A Comparative Analysis of Wear and Hardness Characteristics using FSW on TiO2 Reinforced AL Alloys

Mahendra K C[1]
Assistant Professor,
Rao Bahadur Y. Mahabaleswarappa Engineering College
Ballari, Karnataka, India
Mahendra.kc@rymec.in

Rahul David B[2]
PG Student-MPM
Rao Bahadur Y. Mahabaleswarappa Engineering College
Ballari, Karnataka, India

Virupaksha Gouda H[3]
Assistant Professor
Rao Bahadur Y. Mahabaleswarappa Engineering College
Ballari, Karnataka, India

Channaveera Swamy J M[4]
Technical Staff
Rao Bahadur Y. Mahabaleswarappa Engineering College
Ballari, Karnataka, India

***Abstract*— With the rapid development of industries and their required applications for sustainable conditions, aluminum and their alloys are very much in demand. However, friction stir welding has a potential application prospect with respect to the joining of dissimilar aluminum alloys which possess favorable mechanical properties. Al 6061 & Al 7075 alloys were considered in this study to explore the characteristics under testing conditions. To enhance the strength of the joint Titanium di Oxide (TiO2) is considered as reinforcement nanoparticle.**

This Study focuses upon Wear & Hardness behavior of Friction Stir Welded Reinforced Aluminium Alloys (Al 6061 & Al 7075). Sliding distance, sliding speed and load were considered as parameters for wear Test. Similarly diamond indenter with 150 Kgf is considered for hardness Survey. It was observed that nugget zone possesses maximum hardness number of 180 compared to the HAZ & TMAZ. At a sliding speed of 3 m/s, wear behavior indicates rise in volumetric rate with respect to increasing normal loads.

Keywords: Aluminum alloys; friction stir welding; Wear Test , Hardness

I. INTRODUCTION

Aluminum is a versatile and lightweight metal widely used in various industries due to its excellent mechanical properties, corrosion resistance, and ease of fabrication. Among the numerous aluminum alloys available, 6061 and 7075 are two of the most popular, each with unique characteristics and applications. Aluminum alloys have become pivotal in various industries due to their lightweight nature, excellent corrosion resistance, and high strength-to-weight ratios. Among the myriad of aluminum alloys available, 6061 and 7075 are two of the most widely used. This paper delves into the properties, applications, and the implications of reinforcing these alloys with titanium dioxide (TiO_2).

1) Titanium Dioxide (TiO_2) Reinforcement

a) Overview of TiO_2

Titanium dioxide (TiO_2) is a widely studied ceramic material known for its high strength, thermal stability, and low density. It is commonly used in various applications, from pigments in paints to catalysts in chemical reactions.

b) Benefits of TiO_2 Reinforcement

Reinforcing aluminum alloys with TiO_2 can enhance their mechanical and thermal properties. The incorporation of TiO_2 into aluminum matrix composites (AMCs) can lead to:

- **Increased Strength**: TiO_2 particles can improve the yield and ultimate tensile strength of aluminum alloys, making them more suitable for demanding applications.
- **Enhanced Wear Resistance**: TiO_2 reinforcement can provide increased hardness, resulting in better wear resistance, crucial for components subjected to friction.
- **Improved Thermal Stability**: The presence of TiO_2 can enhance the thermal stability of the composite, making it suitable for high-temperature applications.
- **Better Corrosion Resistance**: The combination of aluminum's natural corrosion resistance with TiO_2 can further enhance the durability of the material.

c) Comparison of 6061 and 7075 Aluminum Alloys with TiO2 Reinforcement

Mechanical Properties

- **6061 with TiO_2**: The incorporation of TiO_2 can significantly improve the mechanical properties of 6061. For instance, studies have shown that the yield strength can increase by up to 20% compared to the unreinforced alloy.

The elongation may also improve, indicating better ductility.

- **7075 with TiO_2**: Similarly, the addition of TiO_2 to 7075 can result in even higher strength gains due to the already high baseline properties of this alloy. The ultimate tensile strength can exceed 750 MPa, depending on the TiO_2 content and distribution.

2) Friction Stir Welding

Friction stir welding (FSW) is a revolutionary solid-state joining process that has gained significant traction in various industries since its invention in 1991. Developed by Wayne Thomas at The Welding Institute in the UK, FSW utilizes frictional heat and mechanical stirring to join materials without reaching their melting point. This innovative approach offers numerous advantages over traditional welding methods, making it particularly effective for joining aluminum and other non-ferrous alloys.

a) The FSW Process

The FSW process involves several key steps:

1. **Tool Design**: A specially designed non-consumable rotating tool, typically made of hard materials like tool steel or tungsten carbide, is used. The tool consists of a shoulder and a pin, where the shoulder generates heat through friction, and the pin stirs the materials.

2. **Plunge**: The tool is plunged into the materials to be joined, generating frictional heat at the interface. The heat softens the material around the pin without melting it.

3. **Stirring and Travel**: As the tool rotates and moves along the joint line, it stirs the softened material. The mechanical action of the pin helps to mix the materials, creating a strong bond.

4. **Cooling**: Upon the tool's removal, the stirred material cools and solidifies, resulting in a joint that retains most of the original material properties.

b) Advantages of Friction Stir Welding

FSW offers several advantages that distinguish it from traditional welding techniques:

1. **Solid-State Process**: Because the material does not melt, FSW avoids many issues associated with melting, such as porosity, oxidation, and segregation. This results in higher-quality welds with fewer defects.

