Investigating the Wear Characteristics of Aluminium356/ Alumina Nanocomposite and Studying the impact of MoS_2 addition into Aluminium356/ Alumina Nanocomposite

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Abstract: The tribological properties of the aluminium matrix composite (AMCs) reinforced with alumina (Al_2O_3) are extremely good. As a result of this evolution, an attempt is made to examine the wear characteristics of nanocomposites A356 reinforced with alumina (0.5 wt.%, 1 wt.%, and 1.5 wt.%). However, the lubrication properties of aluminum-based ceramic composites need to be improved. The inclusion of MoS_2 (0.5 wt.%), which works as a lubricant, is used in this study to try to build a new material using the stir casting. The pin-on-disc technique was used to determine the wear rate of the nanocomposites. The investigations were carried out under dry sliding condition with load varies from 10N to 50N , sliding distances varies from 1000m to 5000m and a constant sliding velocity of 2m/s. Results have shown that 1.5 wt.% of alumina improves the wear resistance in nanocomposites. The incorporation of nano MoS_2 particles into the A356/ Al_2O_3 nanocomposite improves the tribological characteristics of the hybrid nanocomposites. Due to the inclusion of MoS_2 and an increase in alumina, the wear rate of hybrid nanocomposites is reduced.

Keywords: Aluminium356, Wear resistance, Hybrid nanocomposites

1. Introduction:

HMMCs have recently sparked a high amount of interest upon the research field. It has high stiffness, fracture toughness, strength, than conventional materials and can endure high temperature in corrosive environments. AMCs are a type of revalued material that is commonly used to develop tribological and structural components for aircraft and automobiles. However, adding ceramic particle reinforcement to AMCs can improve its tribological and mechanical characteristics. HMMCs with hard ceramic and solid lubricant have good tribological performance.

Hybrid nanocomposites outperform nonhybridized composites in relation to tribological and mechanical properties. The particle size of a composite is one of various methods for improving its characteristics. Nanoparticles reinforced materials outperform traditional materials in terms of microstructure stability and mechanical behaviour. A356 alloy is widely used in a variety of industries, including aircraft, automobiles, electronics and many others, because it is corrosion resistant, less dense and has higher electrical and thermal conductivity.

The wear properties of nanocomposites made of A356/0.5 % Al_2O_3, A356/1 % Al_2O_3 and A356/1.5 % Al_2O_3 were investigated in this study. Later, 0.5 % MoS_2 was added to the above combinations and the effect of inclusion of nano MoS_2 on wear properties was investigated.

Ajay Kumar K et.al [1] analyzed the characteristics of A356 reinforced with MoS_2 and alumina produced by stir casting route. The inclusion of MoS_2 results in reduced wear rate compared to A356 wear rate. Sivaraj.S et.al [2] studied the properties of wear & hardness of A6061/ nano Al_2O_3/ nano TiB_2 composites. The 2.5 wt.% $Al_2O_3$and 2.5 wt.% TiB_2 reinforced composite content performs better and has a lower wear rate. As the proportion of reinforcement increases, the hardness and wear resistance improve. K. Manisekar et.al [3] studied the wear properties of nanocomposites by increasing the reinforcement percentage. The mechanical and tribological characteristics of the 5% Gr and10% SiC Nanocomposites were significantly improved.

Cigdem Gokcen et.al [4] studied the wear characteristics of composites. Vortex and squeeze casting techniques were used to make composites using alumina particles. The wear rate was stated to decrease as the load & volume fraction increases. Purohit et.al [5] studied the abrasion characteristics of aluminium7075/Al_2O_3 MMCs. The findings revealed that when the Al_2O_3 particle percentage in the Al7075/ Al_2O_3 MMCs increases, abrasive wear rate is decreased. C. Velmurugan et.al [6] investigated the tribological properties of the AMCs reinforced with TiC and MoS_2. According to ANOVA, the proportion of MoS_2 in combination with applied load and sliding velocity has a major influence on the wear. The composite reinforced with MoS_2 has less wear rate than the composite without MoS_2.

