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Investigation of Mechanical Properties of Aluminium356 reinforced with Nano Alumina and Studying the effect of addition of MoS_2 on Aluminum Nanocomposites

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Abstract: Aluminum Matrix Composites (AMCs) find use in numerous sectors like Aeronautical, Automobiles, etc., because of its less weight and excellent strength. Nano particles are employed as reinforcement in AMCs since they can operate as an effective reinforcing material and also increases stiffness. A study was done to find out what the mechanical properties were like: ultimate tensile strength, hardness and density of Nano composite aluminium356 reinforced with nano alumina. Aluminum hybrid Nano composite is prepared using stir casting process by adding nano MoS_2 (0.5 wt. %) to the A356/Al_2O_3 Nano composites to investigate the effect of MoS_2 on mechanical properties. SEM was used to conduct microstructural examination of A356/Al_2O_3 Nano composite and A356/Al_2O_3/MoS_2 hybrid Nano composite, which revealed that particulates are distributed homogeneously in the aluminium356 matrix in both cases. The addition of Al_2O_3 to the aluminium356 matrix produced a Nano composite with good mechanical properties, according to hardness and tensile tests. The addition of MoS_2 to the A356//Al_2O_3 Nano composites reduces the hardness and UTS of the aluminum hybrid Nano composites compared to A356/Al_2O_3 Nano composite due to the agglomeration of nanoparticles and lower hardness of MoS_2.

Keywords: Aluminum 356, Nano composites, Hardness, Tensile strength, and density

1. Introduction

AMCs reinforced with alumina particles have excellent physical & mechanical properties. Over the last few decades, their applications in a variety of demanding fields such as defence, automobile, electronics, aerospace, bio-medical, sports have become essential. Stir casting, compo-casting, ultrasonic aided casting, powder metallurgy and liquid infiltration are some of the manufacturing procedures used to make AMCs. Stir casting is the most common and least expensive method of all of them. These composites have improved mechanical and physical properties e.g. lower density, higher tensile strength, good tear & corrosion resistance, high hardness and high stiffness. Lubricating particles like graphite and MoS_2 were used to enhance the tribological characteristics of composites by providing a sufficient lubricating coating. AMCs have aroused a lot of attention due to the present desire for lighter material with higher strength and stiffness.

In this study, Nano composites of A356 + 0.5% Al_2O_3, A356 + 1% Al_2O_3 and A356 + 1.5% Al_2O_3 were made utilizing stir-casting method and looked at the mechanical properties and microstructure. In the later stage, 0.5% nano MoS_2 has been added to the above three combinations and investigated the differences in mechanical properties due to the inclusion of MoS_2.

K. Ajay Kumar et.al [1, 2] investigated the properties of aluminium356 reinforced with MoS_2 and alumina hybrid Nano composites created via stir casting method. The mechanical properties like tensile strength & hardness were improved as compared to base material A356. The addition of MoS_2 has reduced the tear rate, coefficient of friction compared to the tear rate of A356. Wenli Gao et.al [3] investigated the microstructure and tensile properties of A356/nano alumina composites. The SEM image reveals the uniformly dispersed particles. The tensile strength & yield strength for 1.5wt. % alumina composites are enhanced by 38% & 80% respectively, as compared to base metal. Sivaraj S et.al [4] studied tear properties and hardness of Al/ nano Al_2O_3 / nano TiB_2 composites. The SEM image reveals the uniformly dispersed nanoparticles. The 2.5% TiB_2 and 2.5% Al_2O_3 reinforced composite have shown the better result and tear rate is minimized. Tear resistance & hardness are enhanced as the reinforcement percentage increases.

A.A.Tofigh et.al [5] investigated the characteristics of A7075 / nano alumina composites. The SEM image reveals the uniformly dispersed nanoparticles. The hardness, yield strength & tensile strength of composites are better to the A7075 base metal. M Manohar et.al [6] investigated the characteristics of aluminium356/ MoS_2/alumina hybrid composites fabricated by combined stir and squeeze casting. Bending strength and hardness are improved with the raise in reinforcement percentage. When MoS_2 is used as reinforcement in aluminium6061/ alumina composites, the friction coefficient is reduced. P. Seenikannan et.al [7] investigated the characteristics of aluminium6061/MoS_2/alumina hybrid Nano composites. Mechanical characteristics are enhanced by adding the alumina particles. The MoS_2 inclusion as reinforcement in aluminium6061/alumina composites improves the resistance to friction & tear.