2. **Lower Distortion**: The controlled thermal cycle of FSW minimizes thermal distortion and residual stresses, making it suitable for high-precision applications.

3. **Enhanced Mechanical Properties**: FSW can produce welds that maintain or even enhance the mechanical properties of the base materials, particularly when joining high-strength alloys.

4. **Reduced Need for Filler Material**: FSW typically does not require filler materials, which simplifies the process and reduces costs.

5. **Environmentally Friendly**: The process generates less waste compared to traditional welding methods and does not produce harmful fumes or gases.

c) Applications of Friction Stir Welding

FSW has been successfully applied in various industries, including:

1. **Aerospace**: The aerospace sector utilizes FSW for lightweight structural components due to its ability to join high-strength aluminum alloys without compromising their properties.

2. **Automotive**: FSW is increasingly used in the automotive industry for assembling lightweight structures, improving fuel efficiency while maintaining structural integrity.

3. **Marine**: Shipbuilding benefits from FSW, as the technique allows for the creation of strong, lightweight hulls and components that resist corrosion.

4. **Railway**: The railway industry uses FSW to join aluminum components in train bodies and other structures, capitalizing on its strength and durability.

5. **Renewable Energy**: In wind and solar energy applications, FSW is employed for the fabrication of components where strength and weight are critical factors.

d) Challenges in Friction Stir Welding

While FSW offers numerous benefits, it also presents certain challenges:

1. **Tool Wear**: The high strength of materials being welded, particularly in aluminum alloys like 7075, can lead to increased tool wear. This necessitates the use of high-durability tool materials and careful tool design.

2. **Weldability of Materials**: Some materials may be difficult to weld using FSW. For example, certain aluminum alloys are prone to cracking or may have issues with the heat-affected zone (HAZ), which can reduce the overall strength of the joint.

3. **Process Parameter Optimization**: Successful FSW requires careful control of various parameters, including tool rotation speed, travel speed, plunge depth, and tool geometry. Finding the optimal settings can be complex and may require extensive experimentation.

4. **Joint Design**: The design of the joint itself can impact the success of the welding process. Proper alignment and configuration are crucial to achieving high-quality welds.

II. LITERATURE SURVAY

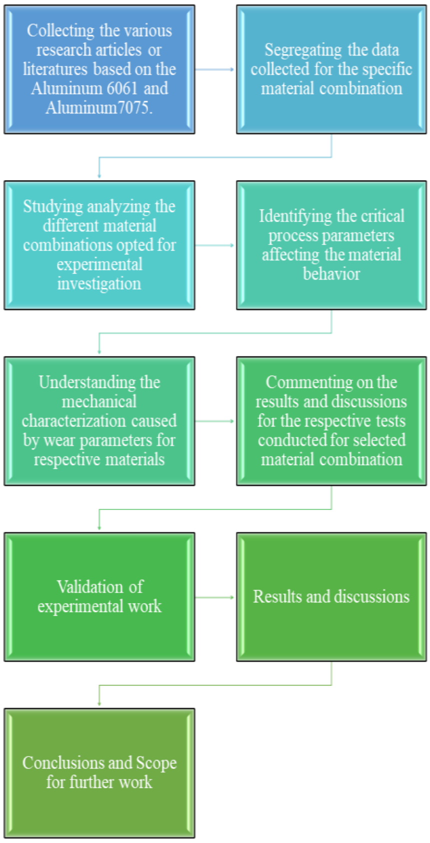
Madhuri Deshpande et.al. successfully prepared Pitch based carbon fiber added to Al matrix composites from Powder Metallurgy (PM) technique. Weight % of carbon fiber are (5-50) % uncoated (UnCf) and coated milled pitch-based carbon fibers (NiCf) and AA7075 as matrix with different volume contents of carbon fibers. Uncoated and Nicoated carbon fibers were reinforced with AA7075 Aluminum alloy powder and subsequently hot pressed and they studied on density and hardness strength. A highest of 11% reduction in density is noticed for 50Vol% Cf Composite compared to as cast Al7075. It indicated that the composites developed with uncoated carbon fiber shows minimum values of hardness as compared with Pure Al7075 hot pressed specimen. Whereas the Ni coated carbon fiber composites show the increase in hardness up to 20Vol%. It is observed from the microstructures that carbon fibers are homogeneously distributed in the Aluminum matrix for all wt. % compositions.

S. Sivakumar, In these study Aluminum matrix composites (AMCs) reinforced with hard metallic particles can be used as reinforcement to improve ductility. The present investigation focuses on using molybdenum (Mo) as potential reinforcement for Mo (0,6,12 and 18 vol.%)/6082Al AMCs. Mo particles were successfully retained in the aluminum matrix in its elemental form without any interfacial reaction. A homogenous distribution of Mo particles in the composite was achieved. The tensile test results showed that Mo particles improved the strength of the composite without compromising on ductility.