Madev Nagaral et.al [7] studied the characteristics of Aluminium6061/alumina composites. Composites have a lower wear rate than Al6061 at a load of 19.1N and a speed of 300rpm. T. Laoui et.al [8] studied the microstructure & characteristics of A356/ Al_2O_3 / SiC/B_4C MMCs. Particle distribution was found to be more effective in A356/B_4C composites than in A356/SiC and A356/Al_2O_3 composites. In comparison to A356/SiC and A356/Al_2O_3 composites, A356/B_4C has a greater interface bonding. The particle dispersion, friction, wear characteristics and material combination was analyzed by SEM, EDX, and pin-on-disc testing method. For a combination of 5wt.% Al_2O_3 and 5 wt.% MoS_2, the aluminium composite has significantly improved wear properties. V M Ravindranath et.al [10] examined the features of Aluminium2219 / MoS_2/B_4C. The inclusion of B_4C and MoS_2 reinforcement has reduced the wear rate and improves the resistance to wear.

2. Experimental Procedure

2.1 Materials

The work uses nano MoS_2 and nano Al_2O_3 particles as hybrid reinforcements, with Aluminium356 alloy as the chosen matrix material.

2.2 Composite Preparation

The nanocomposites A356 + 0.5wt.% Al_2O_3, A356 + 1 wt.% Al_2O_3, and A356 + 1.5 wt.% Al_2O_3were made using matrix material Aluminium356 and reinforcement alumina.. By mixing 0.5 wt.% nano MoS_2 to the above compositions, three more hybrid nanocomposites were created. The nanocomposites were prepared using the conventional stir casting shown in fig 1. In a crucible, measured quantities of Aluminium356 and reinforcements were heated in an electric furnace. A coated mild steel impeller was rotated for a few minutes at 550-600 rpm to maintain homogenous reinforcement distribution in the matrix. The impeller was placed two-thirds of the way down the molten metal's height. The stirring was carried on for additional 4 minutes to make sure that reinforcement & matrix were properly blended. The castings were prepared by pouring molten metal into molds.

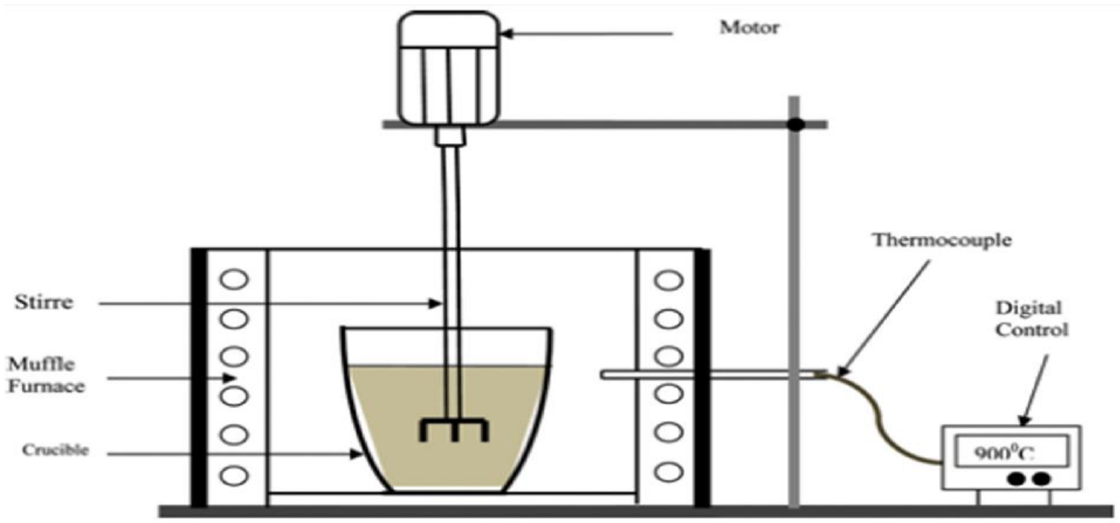


Fig 1. Stir casting technique.

2.3 Wear Test

Many MMC based mechanical elements are used in situations where they are subjected to relative motion with their mating parts. The tribological qualities of the elements involved in these kinds of scenarios have an impact on the mechanical system's performance. Wear is the damage to material surfaces caused by either of two solid substrates moving in a rolling, sliding, or impact action connected to each other. Wear is caused by the interplay of asperities on the surfaces which are in contact with one another.