K.Prabhakaran Nair et.al [8] studied the impact of micro and nano reinforcement on AMCs. Aluminium356 is reinforced with nano graphite and micro Al_2O_3. The SEM image shows that alumina is dispersed exceptionally with graphite. N. Arunkumar et.al [9] studied the properties of aluminium2014/ nano & micro alumina composites, Nano composites have shown higher mechanical characteristics like tensile strength & yield strength compared to micro particles.

Mohsen Ostadshabani et.al [10] investigated the tensile strength & hardness of aluminium356/nano alumina composites. The SEM image reveals the uniformly dispersed nanoparticles. The tensile strength &hardness of aluminium356/nano alumina composite are enhanced as the reinforcement percentage increases. Madev Nagaral et.al [11] investigated the properties of aluminium6061/nano alumina composites. Yield strength, hardness &tensile strength were improved with increasing the Al_2O_3 percentage and ductility is lowered compared to aluminium6061 base metal. C. S. P. Rao et.al [12] studied the properties of aluminium6061+SiC & aluminium 7075+Al_2O_3. The SiC & Al_2O_3 addition results in increasing the tear resistance, hardness and density.

2. Experimental procedure

2.1 Raw materials

Aluminium356 is preferred as matrix material and nano alumina & MoS_2 particles are used as hybrid reinforcements in the work.

2.2 Fabrication of hybrid Nano composites

A356 + 0.5% Al_2O_3, A356 + 1% Al_2O_3 and A356 + 1.5% Al_2O_3 Nano composites were made with A356 as the matrix material and alumina as reinforcements. Another three Hybrid Nano composites were prepared by adding 0.5% of nano MoS_2 to the above three compositions. The Nano composites were made using a traditional stir casting procedure as shown in Fig 1. An electric furnace was used to heat measured amounts of A356 and reinforcement in a crucible. To maintain homogeneous reinforcement distribution in the matrix, a mild steel impeller coated with zirconium was spun at 600 rpm for a few minutes. The impeller was positioned at a depth of two-thirds the height of the molten metal. The mixing was kept going for another 4 minutes to ensure that the reinforcement and matrix were properly blended. The molten metal was poured into pre-heated moulds to form the castings.