N. I. Novokhatskaya et.al. Work on high temperature materials is designed to achieve an acceptable balance between three basic characteristics cracking resistance, creep Resistance and gas corrosion resistance. The molybdate forming elements that are present in the matrix substantially retard molybdenum oxidation in the composite material. The strength of the composite material weakly depends on the time of holding in quiet air at 1250°C for 12 h. The strength of the composite material as a function of the Al: Y ratio in the oxide matrix changes non-monotonically. The maximum strength shifts from the Al_2O_3– Al5Y3O12 eutectic point toward garnet.This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

Sergei T. Mileiko A study was conducted on molybdenum matrix composites reinforced with fires containing yttrium and ytterbium silicates. In this study for the first time, such fires are obtained as reinforcements of molybdenum matrix and mechanical properties of the oxide/molybdenum composites are studied. The raw mixtures of oxide powders $Y2O_3$– SiO_2 for melting and crystallizing Composite and Advanced Materials them to form fires in molybdenum matrix had molar ratios: 0.5 - 0.5. Also, Yb2O3 - SiO_2 with molar ratio 0.6305:0.3695 to produce fiber close to trisilicate eutectic composition. This finding makes molybdenum matrix composites be a candidate for future heat-resistant materials with high creep resistance at high temperatures and sufficiently high fracture toughness at low temperatures.

III.METHODOLOGY



IV.EXPERIMENTAL DETAILS

1) Material selection

Based on the literature review and feasibility of research topic present investigation considered Al 6061 & Al 7075 of 6 mm thickness as the base metal. The material properties of these alloys include good fatigue strength, machinability and less resistance to corrosion than other aluminium alloys. chemical, physical and mechanical properties were stated in the following table3, table 4, and table 5respectively.

Table 1 Chemical composition of AA7075 T6 and AA6061 T6

Constituents	AA6061 T6	AA7075 T6
Aluminium	90.311	97.766
Chromium	0.2	0.064
Copper	1.31	0.19
Iron	0.17	0.25
Magnesium	2.28	0.8
Manganese	0.019	0.12
Zinc	5.61	0.11
Silicon	0.1	0.7

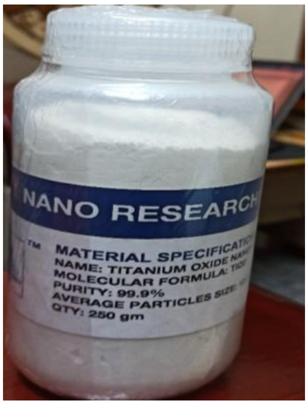
Table 2 Physical properties of AA7075 T6 and AA6061T6

Material	AA 6061 T6	AA 7075 T6
Density (kg/m3	2700	2800
Melting Point (0C)	650	477
Modulus of elasticity (GPa)	70	71.7
Thermal Conductivity (w/MK)	166	130-150

In the present study, receive draw material dimensions were different at the initial state condition as shown fig 3. To suit the requirements needed, the rolled plates of aluminium alloys were remodified with proportions of140 x 70 x 6 mm with the help of CNC machine. To facilitate the insertion of nanoparticles in the workpiece abutting edges, separate holes of depth 4mm and 10 mm apart from subsequent holes were drilled at the peripheral state of both the alloys as shown below.

1) *Titanium dioxide (TiO_2)*

With respect to the literature survey, addition of nanoparticle enhances the joint strength as well as better mechanical properties. In this connection present study employed usage of Titanium dioxide (TiO_2) as reinforcement nanoparticle material as shown . TiO_2 is a barium sulphate salt present in the mineral barite. Titanium oxide is a divalent, alkaline metal, where average particle size is of 10 -20 nm.



2) Wear Behaviour Study Of Aluminium 6061 And Aluminium 7075

- To find out the Wear rate of Aluminum 6061 & 7075 and provide a comparison between the same.
- Evaluation of wear rate for existing and proposed aluminum material of different applications.

a) MATERIALS

The matrix material selected for the present studies is Al 7075 and Al 6061 alloy and is procured from Jindal Aluminum limited, Bangalore, in the form of ingots. The chemical composition of Al7075 T6 alloy and Al6061 T6 is shown in Table 3.1 and Table 3.2. The Sic and $Al2O_3$ of 36- micron size is selected as reinforcement material, which is supplied by M/s Snam Abrasives Pvt. Ltd, Hosur, Tamil Nadu – India.

V. EXPERIMENTAL DETAILS

1) *Experimental setup*

Major part of the friction stir welding is the effective utilization, handling and setting it up of equipment which is very much important for operating processes for duration. In this study, vertical milling machine embedded with friction stir welding fixture setup has been done to execute the experimental works along with an inexpensive tool for making welded joints that uses a vertical head attachment to accommodate high spindle speeds. The friction stir welding involves large forces of about 2500kgf, fixtures with proper clamping design to prevent movement of the specimens. The equipment has the capability of welding plate thickness of from 0.5 mm to 10. Specification and operating range of the equipment has shown in the table5. Experimental setup for conducting friction stir welding process for butt welding has shown in the fig 7. The abutting faces of the plates are well ground to minimize the joint gap between plates and cleaned to remove the dust, dirt etc. with acetone. The direction of welding is normal to the rolling direction, single pass welding has been employed to facilitate the joint configuration. Non-consumable welding tool made of high-Speed steel (D2) was applied as solid-state welding to inculcate the process operation.

Table 3 Welding machine specifications.

