

ENHANCEMENT OF MICROSTRUCTURAL AND THERMAL PROPERTIES OF EPOXY POLYMER COMPOSITE BY INTRODUCING GRAPHENE OXIDE

Mohammed Asif Kattimani¹, Mohd Ibrahim¹, Syed Amer Ur Rahman¹,
Ahmed Mohiuddin², Syed Ahmed Hussain²

¹Assistant Professor, Department of Mechanical Engineering, Lords Institute of Engineering and Technology, Hyderabad -India

¹md.asifkattimani@lords.ac.in, ibrahim@lords.ac.in, sd.rahman@lords.ac.in

²Research Scholar, Department of Mechanical Engineering, Lords Institute of Engineering and Technology, Hyderabad -India

abdul.hasseb30@gmail.com, hsyedahmed498@gmail.com

ABSTRACT

The goal of this study was to improve the microstructural and thermal performance of epoxy polymer composites by investigating the effects of different concentrations of graphene oxide (GO). By methodically changing the amount of GO in each sample specimens were created using the Composite Fabrication technique. Thermogravimetric analysis (TGA) transmission electron microscopy (TEM) X-ray diffraction (XRD) and dynamic mechanical analysis (DMA) were among the analyses performed to assess the composites. The findings showed that the addition of graphene oxide greatly enhanced the composites thermal and microstructural characteristics. The composite sample that had 0.8 weight percent GO had the best overall performance out of all the samples that were tested. This suggests that epoxy polymer composites can be effectively reinforced with graphene oxide to increase their stability functionality and durability. These improved qualities pave the way for numerous uses where high-performance composite materials are necessary.

KEYWORDS: Polymer Composite; GO; Microstructural and thermal Properties

I. INTRODUCTION

Epoxy resin is a versatile thermos-responsive material known for its strong adhesion mechanical properties and affordability that finds widespread application in industries such as electronics aerospace and construction [1-2]. Graphene oxide is a single-layer material that is hydrophilic and soluble in water. It is derived from graphite and contains groups that contain oxygen. It is less electrically conductive than pure graphene but it is still very strong mechanically and chemically reactive. Zhang along with others, examined the effects of four metal-mediated catalysts—zinc acetate lithium hydroxide sodium carbonate and barium hydroxide—on the synthesis of phenol-formaldehyde resin in an effort to improve its performance and avoid high curing temperatures and slow curing [3]. Bodaghi et al. developed a constitutive model to predict the behavior of shape-adaptive composite plates under complex thermo-mechanical loadings including axial and transverse shear stresses. examined a thermomechanical study of surface-bonded shape memory alloy ribbons used in shape-adaptive composite plates [4]. Arun et al. looked into the impacts of graphene TiO₂ nanoparticles and their combination on the mechanical properties EMI shielding and anti-corrosion of an epoxy matrix. [5]. The nanocomposites produced by ultrasonic mixing were examined using microscopy techniques. With a weight percentage of 0 point 25 for each filler the graphene/TiO₂-epoxy nanocomposite demonstrated significant improvements in tensile strength (36%) and storage modulus (84 %) and offered 99.96 percent corrosion protection (with an efficacy of -11 dB) when compared to neat epoxy. Dhand and others, revealed the benefits of using eco-friendly basalt fibre

such as their superior mechanical properties and biodegradability—as reinforcement in lightweight affordable polymer composites. [6] examined this growing application of basalt fibres. The article addresses the chemistry categorization and growing body of research on basalt fibre-reinforced composites for improved chemical mechanical and heat resistance. Yang et al. employed experimental testing along with finite element calculations. [7] looked into how hybrid composites made of woven carbon and glass responded to impacts at low speeds. ABAQUS/Explicit was utilized for conducting simulations and a vacuum-assisted prepregs procedure was employed to create specimens. The results indicated that hybrid composites with a 37:63 mass ratio had better energy absorption and perforation thresholds than pure composites and the models closely matched the experimental data. Deng along with others. In order to produce Janus colloidal particles with hierarchical architectures a polystyrene-block copolymer and a poly homopolymer were phase separated in a constrained geometry [8]. Size interfacial properties solvent selectivity and copolymer composition were among the numerous factors whose effects on the morphology of these Janus particles were examined in this work. Comparing thermosetting shape memory cyanate polymers treated with polyethylene glycol and those modified with polybutadiene/acrylonitrile Xie et al. produced the polymers and examined them. The aim was to develop shape memory polymers with a controlled glass transition temperature and high temperature resistance for use in aerospace applications.