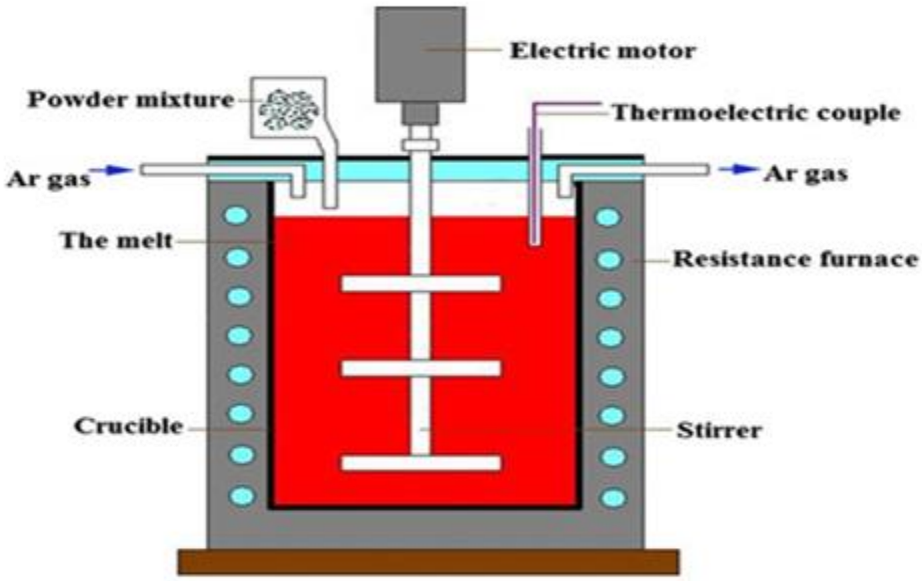


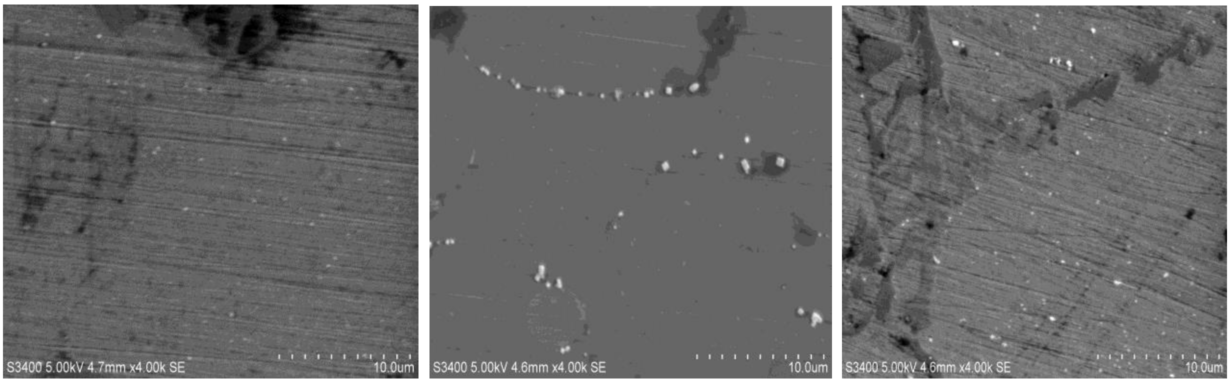
Fig. 1: Stir casting method

3. Discussions and Results

3.1. Microstructure Characterization

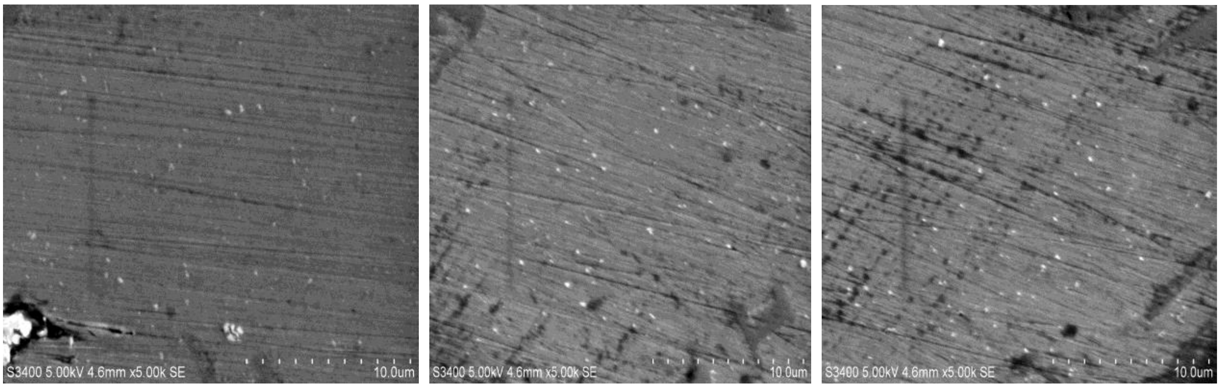
A "SEM" was used to examine the microstructure of the cast specimens in order to analyse particle dispersion and voids.

SEM images of Nano composites as well as hybrid Nano composites are depicted in Fig 2 and Fig 3 respectively. The reinforcement distribution was examined at the micro-scopic level using SEM. Nano alumina particles in the base metal were identified at a higher magnification. The particles in all composites were found to be well distributed. Mechanical properties in AMCs have been demonstrated to be largely dependent on the homogenous dispersion of reinforcements.



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

Fig 2: SEM of A356/Al_2O_3 Nano composite



(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

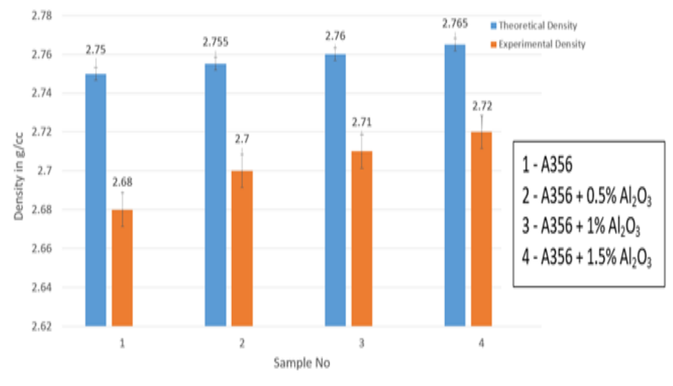
Fig 3: SEM of A356/Al_2O_3/MoS_2 hybrid Nano composite