Sl no	Specifications	Operating range
01	Main Motor Capacity	5.5/1500 kw/RPM
02	Number of Speeds	18 RPM
03	Bed Size Length	1m (1000 mm)
04	Tool rotational speed	35.5-1800 RPM
05	Overall dimension (L*W)	1520*310 mm

Figure 3 Frictions Stir Welding Fixture Setup and Welding Tool

During the welding process, immense forces and plastic deformation will develop when friction stir welding tool plunges into the work pieces to be welded directly act on the base plate and cause the workpieces to drift apart. Hence, a rigid clamping fixture is necessary to withstand the forces and to prevent the extrusion of plasticized material from the joint section to the bottom of the joint.

In the present study, to improve the mechanical properties at the welded joint, Titanium dioxide (TiO_2) reinforcement particles were added at weld interface with same proportions by creating separate geometries such as whole of depth 4mm as shown in the weld interface. Two clamping plates are used to align and stabilize the plates during welding. Clamping screws are used to hold the work piece rigidly on its top surface to prevent the longitudinal movement of work plates during the process.

The photographic view of the fabricated friction stir welding fixture for the experimental work. The fixture is aligned to the T-slots of machine table. Hexagonal socket screws are used to assemble the fixture components and clamping work plates. The sockets screws are tightened with uniform torque level to avoid the movement and bending of the work plates during the process.

The side where the tool rotation is in the same direction of translation of the tool considered as advancing side, whereas when this two tool motion counters referred as retreating side. Dissimilar friction stir welding process is carried out by placing the high strength aluminium alloy AA7075-T6 at the retreating side (RS), and by placing the aluminium alloy AA6061-T6at the advancing side (AS)

The Friction stir welds between AA6061-T6 and AA7075-T6 aluminium alloys were produced using HMT FN2EV Vertical milling machine with hydraulic power pack motor 5.5/1500 kw/rpmwith 1800RPM maximum rotational speed;800mm/min as X axis rapid traverse speed and maximum axial thrust as 5kN. The thicknesses of both plates were 6 mm. The plates were in a butt joint configuration and the welding process was carried out normal to the rolling direction of the plates. The dimensions of the aluminium alloy plates are 140 mm length and 70 mm width. Five pin profiles are used for different experimental level combinations.

2) Selection of process parameters

Based on the literature, percentage of reinforcement, Tool pin profile, Tool rotational speed and welding speed, tool tilt angle were selected as control variables. Tensile strength and elongation are chosen as the responses in the current work. From the literature survey, it was found that the responses varied due to the interaction effects of control variables and the higher order effects of control variables had significant contribution to the variations in the responses. In order to determine the higher-order effects and interaction effects, Response Surface Methodology (RSM) was selected to generate the experimental design. Design expert software was used in this research work to analyze and to predict the results. Five level experimental design was selected.

3) Friction stir welded specimens

This process involves significant material movements and also plastic deformation. Operational parameters determine the weld characteristics and material behaviour under several conditions. Present investigation involves tool pin profile, tool rotational speed, welding speed and tool tilt for experimentation contributing for friction stir welding process. Based on the design matrix shown in the table various parameters along with their range are selected for conducting trials.

Titanium dioxide (TiO_2) reinforcement particles are added proportionally for each set of conduction and subsequently for all the combinations. shows the Friction stir welded joint for both the plates along with rear face of the welded joint.

Experiment conducted for trial 1 included taper cylindrical pin profile of the tool, rotational speed of 800 rpm, welding speed of 50 mm/min and tool tilt angle of 1 deg. Welding action was performed by keeping AA6061-T6 on Advancing Side (AS) and AA7075-T6 on retreating side (RS) as shown in the fig 9. Movement of tool is normal to the direction of the plates as indicated by arrow mark (Blue).

Similarly for all the remaining combinations, friction stir welding was conducted as shown in the fig 10. After the welding of each combination of workpieces, these plates were allowed for normal cooling, later subjected to surface polishing for subsequent operations and tastings.

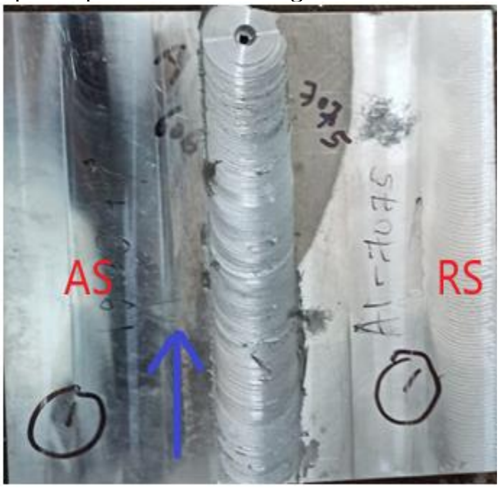


Figure 4 Welded Plate and Rear Face of The Plate

4) Standard Specimen Preparation for Wear and Hardness Test.

In the present study, receive draw material dimensions were different at the initial state condition . To suit the requirements needed, the rolled plates of aluminum alloys were re- modified with proportions of 140 x 70 x 6 mm with the help of CNC machine. To facilitate the insertion of nanoparticles in the work piece abutting edges, separate species 30X10X6 mm apart from cut both the alloys as shown below.

