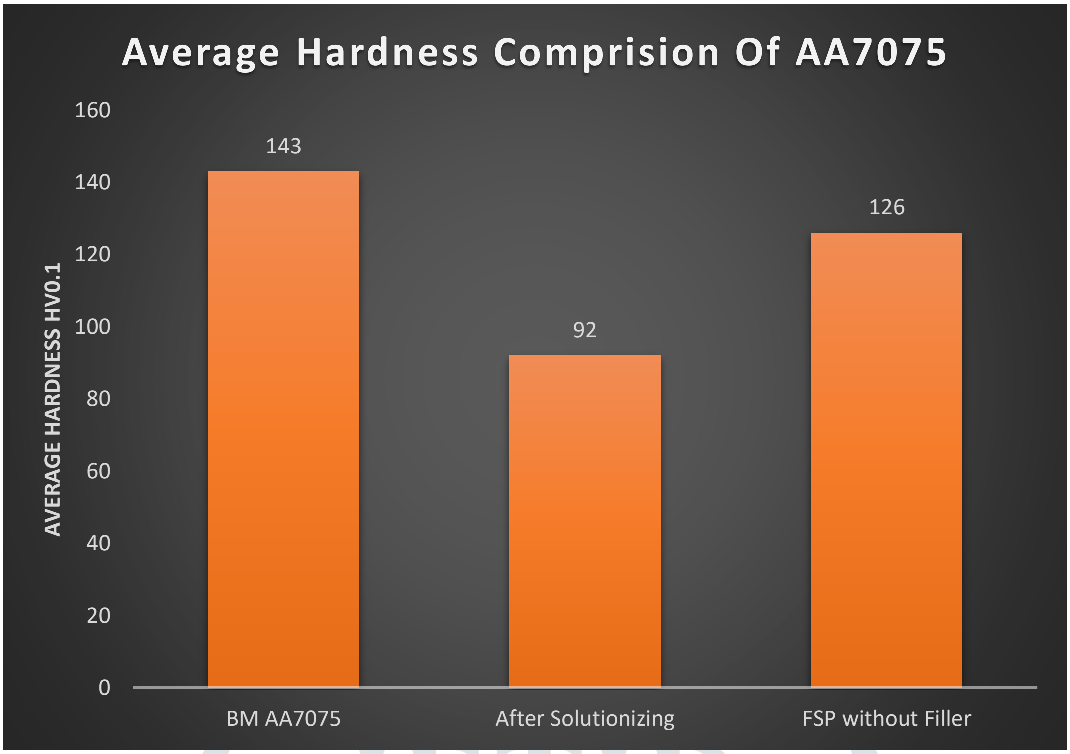

Fig 3. Average hardness comparison of BM7075, after solutionizing and FSPed without filler

