THE STUDY OF SAND ABRESIVE WERA BEHAVIOUR OF FORGED Al7075-AlN COMPOSITES

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Abstract

The Al7075 alloy reinforced Aluminium Nitride composites was processed by vortex method, which were then hot forged at a temperature of 440ºC. The continual deformation ratio is set at 2:1. After being hot forged, the Al7075 alloy and Al7075-AlN composites undergo a two-hour solutionizing process at 420°C, followed by ice quenching. The quenched samples were aged naturally and artificially at 120°C for a total of 8 hours. Both matrix alloy and produced composites had their microstructure, micro hardness, and dry sand abrasive wear behaviour assessed in their forged and heattreated states. Scanning electron microscopes have been used to conduct investigations on worn surfaces. Results showed that the matrix alloy's AlN particles are evenly dispersed. Al7075-AlN composites' micro hardness rises when the percentage of reinforcement is increased. When compared to composites that were cast as is, heat-treated forged alloy and its composites are harder. Comparing forged Al7075-AlN composites to the Al7075 matrix alloy, lower abrasive wear loss was seen. As-forged Al7075 alloy and Al7075-AlN composites' abrasive wear resistance is significantly impacted by heat treatment.

KEYWORDS: solutionizing temperature, ageing process, forging.

1. Introduction

Due to its better performance over ordinary alloys, particulate reinforced aluminium alloy matrix composites [1]. They are useful for a wide range of engineering applications thanks to their various custom features, including low density, high stiffness, and high strength. Due to its simplicity, mass manufacturing, ease of adaptation, and suitability for large-scale production, the liquid metallurgical process is the more successful method to create MMCs based on aluminium. [2, 3]. On the other hand, the ease with which they may be molded using traditional secondary metal working methods like extrusion, forging, rolling, etc. makes aluminum-based composites a prime candidate for engineering uses, especially in the aerospace and automotive industries. [8]. these activities have an impact on the mechanical and wear characteristics of composite materials because they can change the microstructural features of the materials [9]. Furthermore, when compared to heavily processed processes like casting, spray deposition, etc., the heat treated aluminum-based composites do show outstanding strength together with great ductility. [10]. Forging is the most popular secondary

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processing method for automotive applications because it can provide significant plastic deformation without causing produced parts to break [11]. Additionally, it is feasible to produce components in a near-net shape [12]. Additionally, by using the right heat treatment, aluminium matrix composites' mechanical characteristics and wear resistance can be improved. Das et al. [13] have discussed the abrasive wear properties of sic-reinforced Al-Si composites in both. According to their findings, unreinforced alloys wear out more quickly than composites do under both as-cast and heat-treated conditions. Additionally, heat-treated composites perform better in all of the examined conditions. Modi et al. [14] Al2O3 reinforced aluminum-zinc alloy's three body abrasive wear behaviour has been studied, and it has been discovered that composites display good wear resistance under all commonly used test conditions. Sanjeev et al. [15] had compared the abrasive wear resistance of aluminium matrix composites enhanced with zircon sand and alumina. Their findings showed that both composites' abrasive wear resistance increased when the particle size was reduced. In contrast to zircon-reinforced composite, alumina particle reinforced composite exhibits comparatively poor wear resistance after forging. Batluri Tilak Chandra et al. [16] has investigated the cast Al7075-Albite composites' adhesive wear behaviour. Their research revealed that Al7075-Albite composites have greater wear resistance than matrix alloy and that this resistance rises with increasing Albite particle loading. Given the foregoing, the current work focuses on the hot forged Al7075-AlN composites' sand abrasive wear behaviour. Al7075-AlN composites' wear resistance after heat treatment has also been researched.

2. EXPERIMENTAL DETAILS

2.1 selection of Material

Due to its many benefits, including outstanding casting qualities, moderate strength, and formability, and heat treatment capacity, the matrix material was considered to be Al7075 alloy. The composition of Al7075 alloy employed in this study was described in Table 1. Aluminum nitride of particle size 75-150 µm was included into the Al7075 matrix as reinforcing material. AlN has very high modulus and hardness, and it has excellent corrosion resistance.

