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RESEARCH ARTICLE

TRIBOLOGICAL PROPERTIES OF ALUMINIUM- KYANITE COMPOSITES.

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Abstract

Kyanite is a natural mineral and has a common chemical formula (Al_2SiO_5) along with Andalusite, Sillimanite and Mullite. An experiment is conducted in order to study the tribological properties of this natural mineral. In this regard, kyanite is used along with aluminium to synthesize composite with a solidification technique. 99.8% aluminium is used as matrix alloy. 16- 30 µm mean size kyanite particles are used as reinforcement. By creating vortex with the help of a mechanical stirrer, kyanite particles were added and the temperature is maintained in between 750 ^{0}C to 1200 ^{0}C. It is observed that kyanite particles were uniformly distributed within the base matrix and exhibited good bonding. The casted composite is tested for corrosion test, wear test, frictional force and coefficient of friction. It is found that all the tribological properties are significantly higher than the base alloy.

Introduction:-

Composites are generally prepared by adding dissimilar materials together to work as single mechanical unit properties of such materials are different in scale and kind from those of any of its constituent. These materials may have a hard phase in soft matrix and vice-versa. In most cases a hard phase is embedded in a soft matrix and it increases the modulus or strength of the matrix. A soft phase embedded in hard matrix increases the shock resistance of the materials. Aluminium is known for low density and ability to resist corrosion. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. Aluminium is three times lighter than steel, and it is this lightweight property along with its strength that can be obtained in certain alloys (by altering the structure), that makes aluminium particularly important in air travel. It's high level of malleability (2nd most malleable metal) means it can be easily moulded into many shapes.

Kyanite is an alumino – silicate mineral with the chemical formula Al_2SiO_5. Kyanite is a member of the aluminosilicate group which includes andalusite and sillimanite. Kyanite hardness varies depend on its crystallographic direction. Kyanite has a high melting-point and excellent refractory properties. When it is heated to about 1350ºC it converts into mullite and free silica. The conversion takes place with considerable increase in volume (which is about 20%), hence it is necessary to calcine kyanite before use. For refractory purpose, kyanite should contain a negligible quantity of impurities like iron oxide, free silica, oxides of calcium and manganese and alkalies.

Experimental Procedure:-

Materials:-

Aluminium was used as the base alloy. The chemical composition of the matrix alloy is given in Table 1. Kyanite was used as dispersoid material and it was procured from Navbhan exporters, Bangalore, India. The chemical composition of the kyanite particles is given in Table 2. The particles were heated up to 1200ºC in the presence of air.

Table 1:- Chemical composition of the matrix alloy.

Constituent	Wt.%
Si	0.15
Fe	0.15
Mn	0.02
Mg	0.02
Cu	0.03
Zn	0.03
Ti	0.03
V	0.05
A	Balance

Table 2:- Chemical composition of the kyanite sample.

Constituent	**Wt.%**
Al_2O_3	55.0
SiO_2	37.04
TiO_2	0.64
Fe_2O_3	0.35
ZrO_2	3.4
CaO	0.01
MgO	0.03

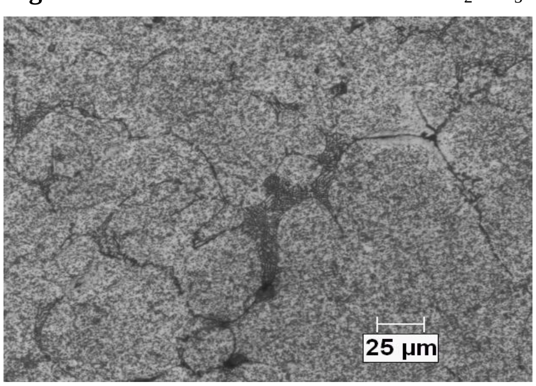
Composite preparation:-

The composite was prepared using coke fired furnace. Aluminium (2 kg) plates were heated in a graphite crucible to their molten state. Degassing of the molten metal was carried out by passing nitrogen gas through the melt after covering the melt with a flux (Coveral-11). The melt was cleaned by taking out the dross collected on the melt surface with a perforated flat spoon. After maintaining the temperature of the melt between 750 and 800ºC, a vortex was created in the melt by using a mechanical stirrer. While stirring was in progress, preheated kyanite particles (3 wt %) were added to the melt. Simultaneously, magnesium pieces were added to the melt to facilitate the dispersion of the sillimanite particles in the melt. Stirring was continued for 5 min after the addition of all the kyanite particles in the melt in order to have a better distribution of the particles in the melt. Test specimen castings in the shape of cylinders (diameter, 28 mm; length, 200 mm) were prepared by pouring the melt into cast iron permanent moulds. The same process will be repeated for 5 and 7 wt %.

