

Mechanical Characteristics Analysis for FSPed AL-7075 alloy Reinforced Composite with and without corroded environment

Akash Gupta^{a*}

a School of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab – 144411*

Abstract

By utilizing FSP (Friction Stir Processing) with proper reinforces can improve material properties. Although FSP can improve the mechanical properties but vulnerability of corrosion needs to be investigated because if material is enhanced mechanical properties where corrosion resistance is declined will result 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 (Friction Stir Processed) material with and without B4C as reinforcement particles and also effect of corrosion on those properties in order to get improved mechanical 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 (B₄C) 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 B₄C powders. Distinctive type of processing will be held by certain proportion of B₄C, tool pass and parameters. For dispersal of B₄C we made a small groove on aluminum of 1.5 mm wide and 2 mm depth. After filling the groove with B₄C 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 B₄C 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

In order to know how much tensile force, the processed zone can withstand universal tensile testing is conducted on UTM on all processing parameters as listed in table 4. This testing enables us to know ultimate tensile strength

of materials processed by FSP. There is a need to know the impact of corrosion on tensile strength for different parameter so from each plate two specimens were taken for tensile testing as shown in table 4. From each plate one specimen is corroded another left un-corroded and subjected to tensile testing.

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

Figure 1 and 2 shows non-corroded and corroded fractured specimens respectively by tensile load. From this two samples of FSPed with and without B₄C in order to study fracture on those processed specimens. Tensile results as shown in fig. 3 that by increasing rpm there is a decrement in tensile strength as a result of increase in grain size by increase in temperature. This relation is found in many research papers when they were using high rpm and low traverse speed rate. If the temperature is below crystallization temperature then there will be strain hardening which resulting in improvement of tensile strength, this can occur by using low rpm and high traverse speed rate. But here heat is more that makes grain growth resulting in decrease in TS. TS of specimens processed without particles also having the same phenomenon whereas it has high TS than processed with B₄C particles. Also note that TS of processed zone without particle was more than the given value because breakage occurred away from the processed zone as seen in fig: 1 and 2 which means processed zone has more strength than the broken zone. From the result 1400 rpm at 30 traverse speed without particles has the better tensile strength.