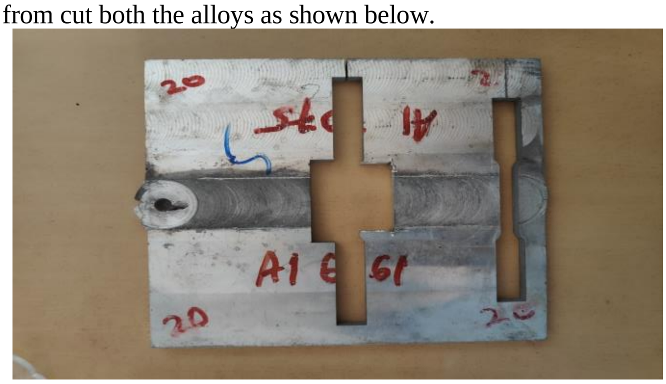


Figure 5 Al7075 and Al6061 Plates

Figure 6 Wear Specimens of Al7075 and Al6061 Species

5) *Hardness Survey*

Present study involves the hardness investigation of the welded specimen by Vickers hardness (MVD 401). In the present investigation, an indentation force of 0.5 kgf and along with an dwell time of 10 seconds in steps of 0.3 mm as per ASTM E 384-22 standard.

6) Wear Mechanism

Characteristic modes of damage such as scuffing, scoring, pitting. mainly describe the appearance of the surface of worn component. The basic mechanisms for different characteristic modes of wear are as under:

- Mild wear: Delamination and oxidation.
- Severe: Adhesive, diffusive and abrasive.
- Scuffing: Adhesive and diffusive.
- Scoring: Abrasive. Pitting: Fatigue and external attack.

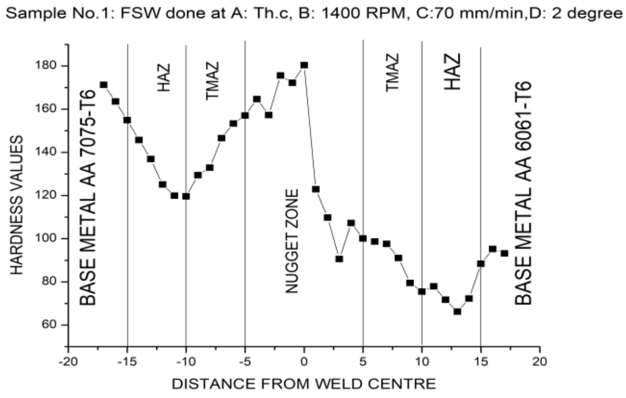
Conditions of wear surface (wear mechanism) in early stages of sliding become different from those attained at steady state after enough sliding. After long time of sliding, factors such as average coefficient of friction, magnitude of friction fluctuation, surface roughness, depth of deformed layer, composition and microstructure of near surface material, tend to control the wear

Wear curve for Al–Si alloy under dry sliding condition typically shows two distinct region namely: (1) run-in wear and (2) steady state wear. Run-in wear is the process by which the sliding surfaces are conditioned by mechanical and chemical means to achieve required topography and chemistry at the interface of the mating surfaces prior to the steady state wear conditions.

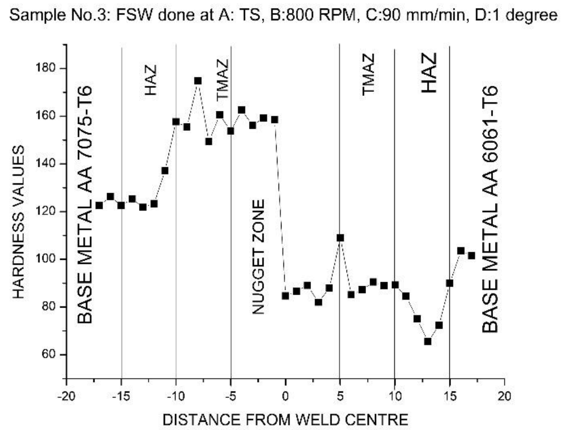
The analysis of run-in wear region has shown that increasing silicon content of alloy tends to reduce both the wear severity and its duration in run-in wear stage [33]. Several theories on sliding wear of metals had been proposed in the past. According to one theory increase in wear rate is due to the loss of hardness of metal with the temperature rise. Another theory assumes that due to temperature rise, sliding surface gets oxidized and external forces peel off oxide layer as it reaches a critical thickness. Wear rate is determined by diffusion of oxygen atoms through the oxide layer. The basic phenomenon for material removal is micro and fracture event is preceded by other phenomenon such as heating, plastic deformation. Laduma on the other hand cited that during sliding material loss occurs by cutting, ductile fracture, brittle fracture, low and high cycle fatigue, corrosion and melting

VI.RESULTS AND DISCUSSION

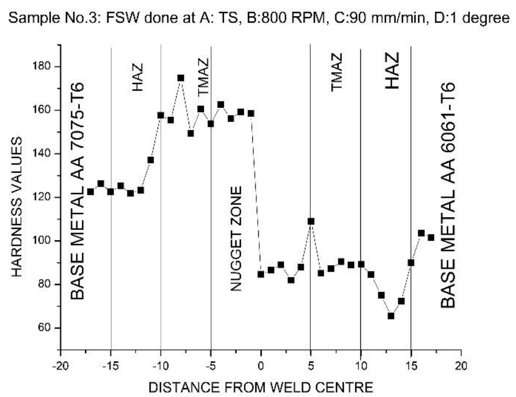
1) *HARDNESS SURVEY*



Above figure represents the hardness values on the material through the different welding zones with the FSW was done at 1400 RPM 70mm/min and 2 degree it is observed that in the Nugget zone the hardness value is observed high compared to other zones. The value is 180.