Table 1:The Composition of Al7075 alloy

Name of the element	***Cu***	***Mg***	***Si***	***Fe***	***Mn***	***Cr***	***Zn***	***Ti***	***Al***
Standard requirements %	1.2-2.0	2.1-2.9	0.5 max	0.5 max	0.3 max	0.18-0.28	5.1-6.1	0.2 max	Bal.
Observed value %	1.539	2.191	1.783	0.290	0.275	0.117	4.416	0.047	89.3

2.2 Composite Preparation and Hot Forging

Al7075 alloy that has been extruded is deposited inside an electric furnace, that is then heated to 750° C and maintained there for 30 minutes until the alloy has completely melted. Preheated reinforcement made of aluminium nitride was continuously introduced into the molten metal to the side of the vertex that was formed by mechanical stirring using a stir impeller. Prior to performing this experiment, the ideal speed of 450 rpm was discovered and chosen. This is carried out to avoid the casting from having an unacceptable level of porosity caused by a high gas concentration that came from excessive metal agitation [5]. The stirring procedure is carried out to promote uniform dispersion of particle aluminium nitride in to the melted, molten metal. The cast is immediately inserted into a permanent mould after five minutes of swirling the composite mixture metal matrix Al7075-AlN composite is removed from the mould.

At Fitwell Forgings Pvt.Ltd., Tumkur, the cast Al 7075 and Al 7075 - Aluminum Nitride Composites are heated and forged using a hydraulic hammer. The cast metal and composites were sized to be 80 mm in diameter and 110 mm in height via machining. Then, using a hydraulic hammer, 300 tons of hot forging pressure was applied to the machined cast samples. The machined billets were preheated to 440±3ºC for 2 hours soaking time.

2.3 Heat Treatment

The developed As-cast Al7075 alloy and its composites were hot forged ,then it is subjected to heat treatment process with solutionzing temperature 470ºC of 2 hours and quenched in ice medium and ageing process with temperature 120ºC,for a duration of 8 hr were carried. Hardness test and Microstructural studies were done on both as cast and heattreated MMCs.

2.4 Microstructure Analysis

SEM structural analyses of forged Al7075 alloy and Al7075-AlN composites were performed. For microstructural study, samples are taken from both Al7075 alloy and its composites, and they were polished using conventional metallographic procedures. With use of Keller's reagent, the polished samples were etched.

2.5 Micro hardness

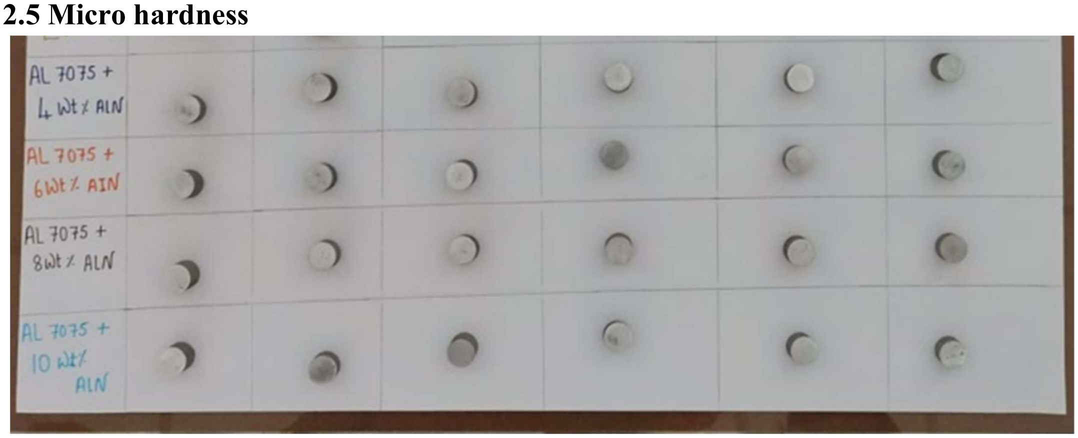


Figure1: The pictorial view of Hardness specimen before and after indentation

The hardness tests specimens before and after indentation is shown in Figure1. In order to compare the specimens of as-cast and composites with Al7075 matrix alloy, a hardness measurement was performed on them. Using emery paper of various grits, round specimens with a 20 mm diameter were made and polished in accordance with ASTM E10-95. The Brinell hardness testing machine is used to analyze the polished specimens. A ball indenter with a 10 mm diameter was used to apply a load of 500 Kgf for 30 seconds (HB500). Five different test sites were used to conduct the experiment in order to rule out any potential effects of the indenter sitting on the tougher particles. By measuring the diameter of the generated indentations, hardness was calculated. The hardness of cast and composite specimens was determined by averaging the five values.