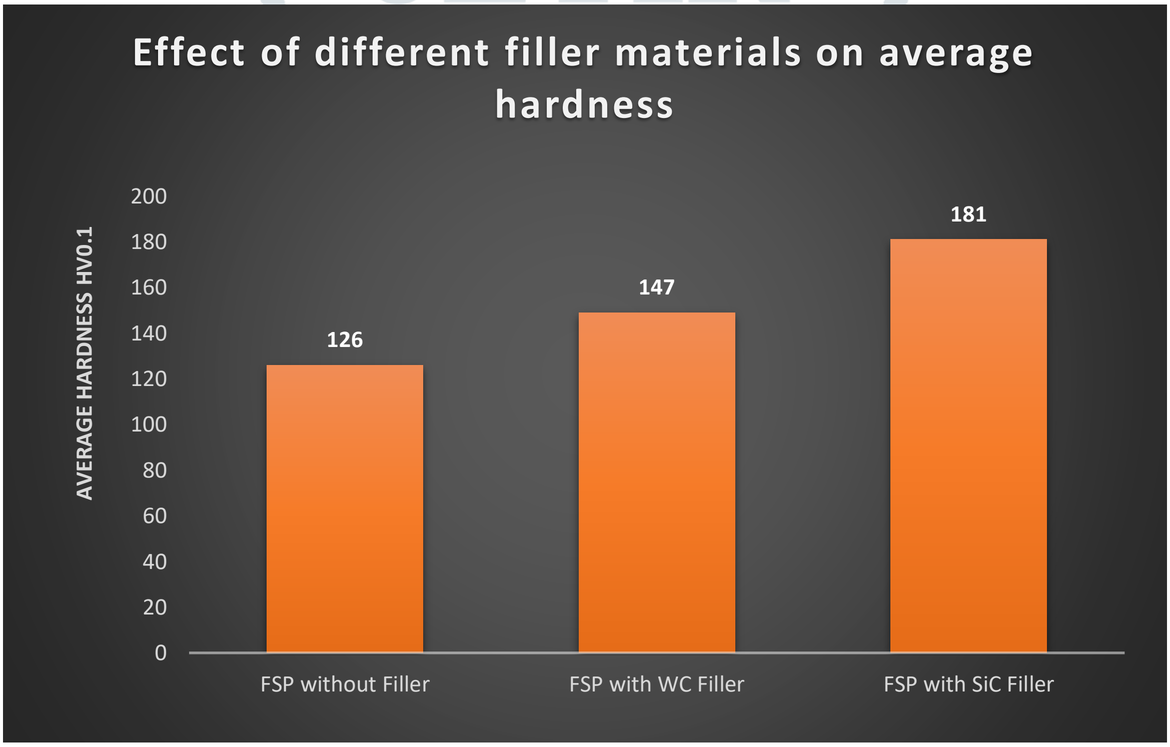

Fig 4. Effect of different filler materials on average hardness

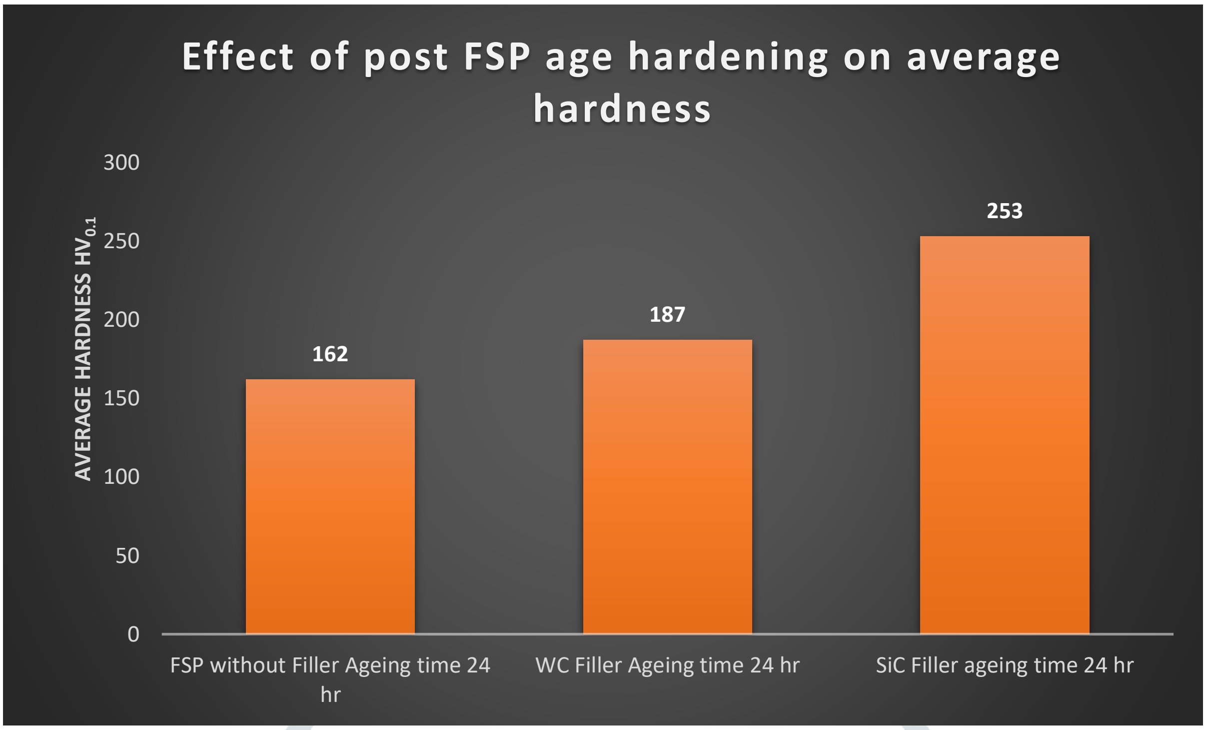

Fig 5 Effect of post FSP age hardening on average hardness

3.2.2 Impact Toughness:

Structural applications demand the materials having high capability of absorbing rapidly applied forces. Performance failures occur in structural components due to internal damage caused by impact loading. A component designer should always see impact toughness as one of the most vital properties so impact toughness of surface composites processed with various condition was evaluated. It clearly signifies that impact toughness decreases because of solutionizing on account of dissolution of strengthening precipitates and it increases due to grain refinement caused by FSP. Effect of various filler material on absorbed impact energy. it is clearly proof that SiC filler surface composite absorbed highest energy. It may be attributed to its capability to restrict crack propagation. Increase in impact toughness could be due to the combined resistance of precipitates and dispersed particles to crack propagation. It is similar to hardness nearly two times increase in impact toughness was observed in SiC filler surface composites compared to the parent metal AA7075.