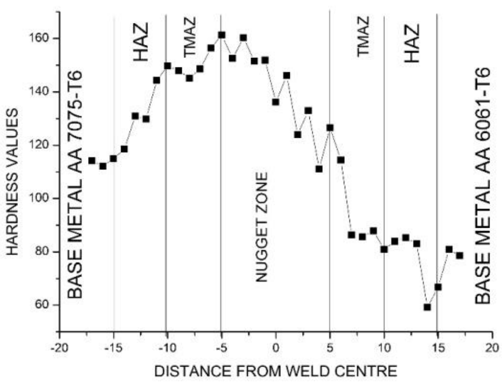


Above figure represents the hardness values on the material through the different welding zones with the FSW was done at 1000 RPM 70mm/min and 2 degree it is observed that in the TMA Zone the hardness value is observed high compared to other zones. The value is 190.

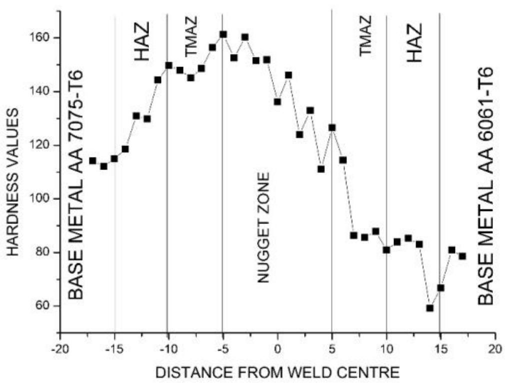


Above figure represents the hardness values on the material through the different welding zones with the FSW was done at 800 RPM 90mm/min and 1 degree it is observed that in the TMA Zone the hardness value is observed high compared to other zones. The value is 175

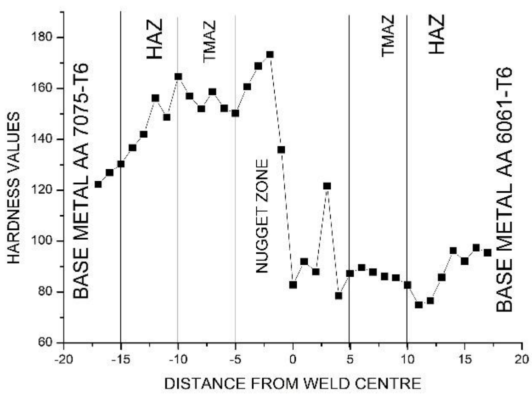
Sample No.6: FSW done at A: Th.c, B: 600 RPM, C:70 mm/min,D: 2 degree



Sample No.6: FSW done at A: Th.c, B: 600 RPM, C:70 mm/min,D: 2 degree

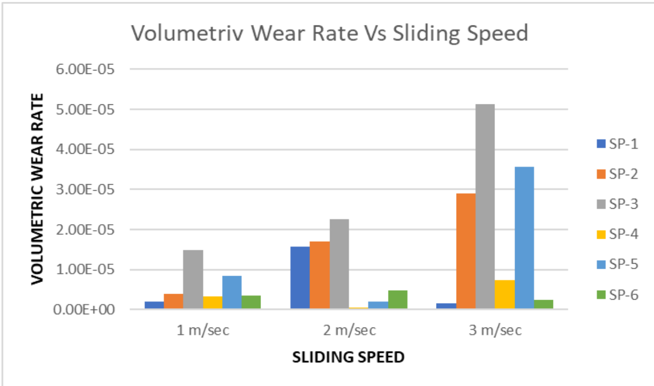


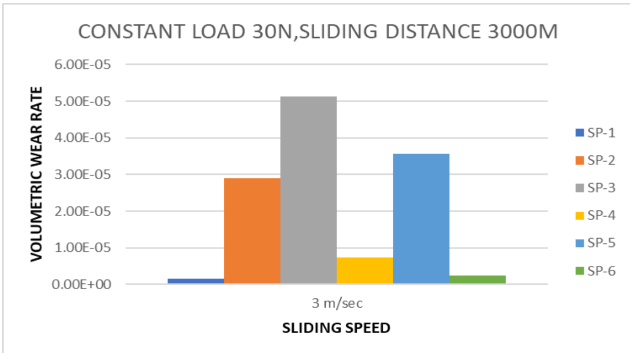
Sample No.5: FSW done at A: TC, B: 800 RPM, C:90 mm/min,D: 3 degree