The structure of this article is organized as follows: first, a theoretical reference provides a comprehensive review of the epoxy polymer composite by introducing graphene oxide; this is followed by the methodology, result and discussions of the main contribution on microstructure and thermal properties of prepared composite.

II. METHODOLOGY

A number of crucial steps are involved in the process of using graphene oxide to improve the microstructural and thermal properties of epoxy polymer composites as figure 1 illustrates. Firstly, materials are chosen such as graphene oxide (GO) and epoxy resin which need to be evenly distributed for best results. To improve compatibility GO may be functionalized and hardener additives are taken into account. GO is mixed into the epoxy resin during the fabrication process by mechanical stirring or ultrasonication. A curing agent is then added and the composite is molded and cured. TEM and XRD microstructural analysis as well as DMA and TGA tests for thermal property testing are examples of characterization techniques. Lastly to evaluate the effect of GO on its properties data from the composite is compared with neat epoxy resin.

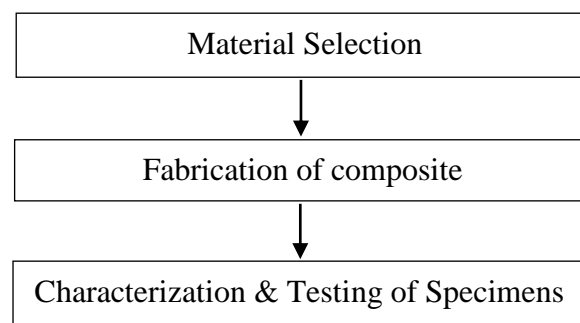


Figure 1. overview of methodology

2.1. Materials

The following sources supplied the materials for this experiment: graphene oxide was purchased from Shilpent Shilpa Enterprises in Maharashtra India. The matrix that was utilized was Epoxy Vinyl Ester Resin from INEOS Composites located in Maharashtra India. The acetone dimethyl aniline and methyl ethyl ketone peroxide used as the hardening and accelerating agents respectively were supplied by Meenakshi AGRO Chemicals Hyderabad India. The weight ratios of the hardening agent accelerating agent and epoxy resin were 100:1:0.5.

2.2. Fabrication of composite

Epoxy resin/GO nanocomposites were made using the following technique. Different amounts of graphene oxide (0 weight percent 0.8 weight percent and 1 weight percent in relation to epoxy resin) were combined with the required amount of acetone and agitated for three hours at room temperature as shown in Figures 2a to 2c. The epoxy resin was preheated for 15 minutes at 60°C in a water bath to reduce its viscosity which made mixing simpler. After adding the GO-acetone mixture to the epoxy resin it was manually stirred to ensure adequate dispersion. After the acetone was removed by evaporation the mixture was left to dry for 12 hours [9, 10].

After the mixture had dried and was stirred for ten minutes the curing ingredient was added. The mixture was then placed into a mold and allowed to cure at room temperature for 12 hours. Throughout sample preparation and testing ASTM standards were followed [11–12].

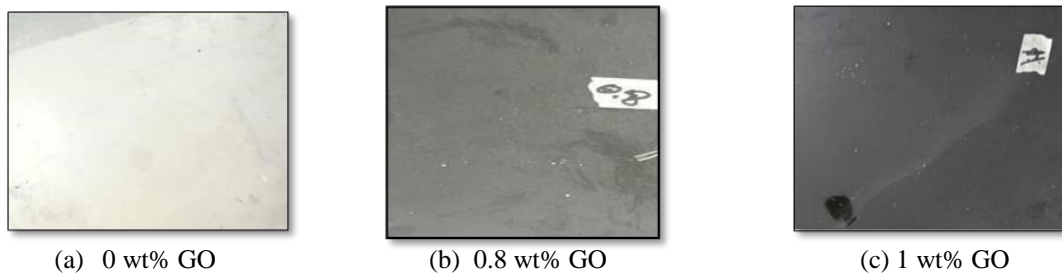


Figure 2. Epoxy resin/GO nanocomposites

III. RESULTS AND DISCUSSION

3.1 Characterization of Epoxy resin/GO

Utilizing cutting-edge imaging technology, it can examine a materials interior structure at atomic or nearly atomic resolution. An ultra-thin sample is passed through an electron beam in Transmission Electron Microscope (TEM) operation and the resulting interactions are recorded to create an image or diffraction pattern. With this technique a materials internal characteristics crystallography and flaws can all be seen in great detail. Using methods like mechanical polishing the prepared samples are thinned to less than 100 nanometres. The samples are then usually mounted on support grids which reduce background interference and offer mechanical stability.