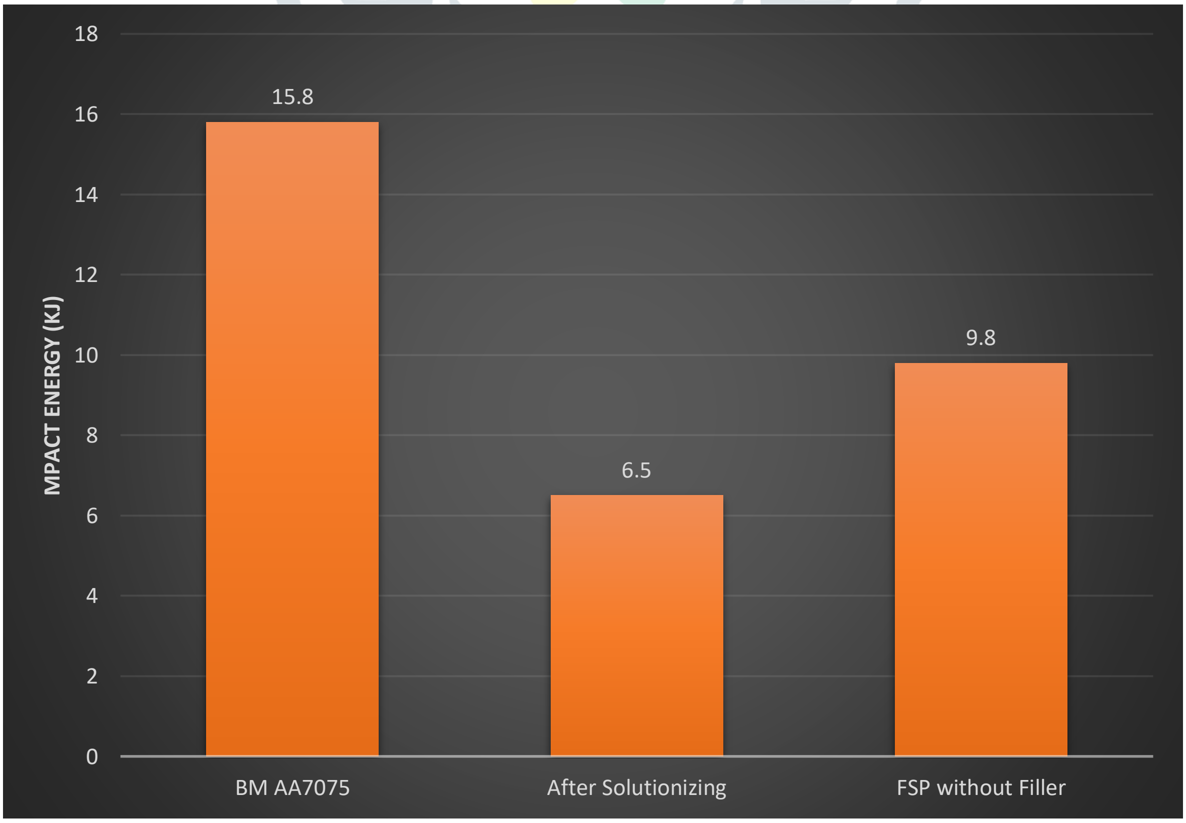

Fig 6. Impact toughness comparison of BM AA7075T6, after solutionizing and FSPed without filler