Results and discussion:-

Micro structure:-

Figure 1:- Microstructure of Al- 3% wt Al_2SiO_5 Particles at 200X.



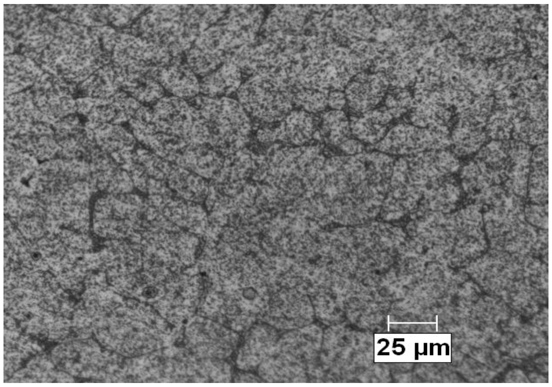


Figure 1 shows the microstructure of the 3% wt Al_2SiO_5 composite, where the uniformly distributed, spherically shaped particles are clearly seen. The figure shows that no broken Al_2SiO_5 particles are observed, but matrix particle decohesion and voids in the matrix were observed.

Figure 2:- Microstructure of Al- 5% wt Al_2SiO_5 Particles at 200X.

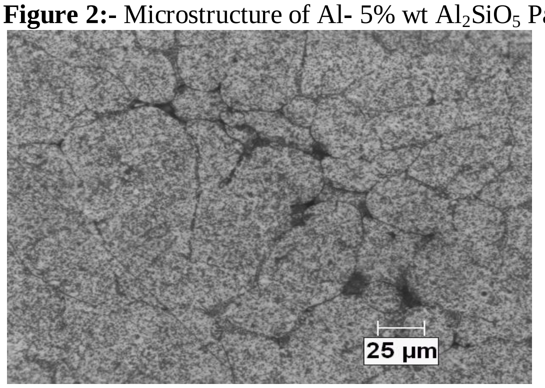


Figure 2 shows the microstructure of the 5% wt Al_2SiO_5 composite. Again, no fractured Al_2SiO_5 particles are seen. In Figure 3, the Al_2SiO_5 particles can be grouped together in which few large Al_2SiO_5 particles are intermingled with smaller, uniform and regular shaped particles.

Figure 3. Microstructure of Al- 7% wt Al_2SiO_5 Particles at 200X.

Wear Test:-

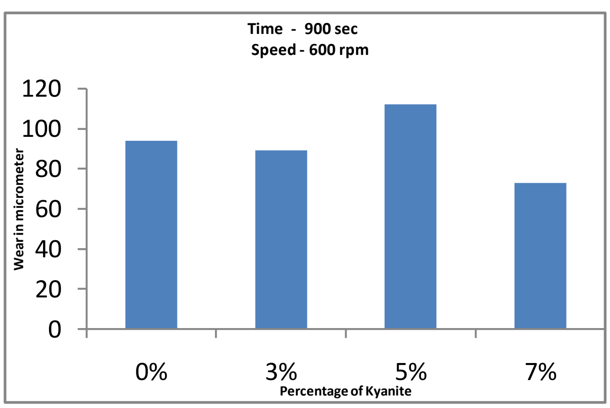


Fig 3:- sliding wear under 2 kg load for different percentage of kyanite

Variation of wear values with increased content of reinforcement studied under 2 kg load is shown in Fig.1 and the results indicates that the wear decreases with increase in reinforcing content except in 5wt%. From the figure it is observed that 3% kyanite & 7% kyanite are having less wear. Increased content of reinforcement results in enhanced resistance to wear of composites for a given reinforcement content. Composites with kyanite reinforcement possess higher wear resistance except in 5% kyanite when compared with base matrix. Al with 7% kyanite composite posses a higher wear resistance of 22% under 2 kg load when compared with Base matrix.