The morphology of graphene oxide (GO) was reported using TEM. The structure of the exfoliated GO sheets was transparent and clear with a few small ripples as shown in Figure 3(a). The average GO thickness of 12.31 nm observed in the TEM data was in agreement with the sheet-like morphology shown in Figure 3(b). Figure 3(b) depicts the regularity of the carbonaceous material indicating that an oxidation reaction occurred during the production of GO and the removal of graphite leading to a noticeable increase in the oxidation ratio. This suggests that the graphites regularity was significantly disrupted during the oxidation process.

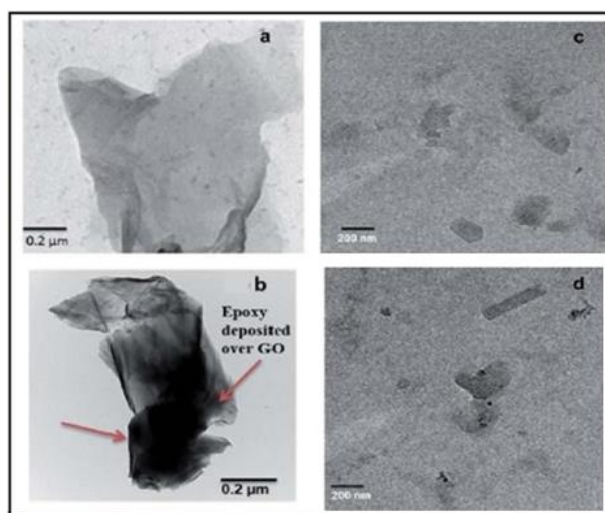


Figure 3. (a). TEM of epoxy polymer Composite (b). 0.8% wt. GO composite TEM image

3.2. X- Ray Diffraction Analysis (XRD)

X-ray powder diffraction (XRD) instrument consist of three basic elements, an X-ray tube, a sample holder and an X-ray detector the specification of XRD instrument are mentioned in table 1. XRD is based on Bragg's Law, which describes the correlation between the angles of incidence (θ) and diffraction (2θ) of X-rays on a crystal lattice.

Table 1 Specifications of XRD instrument

Sl. No	Parameters	Range
1	Make	PAN alytical X' Pert
2	Maximum usable range	-40° to 2200
3	Weight	1100kg
4	Materials	Powders, thin films, nanomaterials, suspension, solid objects.

Graphite exhibits a distinct characteristic peak at $\theta = 26.8^\circ$ which corresponds to the crystal plane of the graphite structure as illustrated in Figure 4. On the other hand GO lacks a peak at this particular angle. Instead it possesses a distinct diffraction peak at $\theta = 10.9^\circ$ which is in line with the (100) crystal plane thereof. The diffraction peak of graphene oxide (GO) changes to a smaller angle when compared to graphite suggesting lattice distortion in the graphene oxide structure [12–14]. The aforementioned observation implies that a considerable quantity of functional groups were incorporated into the graphite interlayer throughout the oxidation process thereby modifying the fundamental structure of the material [12].