Figure1 Broken specimens of non-corroded specimens

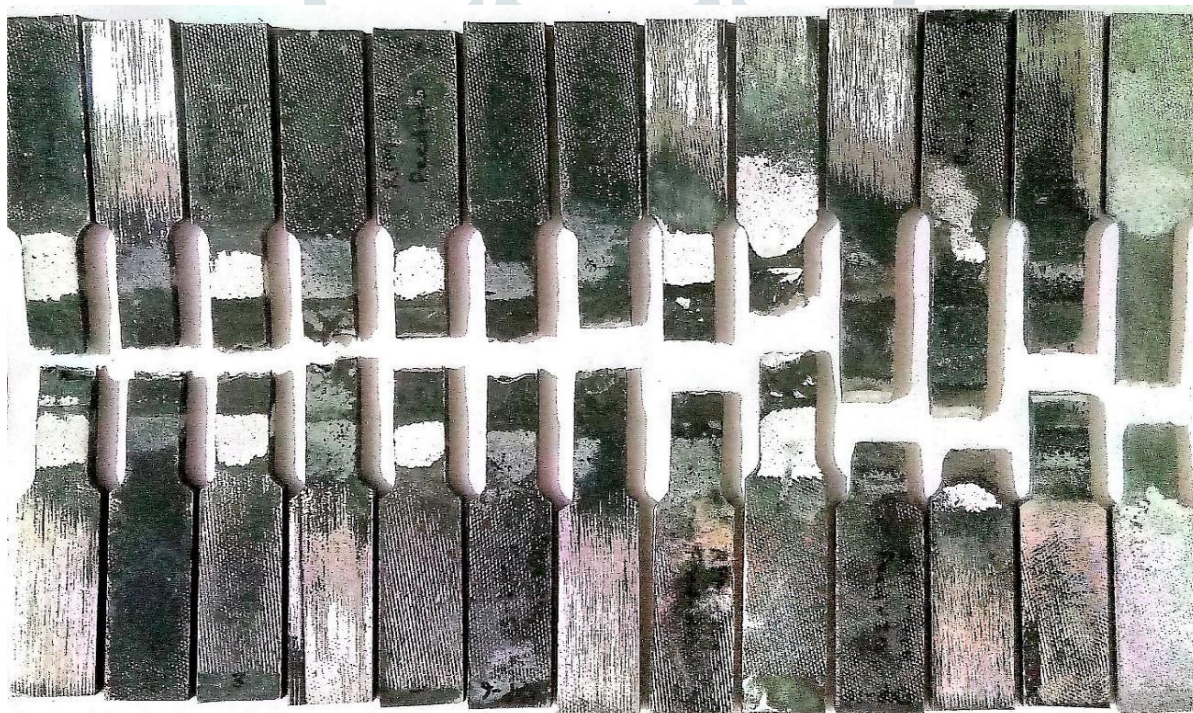


Figure 2 Broken corroded specimen after tensile fracture

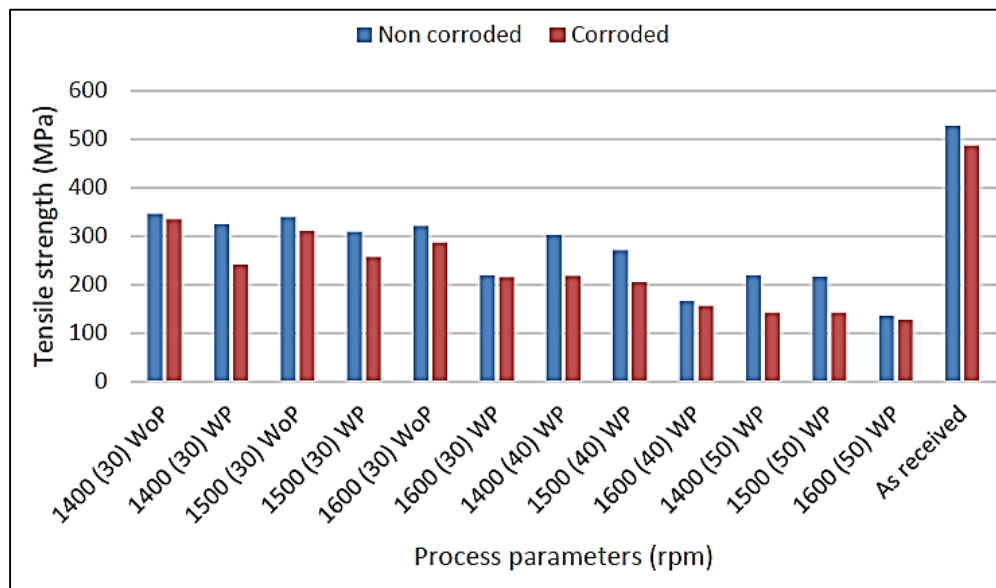


Figure 3 Tensile strength of non-corroded and corroded specimen

Impact of Corrosion on Tensile Strength

It is required to understand the effect of corrosion on tensile strength in order to know at which parameter corrosion effecting more on tensile strength. So, for that reduction in TS of corroded sample with respect to non-corroded samples are calculated by taking difference of both samples at same parameters as shown in figures 4.