2.6 Sand Abrasive Test

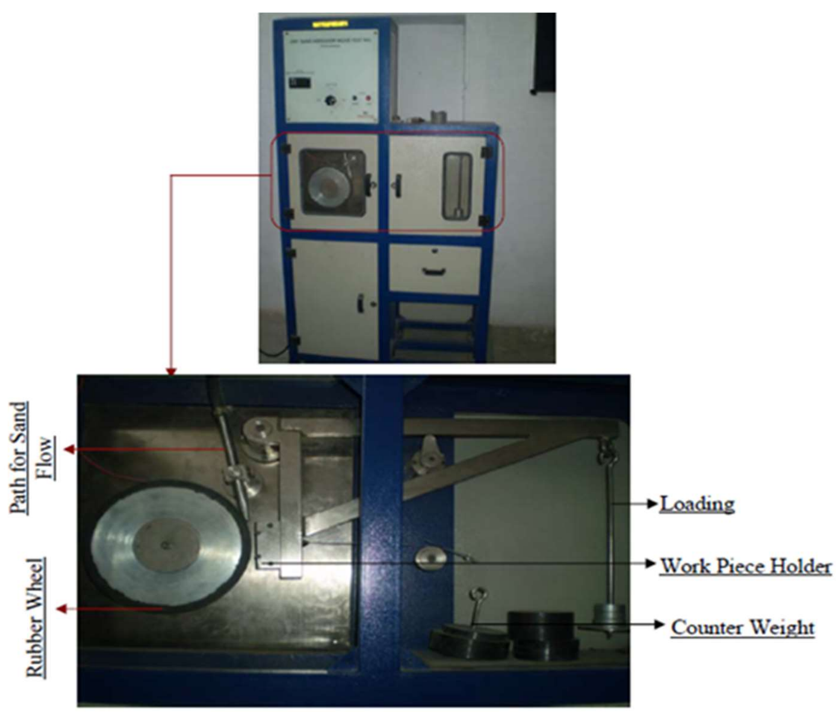


Figure 2: Dry Sand Abrasion Test apparatus

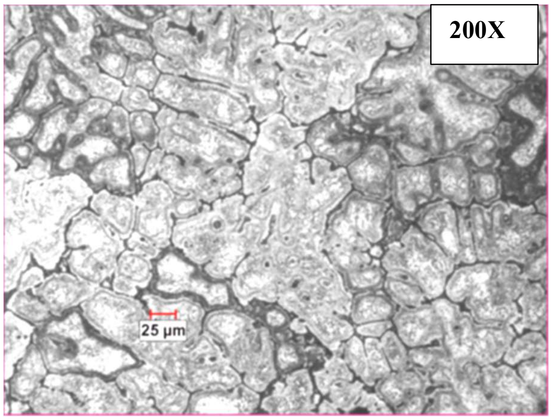
Sl. No.	Description	Particulars
1	Abrasive material	AFS 50-70 test sand
2	Rubber wheel speed	200 rpm through a helical geared motor of 1.5 kW (3 Phase)
3	Test load	1 to 45 N
4	Rubber wheel diameter	228 mm
5	Power	430 V AC (3 Phase)
6	Specimen dimension	75 x 24 x 8 mm
7	Erodent	AFS3080
8	Sand mass flow rate	0.25 kg/min or 2.45 N/min
9	Rubber hardness	60-62 shore A
10	Duration	30 min
11	Pressure	5.88 N/mm^2
12	Load	12.75 N

