INVESTIGATION OF WEAR PROPERTIES OF FRICTION STIR PROCESSED AL 7075 ALLOY REINFORCED COMPOSITE

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Abstract

Finding a material with particular properties is a standout amongst the most imperative issues in numerous mechanical applications, particularly in the aviation and transportation ventures. So there is a need of outlining material with the coveted properties. High strength combined with high ductility is conceivable with materials having fine and homogenous grain structures. New preparing strategies like Friction Stir Processing (FSP) are being produced for this reason notwithstanding the upgrades in traditional handling. By utilizing FSP with proper reinforces can improve material properties. Although FSP can improves the mechanical properties but vulnerability of corrosion needs to be investigated because if material is enhanced mechanical properties where corrosion resistance is declined will results in affect more on the mechanical properties especially for the materials having applications in corrosive environments such as aviation, marines and auto motives like aluminums. The study of mechanical and tribological properties of FSPed material with and without B4C as reinforcement particles and also effect of corrosion on those properties in order to get improved mechanical and wear properties in corrosive environments.

Introduction

Aluminum, the second rich metallic substance on earth, turned into monetary rival in engineering applications. Aluminum has many alloys having main alloying elements are magnesium, tin, zinc, silicon, copper and manganese. The properties of aluminum that make this metal and its alloys the most economical and attractive for a wide variety of uses are appearance, light weight, fabric ability, physical properties, mechanical properties, and corrosion resistance. Aluminum sheet, plate, and extrusions are used in body components and bumpers and forged wheels [1] and also used in kitchen utensils etc. And when it kept in corrosive environment a white coating of oxide will form around surface which resist further corrosion, but when pH range go below or above 4 and 9 make Al corrode further and unlike iron Al won't get rust. The first aluminum 7075 was produced in 1943. Al 7075 in which zinc is the predominant foreign element in aluminum. AA7075 is the high strength aluminum compound of the 7xxx family in light of Al-Zn-Mg framework, in which Mg consolidates with Zn, and structures the strengthening precipitates, for example, MgZn2 and Mg3Zn and add to the change in mechanical properties [2]. Some of the mechanical and electrical properties of Al 7075 is mentioned in table 1. Al 7075 has good strength, appreciable fatigue strength and normal machinability. But it has lower corrosion resistance than most of aluminum alloys, it is created in different tempers, 7075-0, 7075-T651 and 7075-T6. As indicated by above table 3 aluminum 7075 T6 has tensile strength around 570 MPa which is better than other aluminum alloys and density of 2800 kg/m3 still it has good strength.

Table 1 Physical & Mechanical Properties of Al 7075 [3]

Property	**Value**
Density	2800 (kg m^{-3})
Specific Gravity	2.8
Melting point	900 (degree F)
Modulus of elasticity	71 (GPa)
Poisson's Ratio	.33
Ultimate tensile strength	140 – 580 (MPa)
Yield strength	505 (MPa)
Strength	495 (MPa)
% elongation	11
Thermal conductivity	130 (W $m^{-1}k^{-1}$)
Coefficient of Thermal expansion	23.4
Specific Heat	960 at 0°C (J $Kg^{-1}k^{-1}$)
Electric Resistivity	5.22 * 10^{-8} (OHM M)

Friction stir processing is an emerging method for surface modification of aluminium alloys. In this method some selective locations on the surface of the materials are processed thermo-mechanically to enhance certain properties of the material up-to appropriate depth. The microstructure and mechanical properties are affected on the basis of heat generation and level of plastic strain attends in the processed area [4]. Some researchers informed that FSP is suitable for two different material modification techniques: one is in-volume FSP (VFSP) where the full thickness of the material gets modified and the other is surface FSP (SFSP) where up-to 2mm depth of the materials get modified [5]. Due to grain size refinement, a considerable increase in the formability of material was observed with increased ductility. After processing FSP zones was created and in context with original microstructure thermo-mechanically worked microstructure was formed with fine grains [6]. Navaser *et al.* [7] Experimented impact of FSP on Intergranular and pitting attacks of 7075 Aluminium Alloy. FSP materials pitting corrosion was incremented by incrementing rotational speed. Whereas, no IGC attack developed in HAZ and TMAZ. By incrementing rotational speed, the extent of IGC was decreased. Giardini *et al.* [8] Investigated impact of process parameter on corrosion characteristic in FSW of Al alloy. He utilized AA7075 and AA2024 Al alloys. They found that attacks morphology pivot on the alloy: in AA2024 a serious crevice and pitting attack happens, while the AA7075 indicates exfoliation corrosion parallel to rolling band. Coupling of various alloys lead a serious galvanic attack happens on AA7075. Shafiei *et al.* [9] they carried out FSP of small Al2O3 into the Al6082 aluminum for creating good composite surface. The Al2O3 particles has 50 nm sizes. They achieved favorable bonding of particles and aluminum substrate which has defect free interface. Hyun *et al.* [10] Conducted experiment of effect of SiC powder particles on Aluminum 6061 –T4 parent metal by using method of friction stir processing. They evaluated microstructure of friction stir processed