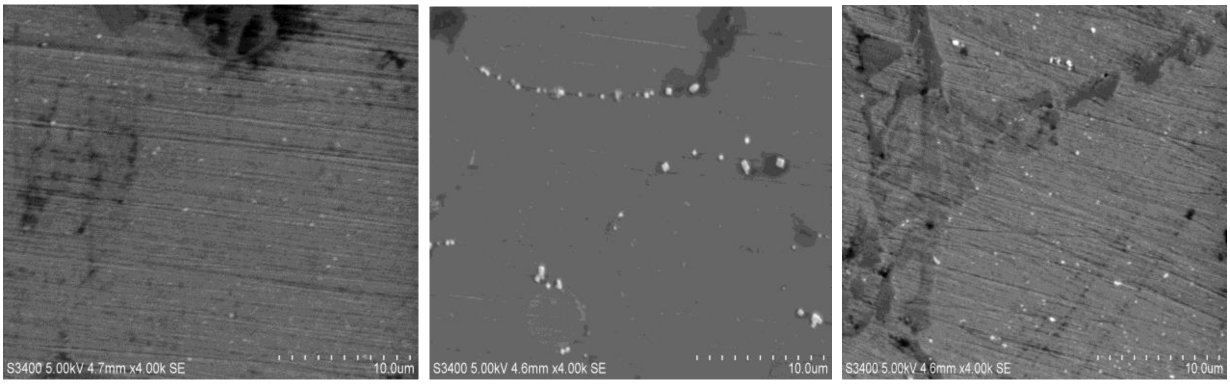
Pin on disc equipment with an electronic data gathering system shown in fig 2 is used to assess wear rate of substances during sliding motion.

Fig 2: Wear test equipment

3 Results and Discussions

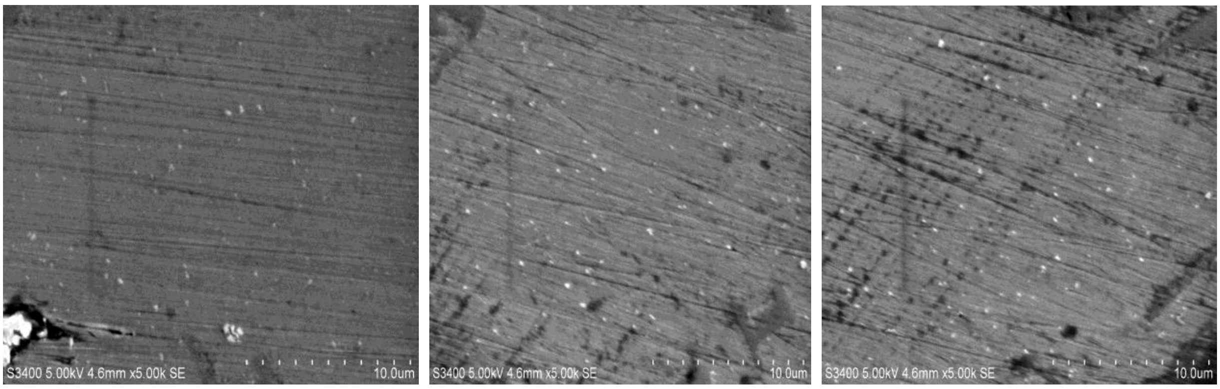
3.1 Microstructure Characterization

The microstructure of the specimens was examined using a (SEM) to determine particles distribution and voids.



(a) A356 + 0.5% Al_2O_3 (b) A356 + 1% Al_2O_3 (c) A356 + 1.5% Al_2O_3

Fig 3: SEM of A356/Al_2O_3 nanocomposite



(a) A356 + 0.5% MoS_2 + 0.5% Al_2O_3 (b) A356 + 0.5% MoS_2+ 1% Al_2O_3 (c) A356+ 0.5% MoS_2 + 1.5% Al_2O_3

Fig 4: SEM of A356/Al_2O_3/MoS_2 hybrid nanocomposite (1)

Fig 3 and 4 shows SEM micrographs of nanocomposites and hybrid nanocomposites respectively. SEM was used to analyse the reinforcement distribution. All of the composites had evenly distributed particles. The homogenous distribution of reinforcements in AMCs has been shown to have a significant impact on mechanical characteristics.