Table 2: Details of Sand Abrasive Wear Test Apparatus

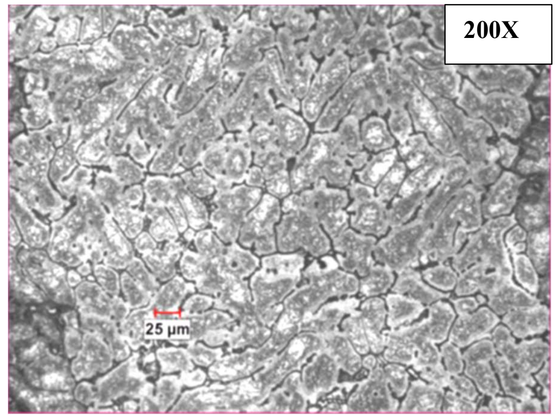
Figure 2 displays the image, and Table 2 provides information on the sand abrasion tester utilized in this study. According to ASTM G65-81 standard, the Al7075 alloy and Al7075-Aluminum Nitride particle composites were subjected to three body abrasion wear tests. A specimen measuring 75X25X8 mm was used for the wear test, and silica sand with a particle size of 50 µm is used. The samples were cleaned meticulously, and their starting weights were noted. For 30 minutes duration, the speed is maintained at 200 rpm. The experiments were carried out by increasing the load by increments of 2N from 2N to 10N silica sand as the abrasive medium. The specimens were carefully cleaned with acetone once more after each test was finished, and each specimen’s final weight was noted. The specimen's weight loss was reported as the difference between its initial weight and final weight. Using a digital scale, the wear was calculated in terms of mass loss. with a 0.1 mg precision. After the test, SEM analyses were performed on the worn surfaces to determine the causes of the wear [11].