6061-T4. SiC particles were dispersed uniformly in parent metal. Also SiC particles enabled grain refinement of the matrix using FSP. The average grain size of zone with the SiC particles was smaller than zone without SiC particles.

Methods and Materials

For friction stir processing, there is a need to outline a reasonable and precise tool. So, we choose a tool which is made by H13 steel. After employing FSP the mechanical properties of tool may get changed. It is a molybdenum-chromium hot work steel. It has good hot hardness, thermal fatigue cracking resistance and toughness made us to choose H13 as our tool material. Tool consists of shoulder and tapered pin. Taperness is provided in order to reduce stress concentration else there is a change of breakage of pin. A small concavity also provides to the tool shoulder that's results in reduction of chips out.7075 aluminum is an Aluminum alloy in which zinc is the essential alloying component. Al 7075 has ductile nature which is preferred for FSP. Table 2 shows the chemical composition of AL 7075 Alloy. Boron carbide (B_4C) also called black diamond because of its hardness. It's an odorless, insoluble, black ceramic powder having highest hardness after diamond and boron nitride.

Table 2 Chemical composition of Al 7075 Alloy

Element	Al	Zn	Mg	Cu	Cr	others
Content %	90	5.6	2.5	1.6	0.23	0.07

Investigation of mechanical and wear properties of FSPed aluminum alloy reinforced composites in a corrosive environment will accomplish with a several series of process. Aluminum 7075 with 5 mm thickness is going to be used as our plate and reinforcement will be carried by using B_4C powders. Distinctive type of processing will be held by certain proportion of B_4C, tool pass and parameters. For dispersal of B_4C we made a small groove on aluminum of 1.5 mm wide and 2 mm depth. After filling the groove with B_4C a pass of pin less tool will be carried out in order to close the groove known as capping. Capping is to avoid spattering of B_4C away from groove during processing. Further processing with pin and shoulder tool will be completed. Then assessment of aluminum mechanical and wear properties of unprocessed aluminum, processed aluminum and reinforced aluminum will be measured. Tests are carried before corrosion and after corrosion. Corrosion on material is carried out by using sodium hydroxide solution which is highly corrosive and alkaline in nature. Then a comparative study of mechanical and tribological properties of specimens of different parameter will be performed. In order to achieve a successful FSP, the transverse speed and the rotational speed of the tool will also need to be carefully selected. During processing, the material around the tool will have to be locally raised to a temperature range in which severe plastic deformation can readily occur, and at the same time minimizing the forces acting on the tool. In general, the heat input to the work piece increases with higher rotation speed or decreasing transverse speed. Tool and Machine Parameters are given in table 3 and process parameters are given in table 4.

Result and Discussion

Finalized processing parameters for wear test is listed in Table 5. From these plates two specimens were taken and one specimen is subjected to corrosion were another left uncorroded there by we can compare wear properties of corroded and non-corroded samples.

Table 3 Machine and Tool Parameters for FSP

Tool used	H13
Probe Length	4.2 mm
Probe Taperness	4:6
Shoulder Diameter	18 mm
Tilt angle	3.14 degree
Plunge depth	4.4 mm
Dwell time	20 Sec.