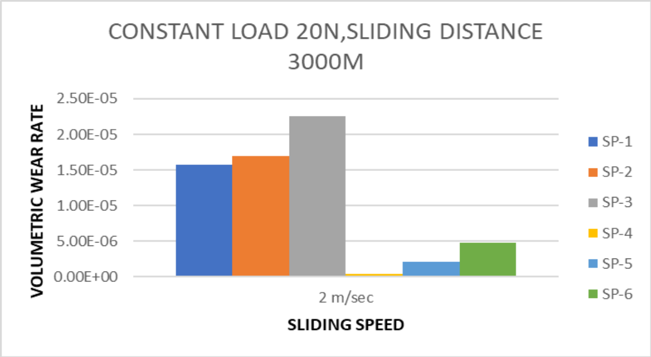


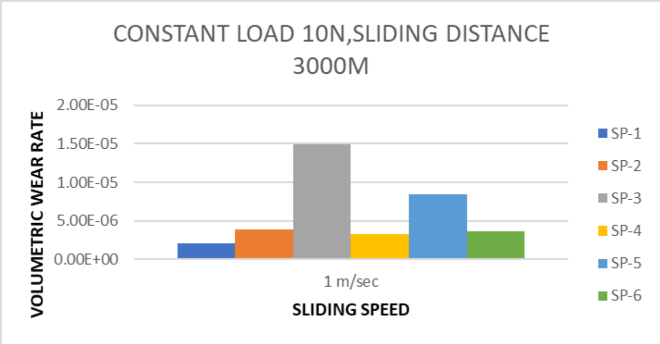
Above figure represents the hardness values on the material through the different welding zones with the FSW was done at 600 RPM 70mm/min and 2 degree it is observed that in between the Nugget zone and TMAZ the hardness value is observed high compared to other zones. The value is 160.

2) WEAR TEST









the effect of normal load on 6061/7075 aluminum alloy where increasing load generally results in a higher wear rate due to elevated contact pressures causing abrasion and surface deformation. however, 6061/7075 alloy, known for its good machinability and weldability, may exhibit more pronounced plastic deformation under higher loads, potentially leading to enhanced wear resistance over time as the surface work-hardens. balancing load considerations is critical for optimizing performance in applications where aluminum alloy is utilized.

at a sliding speed of 1 m/s, the wear behavior graph shows that volumetric wear rate generally increases with higher normal loads across different materials. this trend is influenced by intensified contact pressures and frictional forces, impacting wear resistance and durability in engineering applications.

At a sliding speed of 2 m/s, the wear behavior graph indicates that volumetric wear rate increases with higher normal loads across various materials. this relationship underscores the role of intensified contact stresses and frictional forces in accelerating wear mechanisms, crucial for optimizing material selection and durability in engineering applications.

At a sliding speed of 3 m/s, the wear behavior graph illustrates a trend where volumetric wear rate tends to rise with increasing normal loads across different materials. this correlation highlights the impact of heightened contact pressures and frictional forces, influencing wear resistance and performance characteristics crucial for industrial applications

The volumetric wear rate of different materials at a constant normal load of 30n varies with sliding speed. generally, higher sliding speeds tend to increase wear rates due to elevated frictional forces and heat generation, which intensify abrasive and adhesive wear mechanisms across metals and polymers. however, the impact varies by material; some alloys and ceramics may exhibit a nuanced relationship where wear rate initially decreases at higher speeds due to altered wear mechanisms or enhanced surface interactions. understanding these speed-dependent wear characteristics is crucial for optimizing material performance and durability in engineering applications.

The influence of sliding speed on the volumetric wear rate of various materials under a constant normal load of 30n reveals a notable effect on wear behavior. typically, increased sliding speeds result in higher wear rates due to elevated frictional forces and heat generation, which can lead to enhanced material loss through abrasive and adhesive wear mechanisms. softer materials, such as polymers and certain metals, generally display greater wear rates at higher speeds. in contrast, harder materials like ceramics may exhibit more complex behaviors, sometimes showing an initial reduction in wear rate due to changes in surface interactions. therefore, optimizing sliding speeds is essential for achieving the desired durability and performance across various engineering applications.

VII. Discussions And Conclusions

Different graphs are produced and given in Graphs for changing percentages of reinforcement (TiB2 & Fly Ash) under various test settings at speed 191,382,573 rpm and varying loads based on the tabulated results. The plot shows that the wear of the hybrid composite and the Al6061 & 7075 alloy showed a decreasing trend as the sliding distance increased. This resulted from the fact that at first there were many sharp asperities on both surfaces, and contact between them occurred mostly at these spots. The influence of low applied loads and low speeds was noted during the preliminary wear process in the form of work material smoothness and a tiny lubricant layer between the work material and counter surface.

A few asperities on both surfaces may have fractured during the process, producing very fine 43 debris, and the plastically warped surface will fill the material valley in both the pin and the counter face.

Asperities on the sliding pin surface came into contact with the steel disc surface, causing the matrix to become work hardened. The graph illustrates how TiB2 and fly ash affect the friction coefficient. The hybrid composite's coefficient of friction is lowered by the addition of graphite. The release of TiB2 is responsible for the hybrid composite's lower coefficient of friction when compared to Al 6061 and 7075.

Wear, however, is seen to decrease in all situations in relation to an increase in the percentage addition of reinforcement up to 5%. The detrimental effects of the hard particle addition combined with the growing propensity of fracture initiation and propagation at the reinforcement metal interface may be the cause of the hybrid composites' subsequent marginally increasing trend at 5 weight percent of reinforcement (i.e., TiB2) overshooting the wear rate.

Conclusions about the wear behaviour of alloys made of aluminium 6061/7075 disclose unique properties that are important for engineering applications:

The wearrateof both alloys goes up when thesliding speed and load are higer because thewear from rubbing and sticking gets stronger. This highlights how important it is to improve operat ing conditions to reduce wear and make parts last longer.