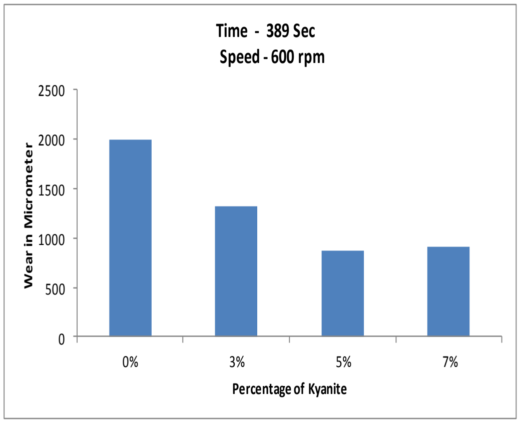
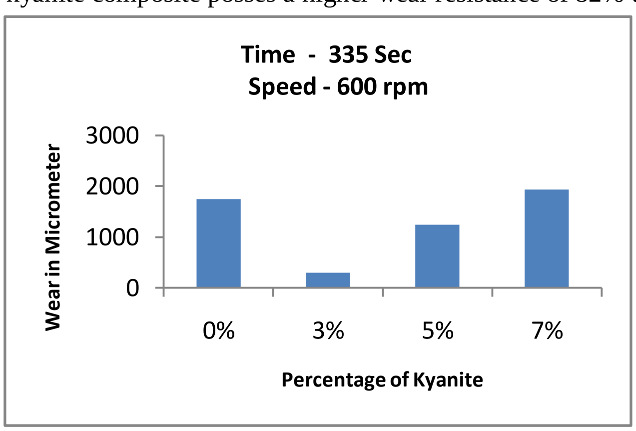


Fig 4:- sliding wear under 4 kg load for different percentage of kyanite.

Variation of wear values with increased content of reinforcement studied under 4 kg load is shown in Fig.2 and the results indicates that the wear decreases with increase in reinforcing content.

From the figure it is observed that 3% kyanite, 5% kyanite and 7% kyanites are having less wear when compared to base matrix. Increased content of reinforcement results in enhanced resistance to wear of composites for a given reinforcement content under 4 kg load. Composites with kyanite reinforcement possess higher wear resistance when compared with base matrix. Al with 5% kyanite composite posses a higher wear resistance of 56% under 4 kg load when compared with Base matrix.

Fig 5: sliding wear under 6 kg load for different percentage of kyanite
Variation of wear values with increased content of reinforcement studied under 6 kg load is shown in Fig.3 and the results indicates that the wear decreases with increase in reinforcing content except in 7wt%. From the figure it is observed that 3% kyanite and 5% kyanites are having less wear. Increased content of reinforcement results in enhanced resistance to wear of composites for a given reinforcement content. Composites with kyanite reinforcement possess higher wear resistance except in sample 4 when compared with base matrix. Al with 3% kyanite composite posses a higher wear resistance of 82% under 6 kg load when compared with Base matrix.



Co-efficient of Friction:-

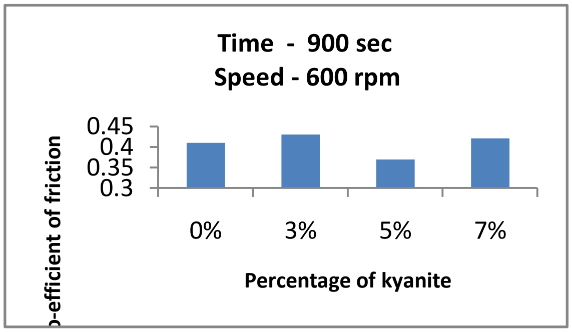


Fig 6:- Co-efficient of Friction under 2 kg load for different percentage of kyanite.

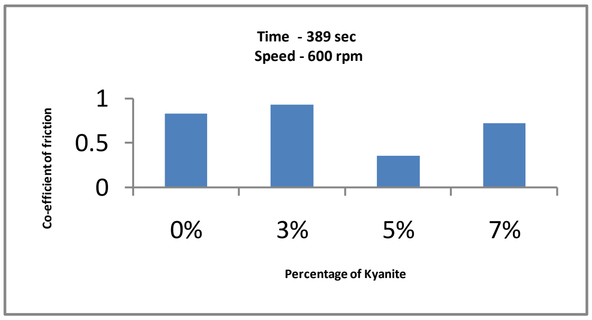


Fig 7:- Co-efficient of Friction under 4 kg load for different percentage of kyanite

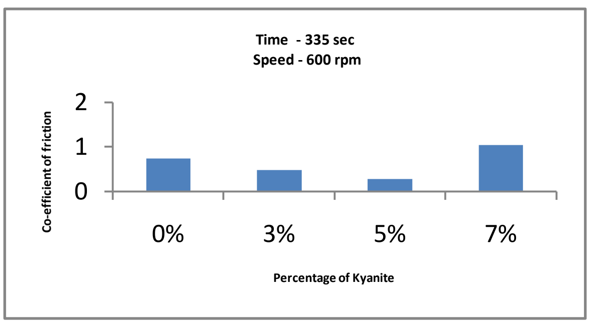


Fig 8:- Co-efficient of Friction under 6 kg load for different percentage of kyanite.