3.2. Density Measurement

The Nano composites' densities, both experimental and theoretical, were determined. Archimedes' principle was used to compute the experimental density, whereas the mixing rule was used to calculate the theoretical density. The experimental and theoretical densities were used to compute the porosity. The density of aluminium356 was 2.7 g/cm^3 while that of Al_2O_3 and MoS_2 was 3.69 and 5.06 g/cm^3 respectively.

Fig 4 and Fig 5 shows the Experimental & Theoretical densities and Porosity percentage of the aluminium356/alumina Nano composites respectively. FIGS. 6 & 7 illustrate the experimental and theoretical densities as well as porosity percentages of the hybrid nano composites of aluminum356/ alumina, and molybdenum disulfide, correspondingly.

A small amount of theoretical value is added with each wt percent of reinforcements due to the high density of reinforcements above the base matrix. Stir casting is indeed a successful method for manufacturing composites, based on the results of the experiment.



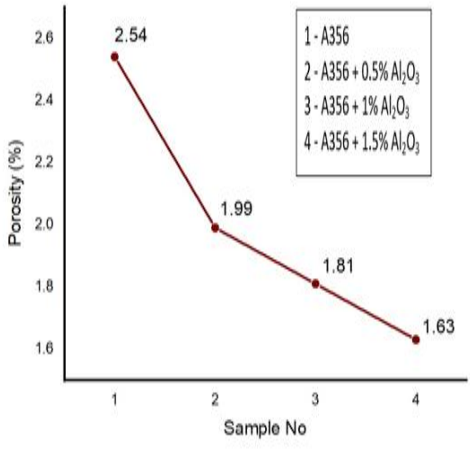
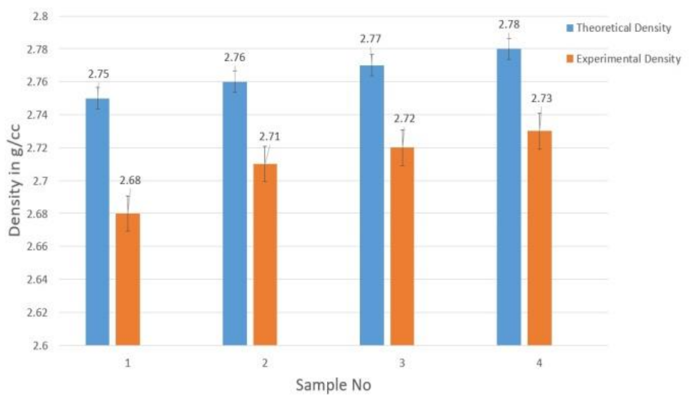


Fig 4: Experimental & Theoretical densities **Fig 5: Porosity percentage**



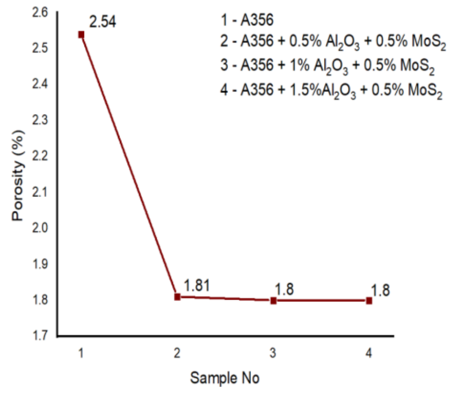
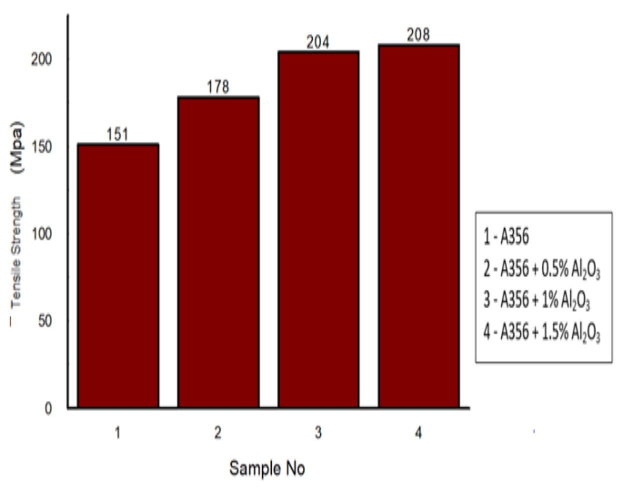