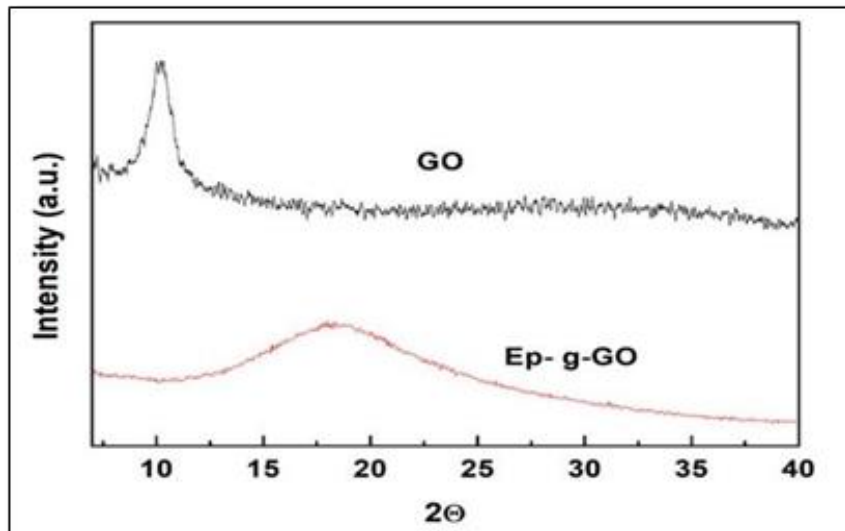


Figure 4. XRD Patterns of GO Composite

3.3. Thermogravimetric Analysis (TGA)

Figure 5 displays TGA curves for epoxy resin composites with varying concentrations of GO. The composites began to lose weight at 360°C the temperature-to-weight relationship in GO-containing composites was similar to that of pure epoxy. Along with the rise in the GO mass fraction so did the temperature at which the composites started to degrade. For instance, when the epoxy resin composite suffered a 5 percent mass loss the corresponding temperatures for composites with 0.8 wt percent and 1 wt percent GO were 376 point23°C and 375 point67°C respectively. GOs creation of a network structure within the sample is the primary cause of this as it restricts the release of micromolecules during the breakdown process and increases the temperature of the decomposition process [3]. It's important to keep in mind that the peak temperature represents the highest decomposition temperature. When the GO mass fraction was kept within a certain range the composites maximum thermal breakdown rate decreased as the GO concentration increased. However, for every GO mass fraction above 0. 8 weight percent the maximum decomposition temperature began to decrease and the thermal decomposition rate increased proportionately. With 0 weight percent graphene oxide (GO) reinforcement the epoxy resin composite displayed the best thermal properties.