Fig. 6 shows the relationship between Co-efficient of Friction and % of Al_2SiO_5 addition under 2kg load. It can be seen that, 3% kyanite showed much higher coefficient of friction 0.43 and whereas 5% kyanite showed lower coefficient of friction 0.37. In dry sliding the reason for the decreased coefficient of friction of Al- Al_2SiO_5 composites as compared with the base alloy is attributable to the presence of the smeared kyanite layer at the sliding surface which acts as the solid lubricant. With increasing kyanite content the thickness of the lubricating film and the amount of kyanite in the lubricating film also increases. This results in lowering the coefficient of friction in the composites. But the coefficient of friction is high in 3% kyanite and 7% kyanite. This is because the amount of kyanite presence at sliding surface is less.

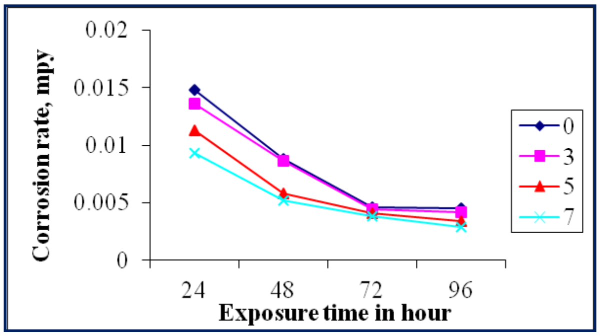
Fig. 7 shows the relationship between Co-efficient of Friction and % of Al_2SiO_5 addition under 4 kg load. It can be seen that, 3% kyanite showed much higher coefficient of friction 0.9 and whereas 5% kyanite showed lower coefficient of friction 0.34. In dry sliding the reason for the decreased coefficient of friction of Al- Al_2SiO_5 composites as compared with the base alloy is attributable to the presence of the smeared kyanite layer at the sliding surface which acts as the solid lubricant. With increasing kyanite content the thickness of the lubricating film and the amount of kyanite in the lubricating film also increases. This results in lowering the coefficient of friction in the composites. But the coefficient of friction is high in 3% kyanite and 7% kyanite. This is because the amount of kyanite presence at sliding surface is less.

Fig. 8 shows the relationship between Co-efficient of Friction and % of Al_2SiO_5 addition under 6 kg load. It can be seen that, 7% kyanite showed much higher coefficient of friction 1.03 whereas 5% kyanite showed lower coefficient of friction 0.27. In dry sliding the reason for the decreased coefficient of friction of Al- Al_2SiO_5 composites as compared with the base alloy is attributable to the presence of the smeared kyanite layer at the sliding surface which acts as the solid lubricant. With increasing kyanite content the thickness of the lubricating film and the amount of kyanite in the lubricating film also increases. This results in lowering the coefficient of friction in the composites. But the coefficient of friction is high in base matrix ans 7% kyanite. This is because the amount of kyanite presence at sliding surface is less.

Corrosion test:-

Fig 7: Corrosion rate values in 3.5 % NaCl for different percentage of Kyanite with varying exposure time

After immersing in 3.5 % NaCl solution for 96 h, the mass loss of all samples is so slight that it can be almost ignored. After being immersed in 3.5% NaCl solutions for 96 h, the mass losses of base matrix and Al_2SiO_5 addition are shown in Fig.7. The mass loss of base matrix in 3.5% NaCl solution is 0.0045 mpy but that of 7% Al_2SiO_5 addition is only 0.0029 mpy, which indicates the better corrosion resistance of composites in comparison with base matrix. The immersion corrosion results confirm the above discussed effects of different percentage of Kyanite on corrosion resistance and shows obvious differences in corrosion performance of base matrix and composites.



Conclusions:-

- Dry sliding wear of Al- Al_2SiO_5 particulate composite was found to decrease with kyanite content and touched a minimum wear rate.
- The coefficient of friction of Al- Al_2SiO_5 composite was also found to decrease with addition of 5wt% kyanite particles and recorded a 2 times lower value than the base matrix at 4 kg and 6 kg .
- In NaOH and NaCl solutions, Al- Al_2SiO_5 composite exhibits improved corrosion resistance in comparison with base matrix.
- Microstructure studies reveal fairly uniform distribution of Al_2SiO_5 particles in the matrix with a good bonding between the matrix and the reinforcement.
- The SEM of fractured surface was rough and covered with a healthy population of voids of varying size, dimples of varying size and shape, and isolated pockets of fine microscopic cracks.

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