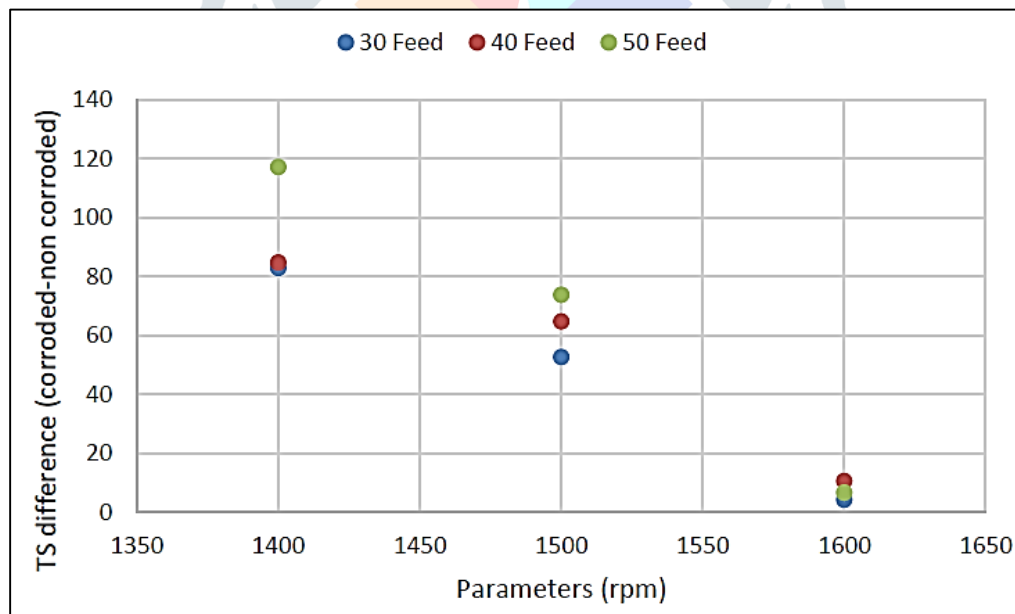


Figure 4 Reduction in tensile strength after corrosion.

By increasing rpm drops in tensile strength after corrosion was reducing at all of the traverse speed rates. It means by decreasing rpm, corrosion attacks on specimen was increasing due low surface finish, voids and low interface bonding between base material and B₄C obtained at lower rpm, thereby chemicals can penetrate and attack specimen deeply. So, 1600 rpm at 30 traverse speed was having lowest effect of corrosion on tensile strength followed by 1600 rpm at 50 and 40 traverse speed respectively and 1400 rpm at 50 traverse speed has highest effect of corrosion on tensile strength.

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.

- FSPed with B₄C has more effect on mechanical properties than base where as this can be reduced by increasing rpm.
- Tensile strength of FSPed specimen was lowered as compared to base. FSPed with B₄C has lower tensile strength as compared to without particles. Tensile fracture occurred for specimens without particles is away from processed zone indicate it has better strength than available result.
- For tensile also impact of corrosion was lowered by increasing rpm. It is as a result of increase in temperature results in higher peak temperature which helps in reduction of defects in processed zone and good interface bonding among B₄C and base materials there by material can resist the penetration of chemicals into the work.

References

- [1] Properties and Selection: Nonferrous Alloys and Special-Purpose Material, ASM International Handbook Committee.
- [2] Polmear I.J. "Light Alloys from traditional alloys to Nanocrystals". Elsevier's Science and Technology. Fourth ed. (2006). Page 421.
- [3] Balasubramaniam E, "Callisters Material science and Engineering" (2009). Page 292 – 294
- [4] Mandal P.K. "New Surface Modification Technique and Their Characterization: Friction Stir Processing of Al-Zn-Mg Alloy", Int. Journal of Engineering Research and Applications. (2015). Vol. no 5. Page 191-195.
- [5] Nascimento F, Santos T and Miranda R.M. "Microstructural modification and ductility enhancement of surfaces modified by FSP in aluminum alloys", Materials Science and Engineering A, (2009). Vol. no 506. Page 16-22.
- [6] Christian B and Fuller. "Surface modification with friction stir processing".
- [7] Navaser M and Atapour M. "Effect of Friction Stir Processing on Pitting Corrosion and Intergranular Attack of 7075 Aluminum Alloy" (2017) Page 155-165.
- [8] Gianluca d'urso, Claudio giardinia, Sergio lorenzib, Marina cabrinib and Tommaso pastoreb. "Influence of process parameter on mechanical properties and corrosion of friction stir welded aluminum joints" (2010) Page 1011-1014.
- [9] Shafiei-Zarghani A, Kashani-Bozorg S.F and Zarei-Hanzaki A. "Microstructures and mechanical properties of Al/Al₂O₃ surface nano-composite layer produced by friction stir processing", (2009) Page 84–91.

- [10] Don-hyun C, yong K and Seung J. “Effect of SiC particles on microstructure and mechanical property of friction stir processed AA6061 – t4” (2012) Page 1-5.
- [11] Devaraju aruri, Kumar A, Kumaraswamy A and Kotiveerachari bazavada.” Wear and mechanical properties of 6061-T6 aluminum alloy surface hybrid composites [(SiC+ Gr) and (SiC+ Al₂O₃)] fabricated by friction stir processing”. (2013) Page 112-124.