3.2 Effect of sliding distance on Wear

Aluminium composites are used for brake lining and drums due to their wear resistance and relatively lower thermal expansion. The composites are put through a wear test to see how resistant they were to wear. The wear performance of the Aluminium356, nanocomposites and hybrid nanocomposites were examined with load varies from 10N to 50N , sliding distances varies from 1000m to 5000m and a constant sliding velocity of 2m/s. Fig 5 and Fig 6 shows the wear rate of Aluminium356, nanocomposites and hybrid nanocomposites of different compositions with respect to sliding distance.

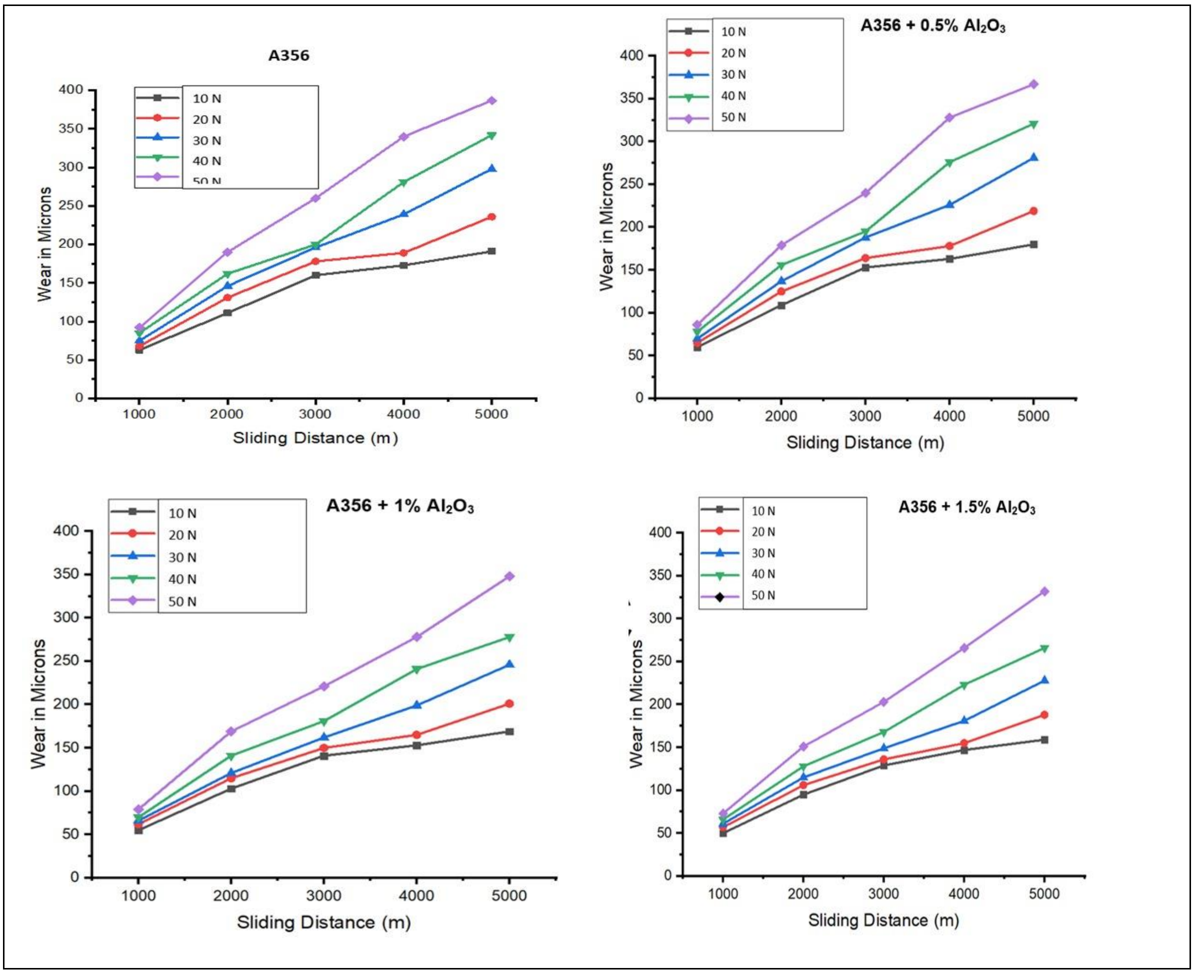
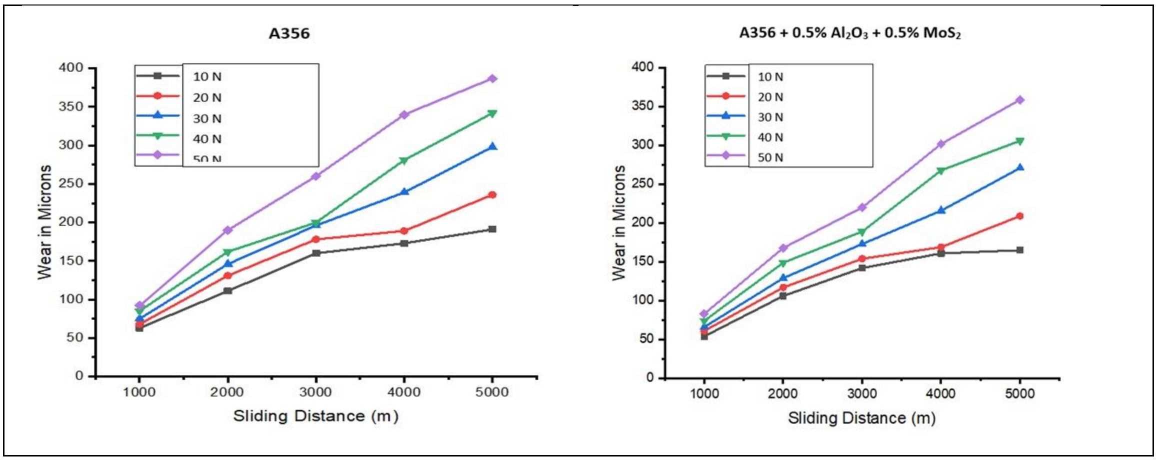