When designing with these alloys, it is important to take into account their wear characteristics as well as their mechanical properties to guarantee the best performance and durability in various industrial environments.
Further advancements in surface treatments, lubrication techniques, and advanced materials could improve the wear resistance of both alloys, broadening their suitability for use in challenging conditions.
In terms of behavior, knowing how aluminum 6061 and 7075 alloys wear is crucial to maximizing their durability and performance in engineering applications and providing specialized solutions to satisfy particular industrial demands.

VIII. REFERENCES

[1]. ASM Hand book, Selection and properties of non-ferrous materials, vol. 2. Ohio: ASM International, Metal Park; 1989. p. 1223–40.

[2]. Prasad BK. Engineering materials. Bombay: TMH; 1989. p. 20–50.

[3]. Dwivedi DK, Sharma Ashok, Rajan TV. Methods to improve the structure and properties of cast Al–Si alloys. Ind Foundry J 2000;46(12):31–9 [December].

[4]. ASM Handbook. Friction, wear and lubrication. Ohio: ASM International, Metal Park; 1989. p. 785–91.

[5]. Siva Ramakrishnan CS, Mahanti RK, Kumar R. Stir cast morphology of aluminum– silicon alloys. Aluminum 1981;57(12):820–1.

[6]. Avner SD. An introduction to physical metallurgy. London: Mc Graw Hill; 1999.

[7]. Dwivedi DK, Arjun TS, Thakur P, Vaidya H, Singh K. Sliding wear and friction behavior of Al–18%Si–0.5%Mg alloy. Mater Process Technol 2004;152(3):323–8.

[8]. R. Karthigeyan, G. Ranganath, S. Sankaranarayanan "Mechanical Properties and Microstructure Studies of Aluminum (7075) Alloy Matrix Composite Reinforced with Short Basalt Fiber" European Journal of Scientific Research, ISSN 1450-216X Vol.68 No.4 (2012), pp. 606- 615.

[9]. Arun Kumar D T, Raghavendra Rao P S, Mohammed Shadab Hussain, Naga Sai Balaji P R "Wear Behavior and Microstructure Analysis of Al-7075 alloy reinforced with Mica and Kaolinite" IOP Conf. Series: Materials Science and Engineering 376 (2018) 012067.

[10]. Madhuri Deshpande, Rahul Waikar, Ramesh Gondil, S.V. S Narayan Murty, T.S. Mahata "Processing of Carbon fiber reinforced Aluminum (7075) metal matrix composite" International Journal of Advanced Chemical Science and Applications (IJACSA), ISSN (Online): 2347-761X, Volume - 5, Issue -2, 2017.

[11]. Jamaluddin Hindi, Achuta Kini U, S.S Sharma "Mechanical Characterisation of Stir Cast Aluminum 7075 Matrix Reinforced it Grey Cast Iron & Fly Ash" International Journal
of Mechanical and Production Engineering, ISSN: 2320-2092. Volume- 4, Issue-6, Jun.- 2016.

[12]. Deepak Singla, S.R. Mediratta, "Evaluation of Mechanical Properties of Al 7075-fly Ash Composite Material", International Journal of Innovative Research in Science,
Engineering and Technology [IJIRSET], Vol 2, Issue 4, April 2013, pp 951 – 959

[13]. Niranjan K N, Shiva raj B N, Sunil Kumar M, Deepak A R, "Study of mechanical properties on AL 6061 hybrid composite by stir casting method", International research journal of engineering and technology [IRJET], Vol04, Issue 01, jan 2017, p-ISSN:2395- 0072

[14]. Madhuri Deshpande, Rahul Waikar, Ramesh Gondil, S.V. S Narayan Murty, T.S. Mahata "Processing of Carbon fiber reinforced Aluminum (7075) metal matrix composite" International Journal of Advanced Chemical Science and Applications (IJACSA), ISSN (Online): 2347-761X, Volume - 5, Issue -2, 2017.

[15]. Rabinowitcz E. Friction, wear and lubrication. New York: John Wiley and Sons; 1965. p. 70–118

[16]. G.B. Veeresh Kumar, C.S.P. Rao, N. Selvaraj, M.S. Bhagyashekar, "Studies on Al6061- Sic and Al7075- Al2O3 Metal Matrix Composites", Journal of Minerals and Materials Characterization and Engineering [JMMCE], Vol 9, Issue 1, 2010, pp 43 – 55.

[17]. Prashant S D, Sushil dange, "experimental analysis of aluminum alloys for aerospace application" IRJET, e-ISSN: 2395-0056, p-ISSN: 2395-0072 Vol: 06 issue:03 Mar 2019.

[18]. Arun Kumar D T, Raghavendra Rao P S, Mohammed Shadab Hussain, Naga Sai Balaji P R "Wear behavior and Microstructure Analysis of Al-7075 alloy reinforced with Mica and Kaolinite" IOP Conf. Series: Materials Science and Engineering 376 (2018) 012067.

[19]. American Society for Testing and Material, Annual Book of ASTM Standards. (USA, 1999)

[20]. K. Umanath, S.T. Selvamani, K. Palanikumar, Friction and wear behavior of Al6061 alloy (Sic? Al2O3P) hybrid composites. Int. J. Eng. Sci. Technol. 3(7), 5441–5451 (2011).