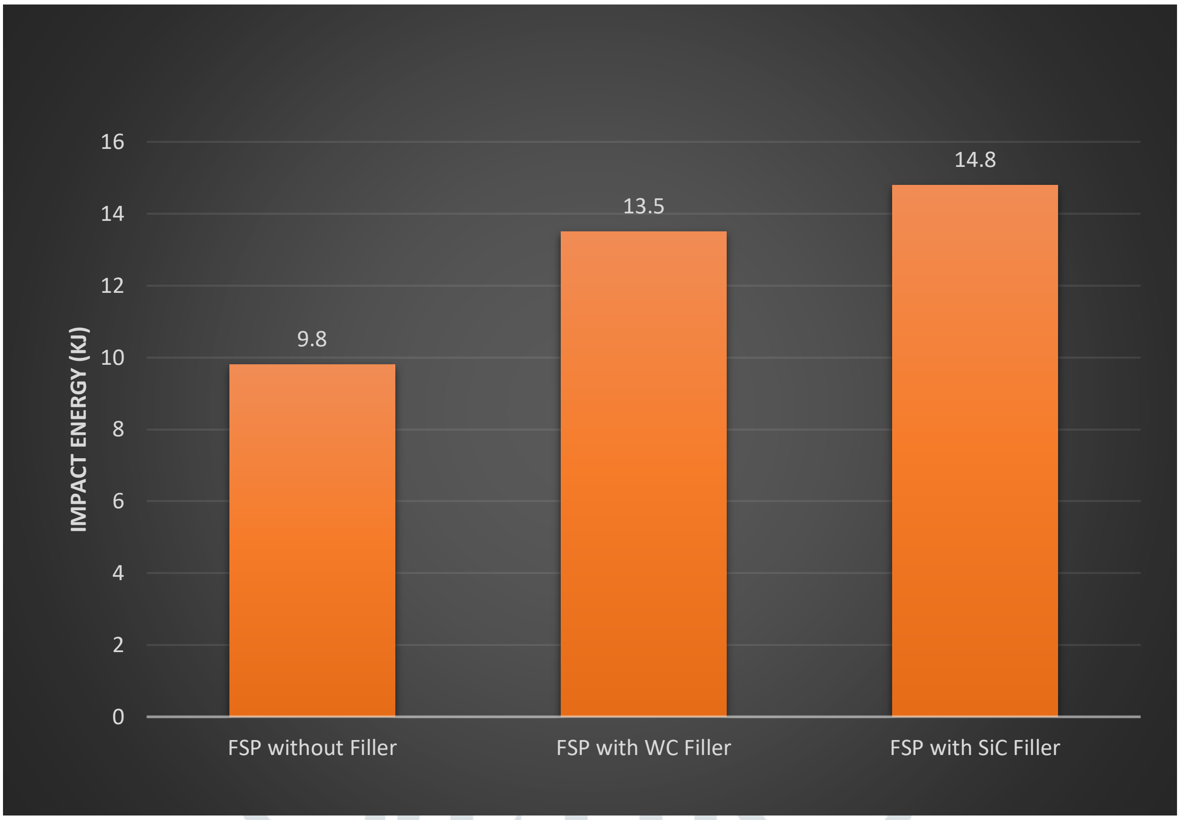

Fig 7. Effect of different filler materials on impact toughness

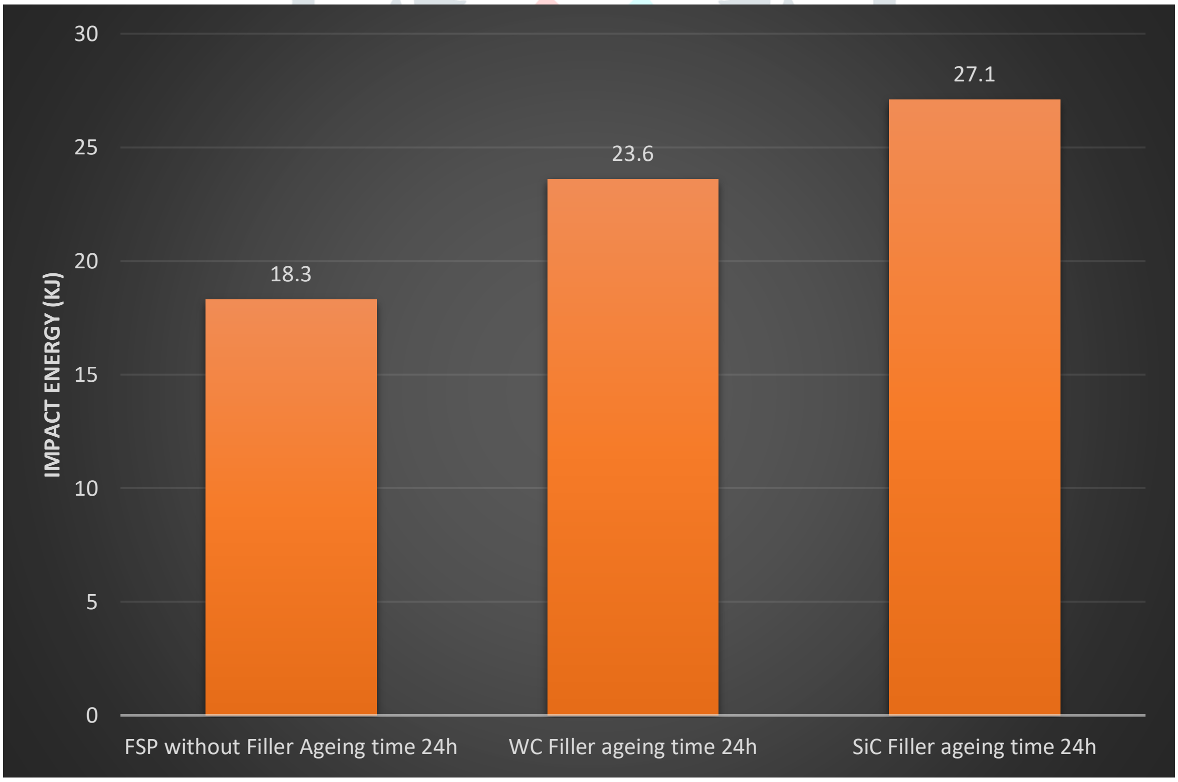

Fig 8. effect of post FSP age hardening on impact toughness

3.2.3 wear resistance:

Highest weight loss was observed in solutionized samples, because of absence of hard intermetallic precipitates. It is evident that, FSP without filler have improved wear resistance compared to solutionized condition owing to grain refinement. Integration of filler particles lead to improvement in wear resistance. SiC had the strongest influence on improving wear resistance, while WC filler has lower influence. shows the outcome of post FSP age hardening on wear resistance of the surface composites prepared by FSP. After age hardening wear resistance of surface composites further increased, because of formation of hard and wear resistant intermetallic compounds (precipitates) which are uniformly distributed in the matrix. It was after revealed that the parent metal (AA7075) experienced higher wear loss whereas the FSPed and consequently age hardened surface shows lower the wear loss. The

WC has the highest wear resistance as compared to SiC.. Furthermore, it was found that, by increasing the sliding distance the weight loss also increases and accordingly, calculated wear rate was increased by sliding distance. Addition of filler particles during FSP and subsequent ageing treatment has major impact on altering the wear mechanism. Only abrasive wear mechanism can be observed on the worn out surfaces of FSPed with SiC filler.

Major improvement in mechanical (hardness and impact toughness) and wear properties was observed in all the two surface composites FSPed with WC and SiC fillers and post FSP age hardened condition. This can be attributed to grain refinement achieved during FSP. Hardness of the processed is decided by the grain size, and how much the filler is present and their uniformly distribution in the Aluminium matrix and size also matters and distribution of strengthening precipitates. Few particle rich and deficient bands observed in WC filler surface composites reveals that at certain locations non uniform distribution and collection of WC particles has occurred, whereas uniform distribution of SiC particles was observed throughout Al matrix showing incomplete onion ring .

filler particles and hardness of composite material are significant parameters for wear behaviour of composites. On account of their better dispersion, good interfacial bonding with Al matrix and high individual hardness SiC particles, WC surface composites showed better wear resistance as compared to that of SiC surface composites for the set of experimental parameters used in this study.

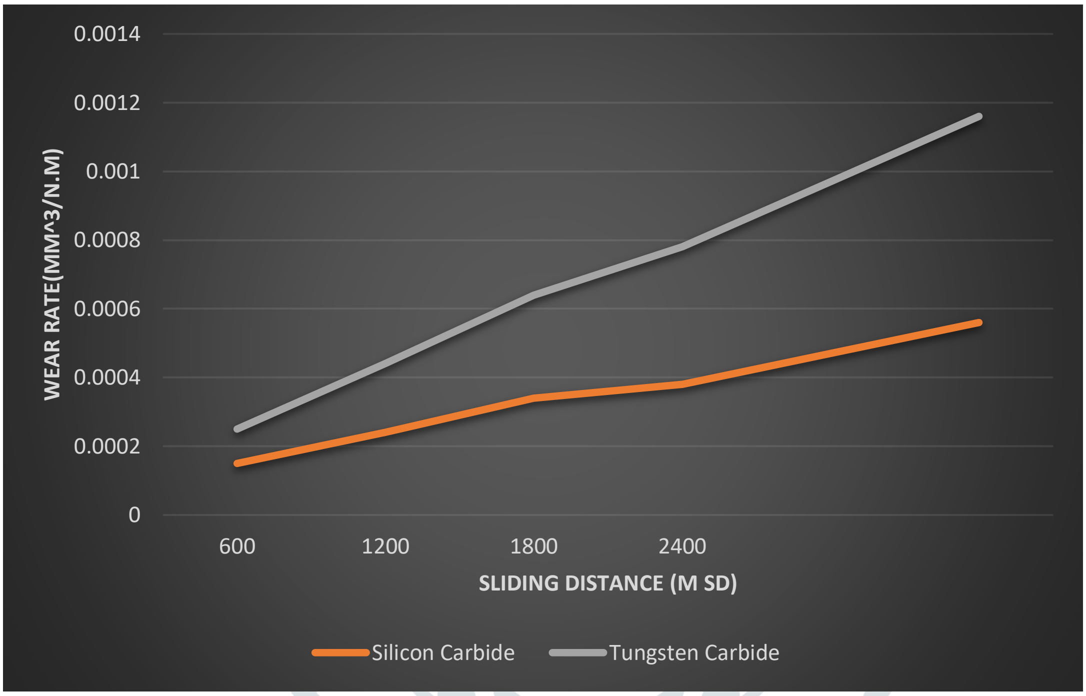

Fig 9 Calculated wear rate for two different fillers Vs sliding Rate

Conclusion:

AA 7075 based surface composites reinforced with WC (tungsten Carbide) and SiC fillers have been successfully manufactured via FSP. The relative effect of different filler materials and subsequent age hardening on the microstructural modification, mechanical property variation and wear behaviour of aluminium matrix surface composites fabricated via FSP were identified and are summarized below.

1. Severe grain refinement was found in FSPed surface composites fabricated with or without absorption of filler material. The existence of filler particles brought about more noticeable grain refinement owing to their grain boundary pinning action, which have inhibited the grain growth during dynamic recrystallization process. Minimum grain size was observed in SiC surface composite.

2. The micro hardness, impact toughness and wear resistance were increased significantly by the addition of filler materials that is SiC (Silicon Carbide). These properties were further increased by post process age hardening.

3. SiC filler was found to be the best among the two fillers other is (WC) for set of FSP and age hardening parameters used in this investigation. Nearly twofold increase in micro hardness, impact toughness and wear resistance was achieved in age hardened SiC filler surface composite.

References:

[1] E.A. Starke, J.T. Staley, Application of modern aluminum alloys to aircraft, Prog. Aerosp. Sci. 32 (2–3) (1996) 131–172.

[2] A. Rosochowski, Processing metals by severe plastic deformation, Solid State Phenom. 101-102 (2005) 13–22.

[3] Yu. Ivanisenko, R. Kulagin, V. Fedorov, A. Mazilkin, T. Scherer, B. Baretzky, H. Hahn, High pressure torsion extrusion as a new severe plastic deformation process, Mater. Sci. Eng. A 664 (2016) 247–256.

[4] H. Zendehdel, A. Hassani, Influence of twist extrusion process on microstructure and mechanical properties of 6063 aluminum alloy, Mater. Des. 37 (2012) 13–18.

[5] R.Z. Valiev, T.G. Langdon, Principles of equal-channel angular pressing as a processing tool for grain refinement, Prog. Mater. Sci. 51 (7) (2006) 881–981.

[6] M.R. Toroghinejad, F. Ashrafizadeh, R. Jamaati, On the use of accumulative roll bonding process to develop nanostructured aluminum alloy 5083, Mater. Sci. Eng. A 561 (2013) 145–151.

[7] R.S. Mishra, Z.Y. Ma, Friction stir welding and processing, Mater. Sci. Eng. R 50 (2005) 1–78.

[8] K. Elangovan, V. Balasubramanian, Influence of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminium alloy, J. Mater. Process. Technol. 200 (2008) 163–175.

[9] Y. Chen, H. Ding, J. Li, Z. Cai, J. Zhao, W. Yang, Influence of multi-pass friction stir processing on the microstructure and mechanical properties of Al-5083 alloy, Mater. Sci. Eng. A 650 (2016) 281–289

[10] A. Kurt, I. Uygur, E. Cete, Surface modification of aluminium by friction stir processing, J. Mater. Process. Technol. 211 (2011) 313–317.

[11] G. Hussain, R. Hashemi, H. Hashemi, Khalid A. Al-Ghamdi, An experimental study on multi-pass friction stir processing of Al/TiN composite: some microstructural, mechanical, and wear characteristics, Int. J. Adv. Manuf. Technol. 84 (1–4) (2016) 533–546.

[12] Dr.H.A.Deore, J.Mishra, A.G.Rao, H.Mehtani, V.D.Hiwarkar, Effect of filler material and post process ageing treatment on microstructure, mechanical properties and wear behaviour of friction stir processed AA 7075 surface composites