3. Results and Discussion

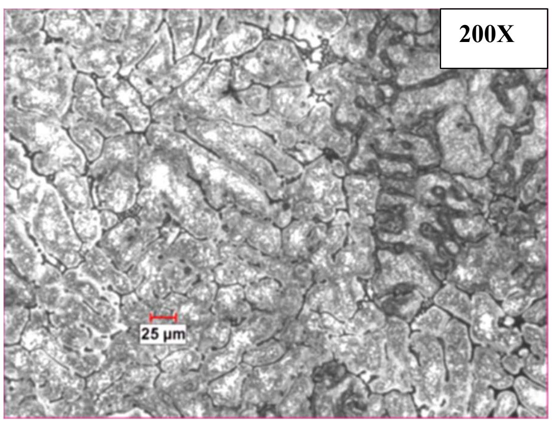
3.1 Microstructural Studies



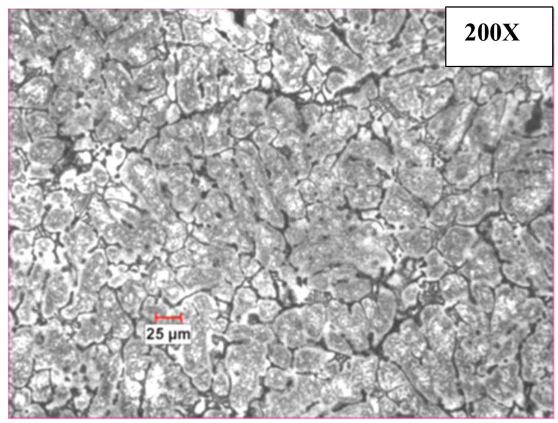
Al7075andAlN 0wt%



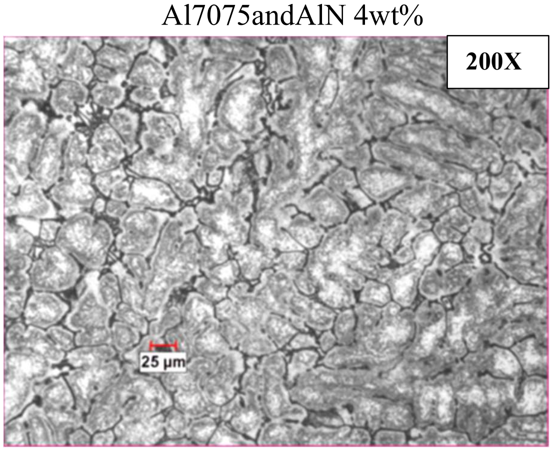
Al7075andAlN 2wt%



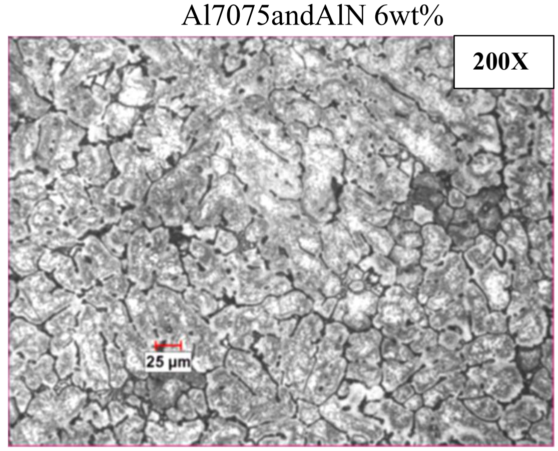
Al7075andAlN 4wt%



Al7075andAlN 6wt%



Al7075andAlN 8wt%



Al7075andAlN 10wt%

Figure 3: optical microstructure of Aluminium alloy (Al7075) – Aluminium nitride composites

After image analysis, Fig. 3 displays optical micrographs of forged composites to demonstrate the homogeneous dispersion of AlN particulate all over the matrix. The SEM of powdered aluminium nitride is displayed in Figure 4. The intermetallic precipitates' SEM micrograph (MgZn2) after heat treatment is shown in Figure 5. The grain boundaries are where the majority of the precipitates are found. The EDAX pattern of MgZn2 precipitates is depicted in Figure 6 with the presence of Mg and Zn peaks being visible.