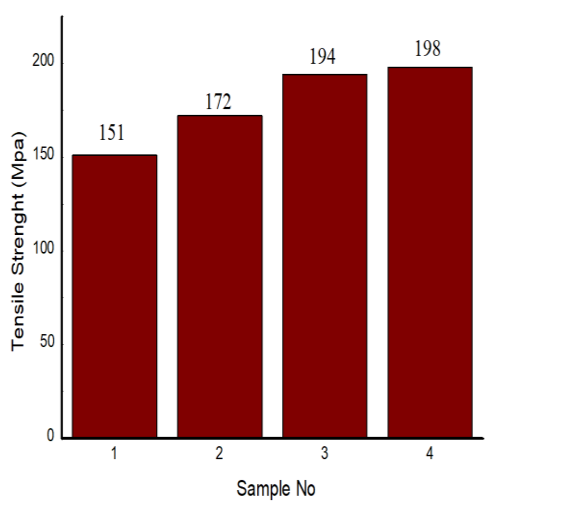
Fig 6: Experimental and Theoretical densities **Fig 7: Porosity percentage**

The composite porosity decreases as the density of the material rises. In hybrid Nano composites, the porosity is observed to be lower than in unreinforced alloy. The porosity percentage in hybrid Nano composites is higher as compared to Nano composites due to higher percentage of reinforcements, wettability complications and nanoparticles agglomeration. Preheating the reinforcements decreases wettability issues and ensures that particles are distributed uniformly.

3.3. Tensile test

The matrix material, reinforcements, as well as volume/weight percentage of reinforcing agents, as well as particle shape and size, all influence the mechanical properties of composites.





(a) **(b)**

Fig 8: Tensile strength v/s percentage of reinforcement

Figure 8 (a) and (b) shows the tensile strength of A356/Al_2O_3 Nano composites and A356/Al_2O_3/MoS_2 hybrid Nano composites respectively.

When compared to an unreinforced material A356, the reinforced material's tensile strength has proved to be superior. The UTS of aluminium356 is 151MPa, but with the addition 0.5 wt.% of alumina, it rises to 178MPa and when 1 and 1.5 wt.% of alumina are added, it increases to 204MPa and 208 Mpa, respectively. The highest UTS noted for Nano composite comprising 1.5% of alumina is 208 Mpa. The increase in the number of reinforcing particles that absorbs external load is responsible for the improved strength.

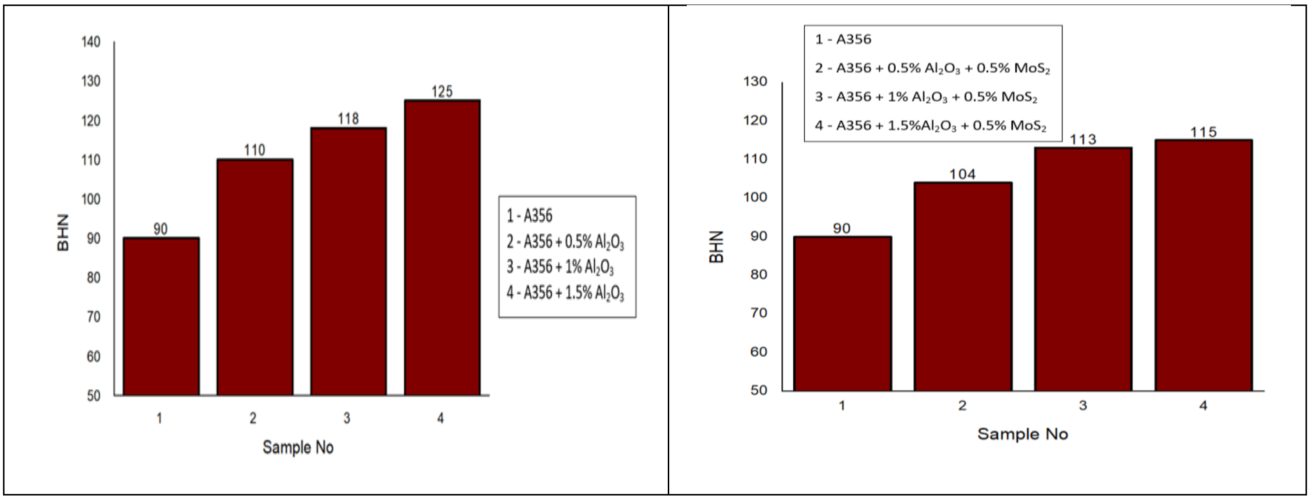
The hybrid Nano composites have a higher tensile strength than the unreinforced material A356. The UTS of aluminium356 reinforced with 0.5 wt.% of MoS_2 & 0.5 wt.% of alumina is 172MPa and when 0.5 wt.% of MoS_2 and 1 & 1.5 wt.% of alumina are added, it increases to194MPa and 198 Mpa, respectively. The tensile load from matrix to reinforcement particulates is efficiently transformed due to the fair and even distribution of alumina and MoS_2.