Fig 5: Sliding distance v/s Wear of nanocomposites A356/alumina

As the sliding distance rises, so does the wear rate. The aluminium356 material has been found to have a greater wear rate than the A356/alumina nanocomposites shown in 7(a) and A356/MoS_2/alumina hybrid nanocomposites shown in 8(a). At the commencement of the wear test, asperity contacts occur between the disc and pin, and contact pressure is higher at these asperities. Asperities are reduced when the sliding distance is extended, as well as the contact region between both disc and pin interface expands. When the sliding distance rises, increasing the contact area lowers the contact pressure, resulting in decreased wear rates.



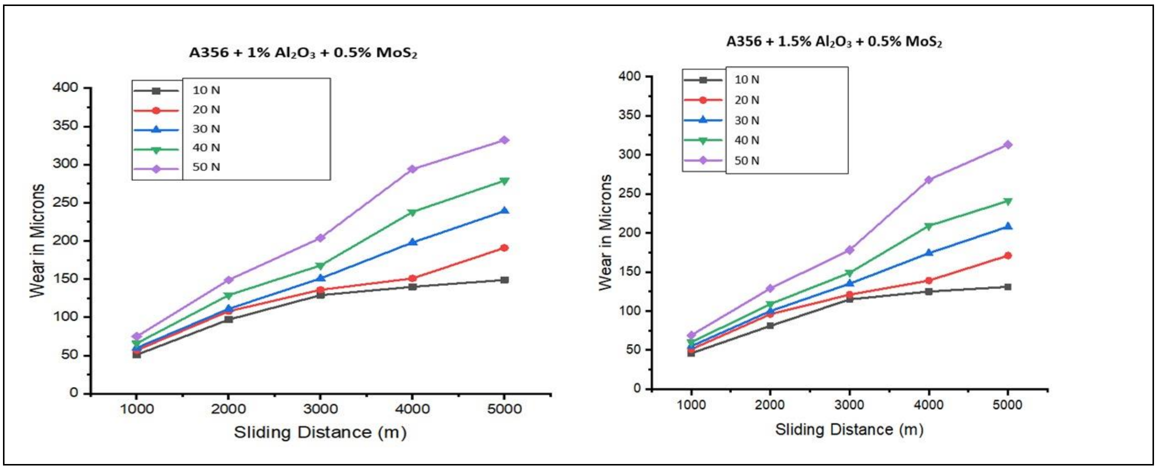
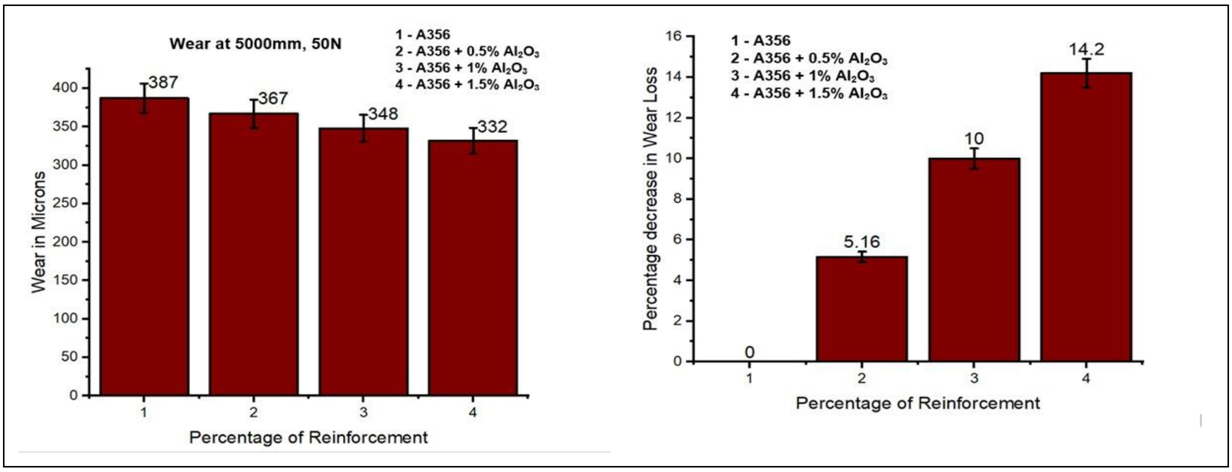


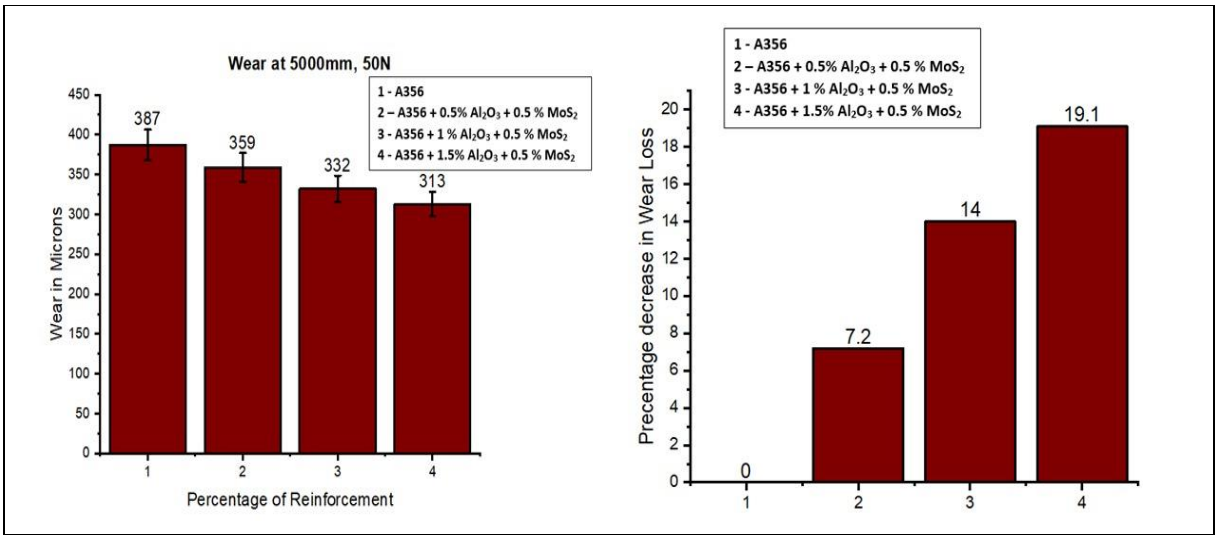
Fig 6: Sliding distance v/s Wear of Hybrid nanocomposites A356/MoS_2/alumina