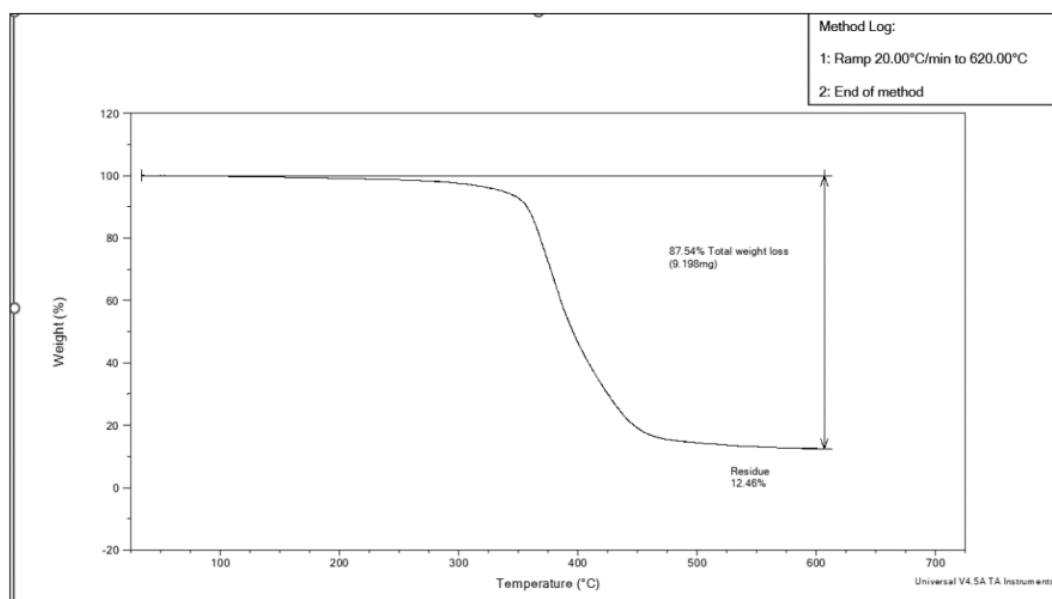


Figure 5. (a) 0.8 wt%. GO of TGA Graph

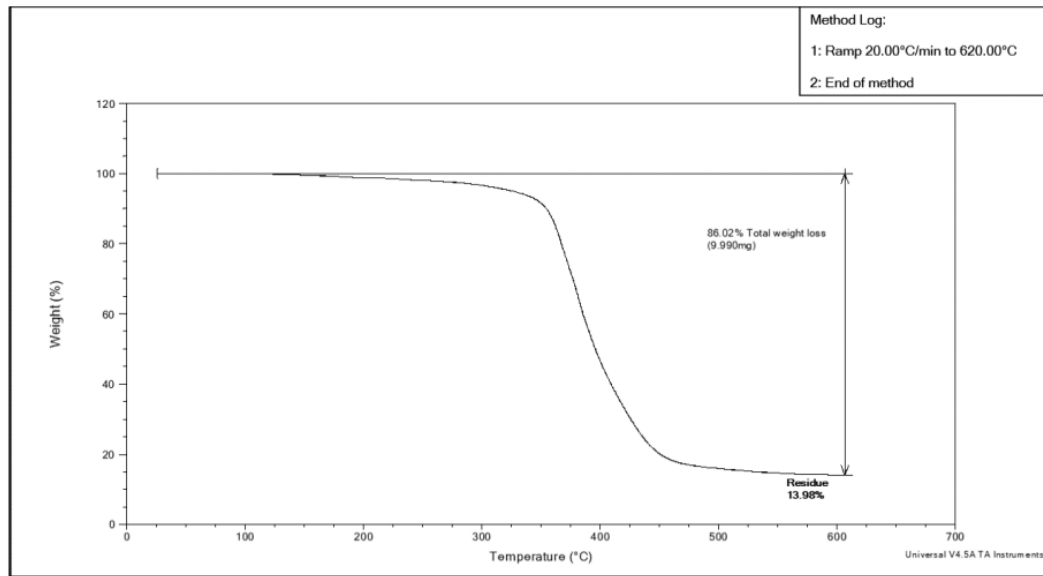


Figure 5. (b) 1 wt%. GO of TGA Graph

3.4. Dynamic Mechanical Analysis (DMA)

The DMA curves of the tan delta versus temperature and storage modulus (E) for both neat epoxy resin and GO-toughened epoxy resin composites are shown in Figure 6(a). The data show a noticeable increase in the storage modulus of the GO-toughened epoxy resin at various temperatures. Specifically, the epoxy resin composites storage moduli improved at 0.8 and 1 weight percent of GO. The storage modulus of the composite decreased at 1 weight percent GO which is important to keep in mind. This is most likely caused by a worsening of GO dispersion within the epoxy resin at higher GO concentrations which reduces the composites storage modulus and lessens the impact of stress transmission [4].