Table 4 Process Parameter of FSP

SI NO	Processing	Traverse speed (mm/min)	Rotational speed (rpm)
1	None (Base)	None	None
2	YES, With Boron carbide	30	1400
3			1500
4			1600
5		40	1400
6			1500
7			1600
8		50	1400
9			1500
10			1600
11	YES	30	1400
12			1500
13			1600

Table 5 Selected samples for pin on disc

Si no:	Traverse speed	RPM	Modification
1	30	None	As received
2		1400	Processed with B_4C
3		1500	
4		1600	
5		1400	Processed without B_4C
6		1500	
7		1600	

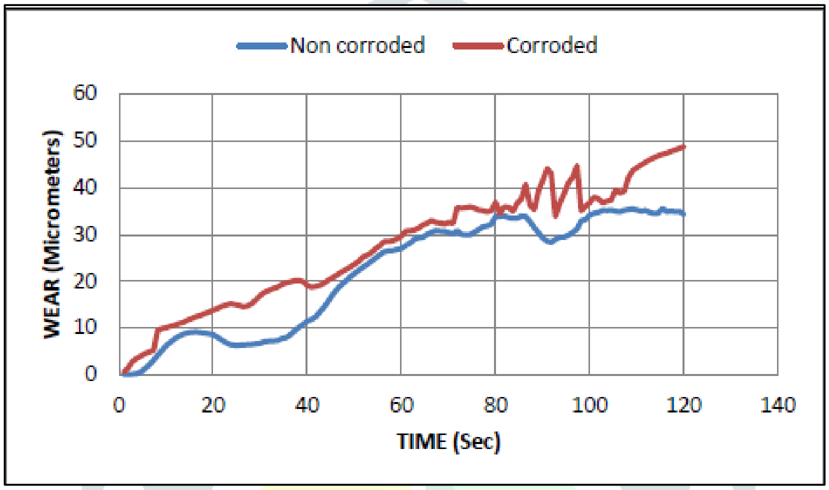

Figure 1 Wear vs. Time graph of 1400 rpm without B4C

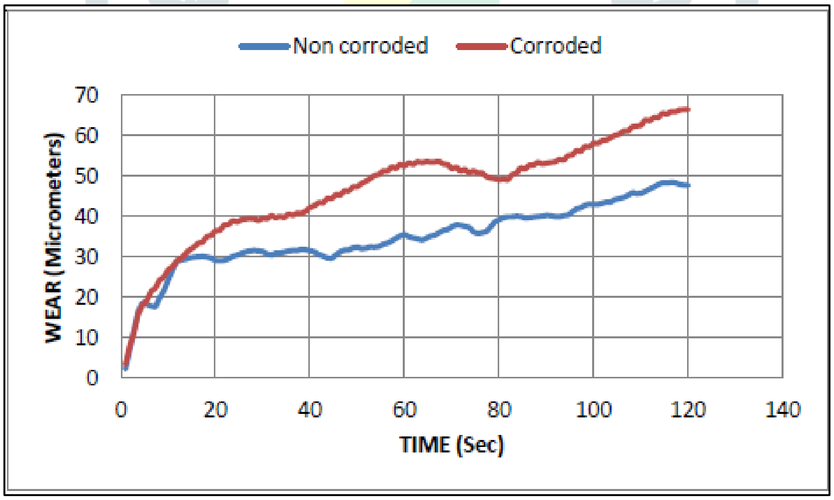

Figure 2 Wear vs. Time graph of 1500 rpm without B4C

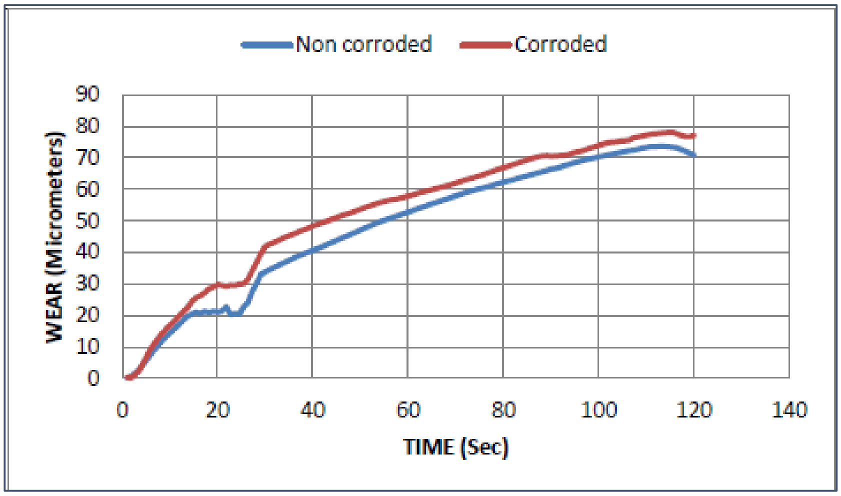

Figure 3 Wear vs. Time graph of 1600 rpm without B4C

Figures 1, 2 and 3 are the graphs plotted on linear wear with respect to times at 1400, 1500 and 1600 rpm respectively at a traverse speed of 30 mm/min without using B_4C. These graphs reported that by increasing rpm of processed specimen without B_4C wear rate was also increasing with respect to it. These results were validated from Devaraju *et al.* [11] that increase in rpm will soften material due to over aging and grain size growth occurred by temperature rise by increasing rpm. More the size of grain reduces material hardness and strength. Figure 1 has some sudden hype and drop as a results of wear debris will stick on rotating plate due to hotness. So, when pin will move through a hype and down will be experienced that makes negative slopes in wear graph. This was mainly seen in between 80 to 100 seconds in figure1.

Table 6 Volumetric wear of FSPed specimens without particles

RPM	Traverse speed	Volumetric wear rate mm^3/sec	
		Non corroded	corroded
1400	30	0.2424	0.3443
1500		0.3367	0.4337
1600		0.5003	0.5442

From the volumetric wear rate (table 6) it is clear that wear resistance dropped for all corroded specimens from non-corroded as obvious that corrosion attacks will weak the specimen and reduce area of contact by degrading surface. Whereas from these corroded 1400 rpm has better wear resistance than non-corroded base. From those linear wear rate obtained volumetric wear rate is reported in table 6. Only 1400 rpm without particles enhanced wear resistance than base material due to reason of strain hardening occurred by deformation with low temperature.