Nanocomposite Aluminium356 with 1.5 wt.% alumina shows a 14.2% reduction in wear than the Aluminium356 alloy as shown in fig 7(b). When MoS_2 (0.5 wt.%) is added to Aluminium356/1.5 wt.% alumina, hybrid nanocomposites demonstrate a 19% reduction in wear than the Aluminium356 is shown in fig 8(b). Because of the incorporation of the solid lubricant MoS_2, hybrid nanocomposites have performed better than nanocomposites. The addition of MoS_2 and alumina has reduced the wear loss, which is due to the formation of tribolayer with MoS_2 lubricant between both the surface of the specimen and disc.



(a) % of reinforcement v/s Wear (b) Percentage reduction in wear loss

Fig 7: Wear and percentage reduction in wear loss w.r.t % of reinforcement of nanocomposites A356/ alumina



(a) % of reinforcement v/s Wear (b) Percentage reduction in wear loss

Fig 8: Wear and Percentage reduction in wear loss w.r.t % of reinforcement of hybrid nanocomposites A356/MoS_2/alumina

3.3 Effect of Normal load on Wear

The wear rate of Aluminium356, Nanocomposites, and hybrid Nanocomposites at different load scenarios are shown in fig 9. The graph indicates that as the load is increased, the wear tends to increase steadily. The wear rate of Aluminium356 is higher than the nanocomposites and hybrid nanocomposites. In comparison to nanocomposites, hybrid nanocomposites have a lower wear rate.

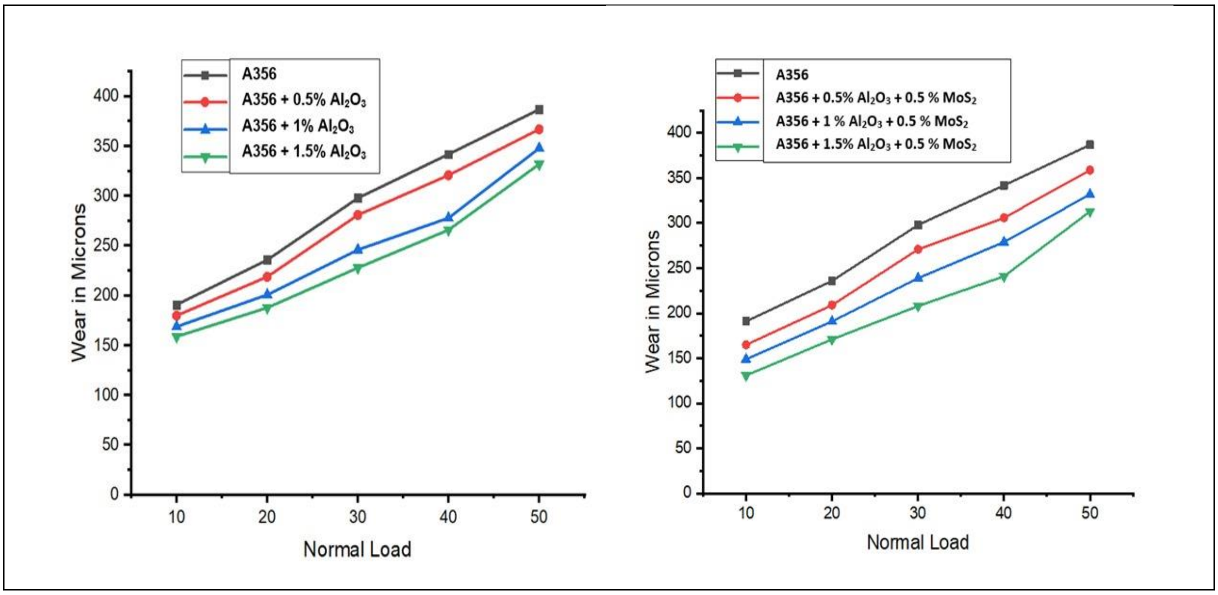


Fig 9: Normal load v/s Wear of nanocomposites and hybrid nanocomposites

Since the aluminium is soft in nature, A356 suffers higher plastic deformation due to an asperity interaction between disc and the pin. This results in higher frictional force and sliding resistance. Hybrid nanocomposite A356 / Al_2O_3/MoS_2 experiences considerably lesser deformation due to the higher hardness of alumina and solid lubricant MoS_2. This results in a lower frictional force as compared to A356 specimens.