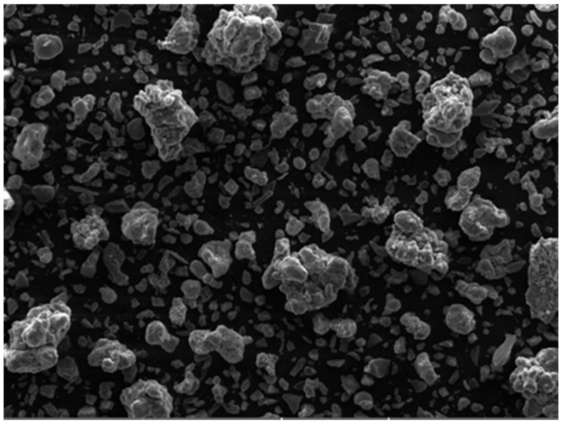


Figure 4: SEM Photography of Aluminium Nitride Particles

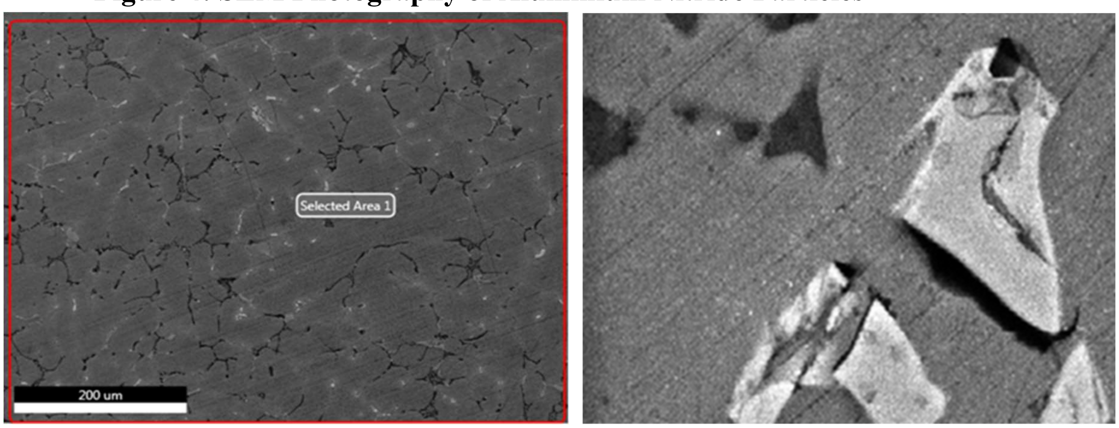


Figure 5: SEM Photograhy of forged Al7075-AlN composites

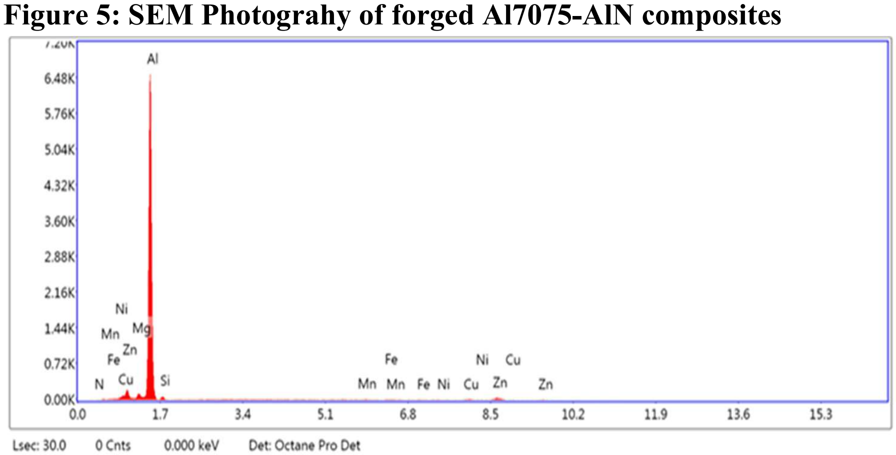


Figure 6: EDAX pattern of the presence of intermetallic precipitate in heat treated Al7075-AlN composite

3.2 MicroHardness

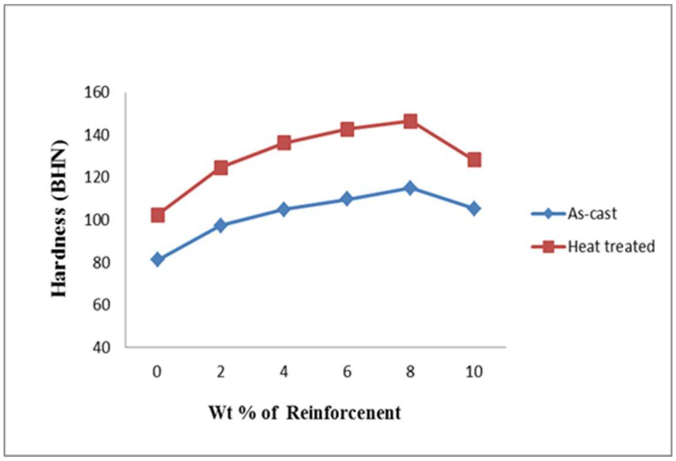


Figure 7: variation of hardness of as cast and forged-Heatreated Al7075-AlN composite

Figure 7 illustrates the differences in micro hardness of Al7075-AlN composites in their as cast and forged- heat treated states. It has been found that the micro hardness of matrix alloys of forged- heat-treated increases as the fraction of AlN particles increases. When compared to Al7075 matrix alloy, Al7075-8 wt% AlN composite as cast and forged and heat-treated Al7075-8 wt% AlN composite, respectively, show improvements of up to 28.78 and 54.5%. The following factors can be used to explain why an increase in the percentage of AlN particles in the matrix alloy causes an increase in hardness.

1. AlN particles have a greater hardness. Hard reinforcement in a ductile, soft matrix always increases the alloy's overall hardness.
2. The matrix alloy and the reinforcement are compatible
3. Due of a thermal mismatch between the Al7075 matrix alloy and the AlN particles, an increase in the reinforcing content in the matrix alloy causes an increase in dislocation densities during solidification, delaying plastic deformation. Together with the reinforcing particles, larger dislocation densities will prevent dislocation movement, increasing hardness.