Because of the adding of MoS_2 as well as agglomeration of nano particles, the UTS of A356/MoS_2/Al_2O_3 hybrid Nano composites are marginally lower than that of A356/Al_2O_3 Nano composites. The addition of Al_2O_3 particles increases mechanical characteristics and also compensates the MoS_2 weakening effects in hybrid Nano composites.

3.4. Hardness

The Brinell hardness test- The cast specimens' hardness was determined using this method. Fig 9 (a) and (b) shows the hardness of A356/Al_2O_3 Nano composites and A356/Al_2O_3/MoS_2 hybrid Nano composites respectively.

The figure shows a gradual increase in the hardness of Nano composite as the percentage of reinforcing particles increases. The load applied to composite materials is shared by a greater number of reinforcing particulates as the reinforcement particles increases, which resists matrix material deformation. With a higher number of reinforcing particles, the material will be more resistant to dislocation during plastic deformation.



(a) **(b)**

Fig 9: BHN v/s percentage of reinforcement

The results of the tests show that hardness of hybrid Nano composite are significantly greater than those of the unreinforced part, and the value increases as the reinforcement percentage increases. When comparing A356/Al_2O_3/MoS_2 hybrid Nano composites to single reinforced A356/Al_2O_3 Nano composites, the inclusion of MoS_2 particles reduces the hardness. The lesser hardness of MoS_2 particles as compared to Al_2O_3 could explain the decline in hybrid Nano composites' hardness.

4. Conclusions

In the current work, Nano composites made of aluminium356 reinforced with nano alumina and hybrid Nano composites made of aluminium356 reinforced with nano MoS_2 and nano alumina particulates were effectively fabricated using traditional stir casting route. Nanocomposites viz., A356 + 0.5% alumina, A356 + 1% alumina and A356 + 1.5% alumina and hybrid Nano composites viz., A356 + 0.5% MoS_2+ 0.5% alumina, A356 + 0.5% MoS_2+ 1% alumina and A356 + 0.5% MoS_2+ 1.5% alumina were prepared. The mechanical and physical properties of hybrid Nano composites are compared to those of single reinforced composites. The following are some of the conclusions that are drawn:

- It was noticed in both Nano composites and the hybrid Nano composites that when percentage of reinforcement increases, the density of the Nano composite is increased more than the base matrix. Furthermore, because of agglomeration of nanoparticles, hybrid Nano composites had a higher porosity percentage than single reinforced composites.
- In comparison to the base matrix, hardness and UTS are enhanced in both Nano composites and hybrid Nano composites with higher alumina content.

- Because of the lesser hardness of MoS_2 particulates, the hardness and UTS of hybrid Nano composite A356/ MoS_2/alumina are somewhat reduced when compared to the A356/alumina Nano composite.
- The hardness enhances by 18.18%, 23.72% and 28% for A356/alumina Nano composite than the A356 base material. The UTS of A356/alumina Nano composites increases by 15.17%, 26% and 27.4% when compared to A356 base material.
- The stiffness enhances by 13.4%, 20.3% and 21.7% for A356/ MoS_2/alumina hybrid Nano composite as compared to A356 base material. UTS of A356/ MoS_2/alumina hybrid Nano composites increases by 12.2%, 22.17% and 23.7% as compared to A356 base material.

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