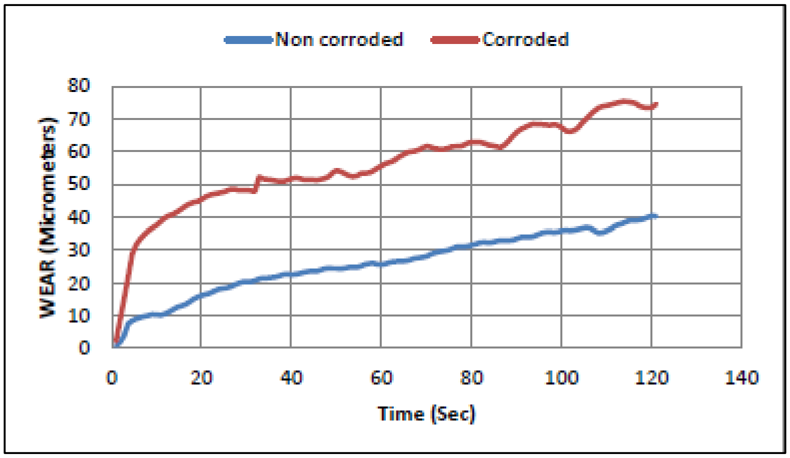

Figure 4 Wear vs. Time graph of 1400 rpm with B4C

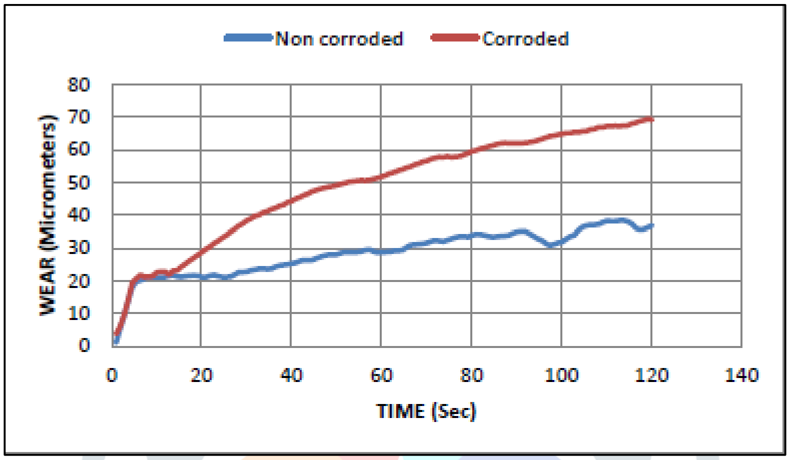

Figure 5 Wear vs. Time graph of 1500 rpm with B4C

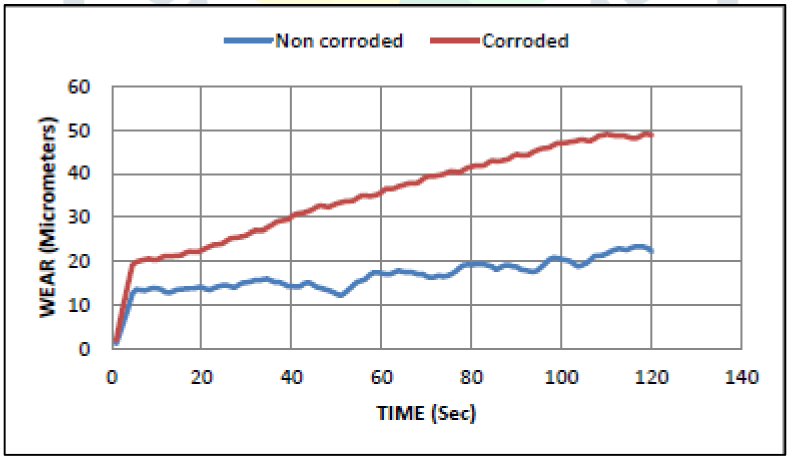

Figure 6 Wear vs. Time graph of 1600 rpm with B4C

Linear wear vs. time graph of 1400, 1500 and 1600 rpm FSPed with B4C is shown in figures 4, 5 and 6 respectively at constant traverse speed of 30 mm/min. in this graphs as compared to wear graph of without B4C wear rate of corroded was increased more from non-corroded .Also by increasing rotational speed of tool at same traverse speed there is an increment in wear resistance with particles whereas without particles how opposite way that is by increasing rotational speed there is a decrement of wear resistance. And increment of wear resistance by increasing rpm in the specimens was due to proper distribution B4C in the processed area. Wear resistance improved for FSPed material with particles at all processing parameter whereas reduction.

Table 7 Volumetric wear rate of FSPed specimens with B4C

RPM	Traverse speed	Volumetric wear rate mm^3/sec	
		Non corroded	corroded
1400	30	0.2854	0.5293
1500		0.2600	0.4869
1600		0.1574	0.3451

Volumetric wear rate corroded and non-corroded samples calculated from wear graph of figures 4, 5 and 6 is listed above in table 7. Volumetric wear rate is high for 1400 followed by 1500 then 1600 rpm. Which means 1600 rpm processed with B_4C has better wear resistance than other two lower rpms. And also wear resistance was improved on all processing parameters specimens processed with B_4C than as received. So, addition of B_4C into AA7075 by utilizing FSP is good for improving wear resistance. Where has there is high drop in wear resistance after corrosion of specimen subjected to wear testing tells that in a corrosive environment without FSPed without B_4C is preferred.

Conclusion

FSP is an achieved fame to fabricate Metal Matrix composites. FSP processing parameter selection is very crucial challenge in order to accomplish a sound composite with fine surface finish, uniform distribution of particles without voids and without compromising strength of materials by producing small grains. From the result if the material required high wear resistance then processing with particle at 1600 rpm is preferred.

- FSPed with B4C has more effect on mechanical and wear properties than base where as this can be reduced by increasing rpm.
- FSPed with particle has better wear resistance than without particles.
- Wear resistance also varying same as hardness with processing parameters. That is by increasing rpm wear resistance was increasing for FSPed specimen with B4C due to proper distribution and breakdown of B4C. For specimen processed without B4C wear resistance is reducing by increase in rpm.

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