3.4 Effect of Normal load on Specific wear rate

The SPW of Aluminium356, nanocomposites and hybrid nanocomposites at different load conditions are shown in fig 10. Lower loads result in further asperity interaction among the sliding surfaces, which leads to a higher SPW. The interface temperature increases as the load increases, flattening asperities and expanding the contact area between both the sliding surfaces. As a result, there is less contact pressure at the contact area, which lowers the wear rate. As a result, the SPW reduces when normal load is increased.

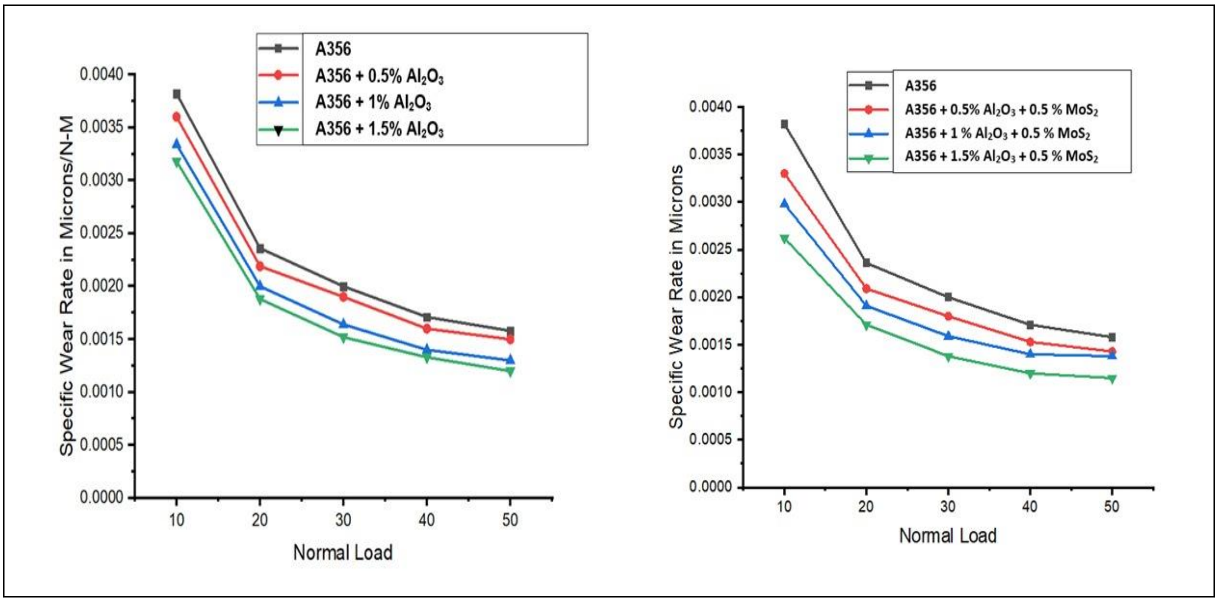


Fig 10: Normal load v/s Specific wear rate (SPW) of nanocomposites and hybrid nanocomposites

4 Conclusions:

The different combinations of nanocomposites and hybrid nanocomposites developed by stir casting are investigated in this work. The use of MoS_2 as a solid lubricant has resulted in considerable tribological behaviour.

- The hybrid nanocomposites had a reduced wear rate compared to nanocomposites and Aluminium356 alloy at all loads. Wear resistance was greater in the A356/MoS_2/alumina hybrid nanocomposite specimen. MoS_2 particles acts as a solid lubricant, while alumina particles acts as a load carrying element.
- Nanocomposites with 1.5% alumina shows14.2% reduction in wear, while 1.5% Al_2O_3 & 0.5% MoS_2 hybrid nanocomposite shows a 19% wear reduction compared to Aluminium356 alloy.
- In comparison to nanocomposites, the inclusion of MoS_2 nanoparticles lowered the wear rate of hybrid nanocomposites. The hybrid nanocomposites displayed self-lubricating properties in the above investigation, indicating that they are resource-efficient materials.

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