3.3 Sand Abrasion Test Results

3.3.1 Effect of Reinforcement

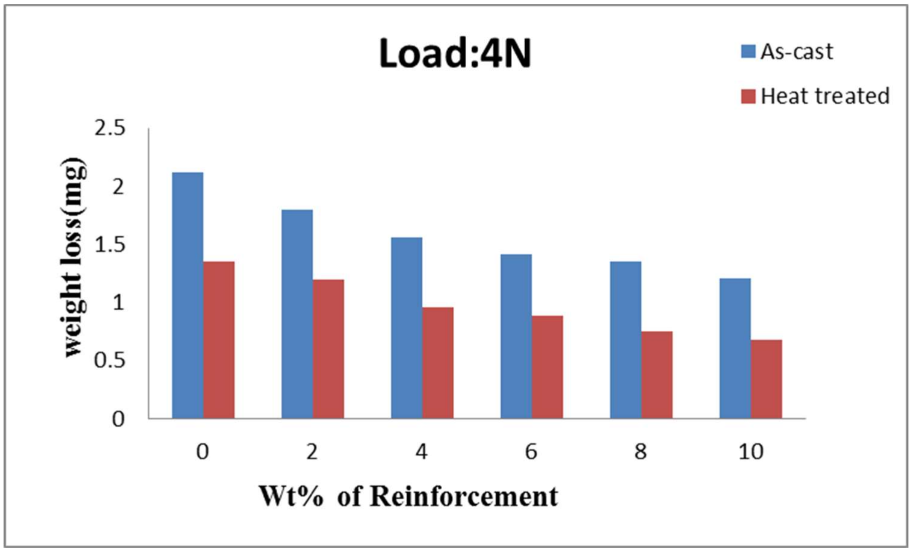


Figure 8: Effect of reinforcement on wear rate of Al7075 alloy and its composites

At speed of 200 rpm and load of 4N, Figure 8 illustrates the impact of reinforcement on the wear rate of Al7075 alloy and its composites. As the reinforcing content in the matrix alloy increases, it is observed from the figure that abrasive wear decreases. This decrease in the rate of abrasive wear was anticipated since aluminium nitride particles are a very hard substance that significantly increases the composites' resistance to abrasive wear. When compared to as cast al7075 matrix alloy, the abrasive wear resistance of as-cast al7075-8 wt% of aluminium nitride composite increased by 34%, while that of heat-treated al7075-8 wt% of aluminium nitride composite increased by 43%. The increased amount of Aluminum nitride particles, which raises the composites' hardness and hence increases their abrasive wear resistance, increases the composites' ability to resist abrasive wear.[22] Under three different body abrasion wear settings, the matrix alloy experienced the highest abrasive wear rate because there were no hard aluminium nitride particles and no interfacial bonding. The interfacial bond between the reinforcement and the Al7075 matrix alloy was determined to be the primary cause of the composite material's significantly better wear resistance. All of the composites had a strong interfacial binding because no AlN particles were pulled out of the material, which led to a lower rate of material removal.

3. 3. 2 Effect of applied load

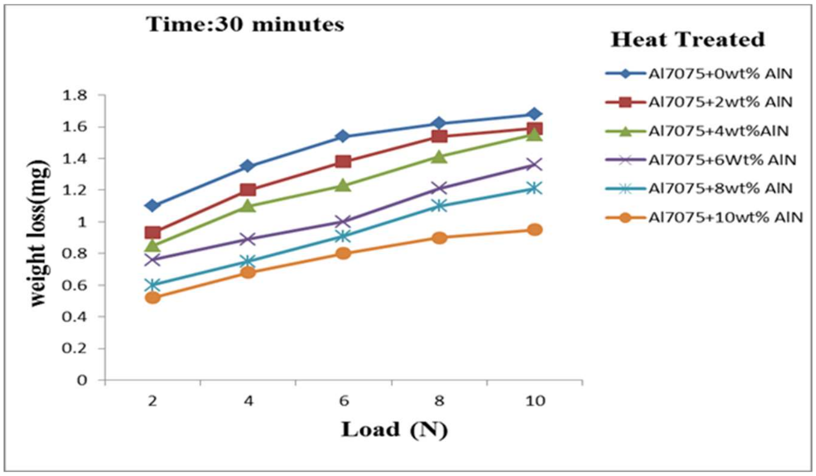
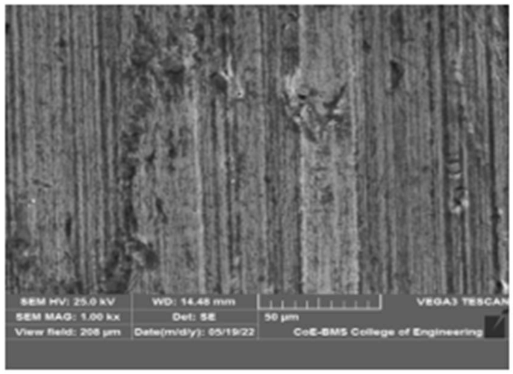


Figure 9: Variation of wear rate of Al7075 alloy and its composites for different applied load at heat treated conditions