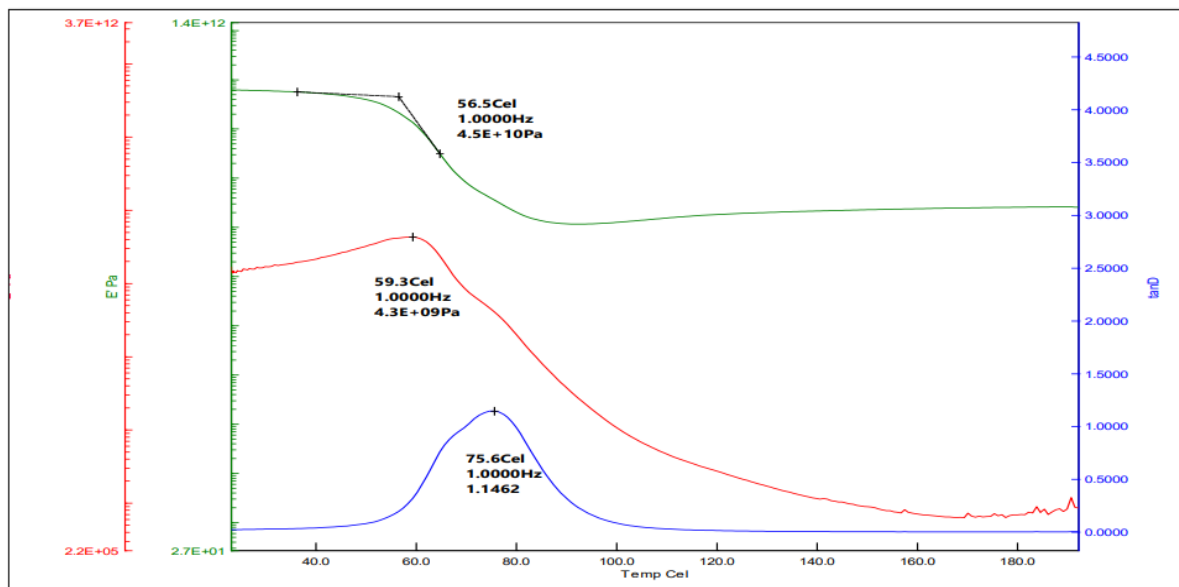


Figure 6. (a) 1 wt%. GO of DMA Graph

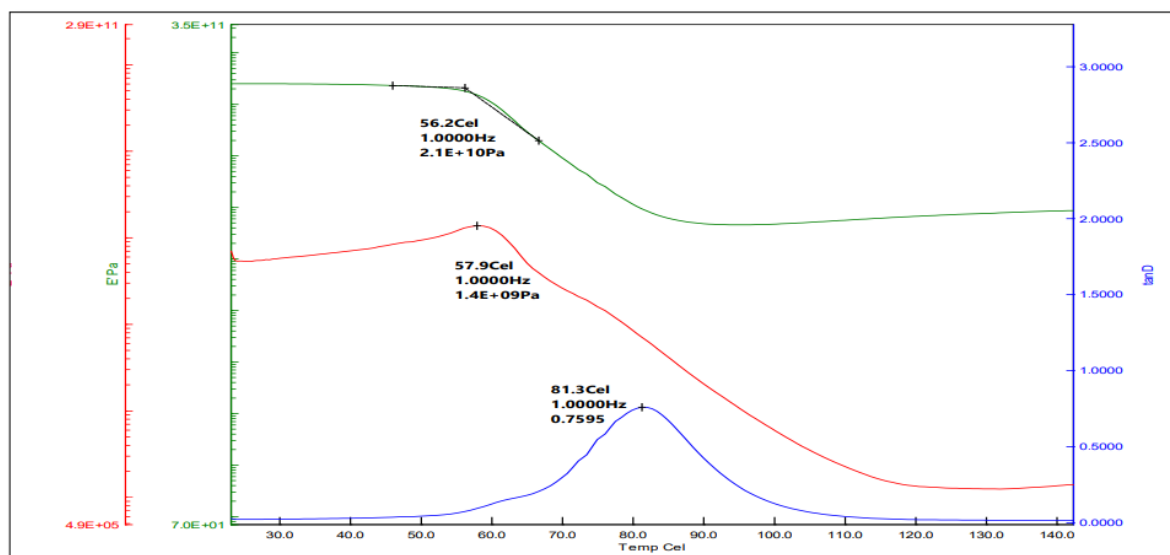


Figure 6. (b) 0.8 wt%. GO of DMA Graph

IV. CONCLUSIONS

In this work the thermal and microstructural properties of epoxy resin composite specimens with various GO mass fractions were investigated using DMA TGA TEM and XRD techniques. The experimental data showed that the composite containing 0.8 weight percent GO had the best mechanical and thermal performance. This suggests that epoxy polymer composites made using the recommended manufacturing process would benefit from this concentration. After GO was added the specimens Tg increased showing a consistent rising trend as GO concentration increased. The maximum thermal decomposition temperature increased initially and then decreased in tandem with the growth of the GO mass percent as did the thermal decomposition rate.

ACKNOWLEDGEMENTS

The authors would like to thank Department of mechanical engineering, lords institute of Engineering and technology Hyderabad, India for conduction this research work.

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Author

Dr. Mohammed Asif Kattimani

He graduated with a Bachelor's degree in Mechanical Engineering SDMCET under VTU – (State University India) in 2013. He earned a Master of Science in Mechanical Engineering with a concentration in Design Engineering from the Master Program in Mechanical Engineering (DSCE- Bangalore) at the VTU (State University India) in 2015. He earned Ph.D. from RVCE – Regional Research Center VTU-Belagavi (State University India). He is a Life Member of MISTE and IAENG. His research findings have been published in SCIE/SCOPUS/Google-indexed international journals. His research interests focus on Material Science, Computational Fluid Dynamics (CFD), Nanocomposite, Heat exchanger, Design engineering (CAD).



Mr. Mohd Ibrahim

He graduated with a Bachelor's degree in Mechanical Engineering MGCET under OU – (State University India) in 2018. He earned a Master of Science in Mechanical Engineering with a concentration in Machine Design from the Master Program in Mechanical Engineering (VCE- Hyderabad) at the JNTUH (State University India) in 2020. He is a Life Member of IAENG. His research findings have been published in Google-indexed international journals. His research interests focus on Design Engineering, Automobile.



Mr. Syed Amer Ur Rahman

He graduated with a Bachelor's degree in Mechanical Engineering GFEC under JNTUH – (State University India) in 2011. He earned a Master of Science in Mechanical Engineering with a concentration in Advance Manufacturing System from the Master Program in Mechanical Engineering (MIST- Hyderabad) at the JNTUH



(State University India) in 2013. He is a Life Member of IAENG. His research interests focus on Advanced Manufacturing, Material Science.

Mr. Ahmed Mohiuddin

He is an Undergraduate Student and Research Scholar in the Department of Mechanical Engineering, Lords Institute of Engineering and Technology, Hyderabad, Telangana, India.



Mr. Syed Ahmed Hussain

He is an Undergraduate Student and Research Scholar in the Department of Mechanical Engineering, Lords Institute of Engineering and Technology, Hyderabad, Telangana, India.