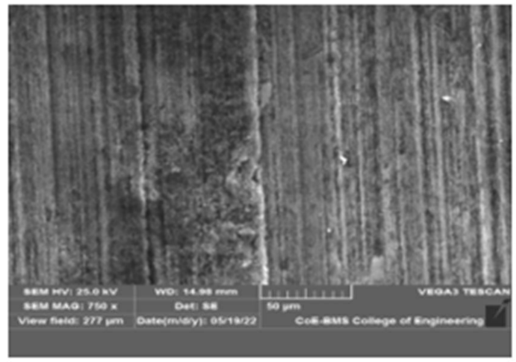
Figure 9 indicates the changes of the abrasive wear rate of heat treated al7075 alloy and al7075-Aluminium nitride composites under different applied loads. The treatment has a significant impact on the composite materials' rate of abrasive wear .heat treated matrix alloy and its composites exhibit excellent abrasive wear resistance when compared with the un hearted al7075 alloy and its composites .however, at all the loads studied, When compared to heat treated matrix alloy, heat treated composites show a lower rate of abrasive wear. D Ramesh[5] reported that when the reinforcement content in the matrix alloy increases, the abrasive wear resistance of composites increases and the heat treated composites materials exhibit superior abrasive wear resistance that the as cast alloy.

By incorporating hard AlN particles in the ductile Al7075 alloy, the penetration of abrasive particles onto the surface is protected and limited [23]. Hardness improves as a result of an increase in abrasive wear resistance. One of the core components affecting the wear resistance of the composite between the reinforcement and the matrix alloy is the interfacial bond strength. [24].

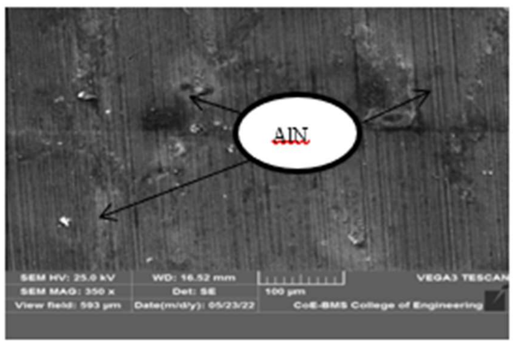
3.3.3 Worn Surface Analysis



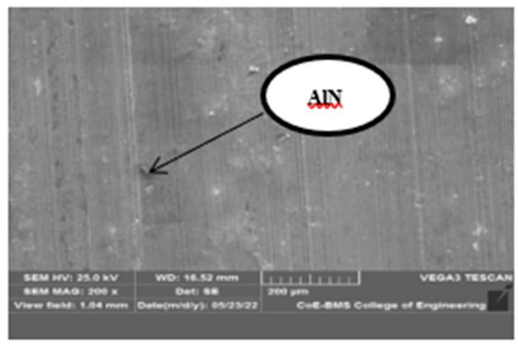
(a) as cast Al7075 matrix alloy



(b) Heat treated Al7075 matrix alloy



(c) as cast Al7075-8wt% composite



(d) Heat-treated Al7075-8wt% composite

Figure 3.10: (a) SEM of as-cast Al7075 matrix alloy (b) SEM of heat treated Al7075 matrix alloy (c) SEM of as-cast Al7075-8wt% composite (d) SEM of heat treated Al7075-8wt% composite

As-cast and heat-treated Al7075 matrix alloy worn surface SEM photos are shown in figure 3.10 (a),(b),(c) and (d) .Contrasted with Heat processed Al7075 matrix alloy, considerable plastic grooving and ploughing was seen in As-cast Al7075 matrix alloy. This is because the Al7075 matrix aged and became harder.

Conclusions

1. The stir casting method was used to successfully create an Al7075 reinforced with AlN particle composite
2. The microstructural investigation clearly demonstrates that the AlN particles are distributed uniformly throughout the Al7075 matrix alloy.
3. The Al7075-AlN particulate composite's hardness increases up to 8 weight percent of AlN but then decreases.
4. As AlN particles added with percentage of the weight to the Al7075 matrix alloy increase the wear resistance of heat-treated composite.
5. Al7075-AlN composites that have been forged and heat-treated outperform Al7075 alloy conditions in terms of microhardness and abrasive wear resistance.

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