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Development of Advanced Materials and Manufacturing Techniques for Engineering Applications

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Abstract

The use of polymeric materials in industrial applications has overcome the restrictions associated with the use of metals. When compared to other metallic and conventional composites, polymers are a significant alternative material for a number of industrial applications because of their high design uniqueness, wide property combinations, light weight, low coefficient of friction, good damping properties, quiet operation, and low lifecycle cost. It raises the innovative idea that the mechanical and tribological properties of the nylon system will be greatly enhanced by the combined action of graphene oxide and glass fiber. Additionally, it was suggested that a relatively low concentration of graphene oxide (GO) be utilized to improve the mechanical properties of polymer composites, while higher concentrations of GO were employed in earlier research. However, the main goals of this study were to maximize the concentration of graphene oxide (GO), which shows better mechanical properties in glass-filled nylon, and investigate the potential for creating a new class of material for the fabrication of mechanical components with longer lifespans for engineering applications. Nanoparticles have been used to reinforce polymeric materials in recent years, providing new technologies for a wide range of industrial applications. A polymer's high strength to weight ratio is a useful characteristic, particularly in engineering applications where weight plays a big role in design. In order to determine their suitability for engineering applications, their characteristics were examined. The primary goal of this research is to determine whether a polyamide nanocomposite system based on graphene oxide may be used in engineering applications.

Keywords: Industrial Applications, Composite, Graphene Oxide.

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Introduction

Newer advancements in many industrial and engineering industries have been made possible by the creation of novel materials with enhanced functionality and performance (Grzesik, 2008). The development of novel materials is influenced by both customer needs and technological advancements. According to a 2012 report from the European Commission's Industrial Technologies section of the Research and Innovation directorate, new material discoveries account for 70% of all new product innovation. The materials are utilized in very difficult conditions in the current technological context, including applications with high and low temperatures, harsh chemical environments, high friction and wear operating conditions, strongly vacuumed and radiated fields, etc. (Xu & Yan, 2010). As a result, high-performance materials that can be used in a variety of demanding settings have been developed. One type of material that may function in a variety of demanding conditions is composite. Generally speaking, composite materials are made by combining one or two distinct components to create a superior and one-of-a-kind substance. The matrix phase and the reinforcing phase are the two stages that make up the composites. Composite materials are categorized into different categories based on the reinforcement and matrix phase (Parinov et al., 2015).

Polymer Nanocomposites

Composites that have at least one phase with a diameter in the nanoscale range are known as polymer nanocomposites (El-Eskandarany, 2001). The nano-additives that reinforce can be one-, two-, or three-dimensional reinforcements. The significant success of polymer nanocomposites from the Toyota Central Research and Development group was originally reported. They observed notable enhancements in the nylon/clay nanocomposites' mechanical and thermal characteristics. Numerous studies are being conducted to significantly improve the mechanical, thermal, optical, and electrical properties of polymer matrices by introducing extremely small amounts of nano fillers. Even though polymer nanocomposites have many benefits, such as enhanced mechanical properties, thermal conductivity, ablation resistance, and chemical resistance, they also have some drawbacks, such as higher viscosities, dominance, and distribution and dispersion issues depending on the matrix and nanofillers used. These materials' potential has yet to be fully realized. Nonetheless, a lot of research is being done to identify these material characteristics in order to create new materials. Carbon nanotubes, nanoceramics, nano clays, and other nanomaterials were the first to be used. The most well-known kind of polymer nanocomposites is made of carbon nanotube (CNT) reinforced polymer. Significant gains in mechanical, thermal, and electrical properties have been made possible by the reinforcement of carbon nanotubes in polymers. Allotropes of carbon known as carbon nanotubes are distinguished by their cylindrical nanostructure or hexagonal arrangement of carbon atoms coiled into tubes. Single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) are the two types of CNTs which is shown in Fig. 1. (Rowe, 2012).

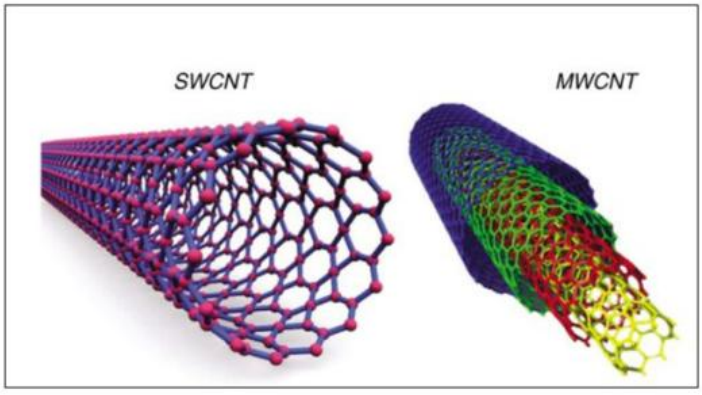


Fig. 1: Single Walled Carbon Nanotube (SWCNT) and Multiwalled Carbon Nanotube (MWCNT)

Applications Of Polymer Nanocomposites

The use of polymer nanocomposites is expanding quickly across a number of domains. Its suitability for a range of technical, medicinal, and astronomical applications is still being investigated by researchers. A thorough overview of polymer nanocomposite uses is given below. It has been discovered that carbon nanotube-reinforced polymer nanocomposites accelerate the healing process associated with bone fractures. Studies are being conducted to learn more about how carbon nanotubes support bone formation. Longer blades are made by combining epoxy polymers with nanotubes. Despite being lightweight, these longer blades are incredibly powerful and aid in the production of

power on a larger scale. Conductive papers are prepared using nanotubes reinforced with cellulose components. Long-term immersion of these conductive materials in an electrolytic solution will create flexible batteries, which are utilized in the smart textile sector. Researchers have recently been attempting to create composites with a higher strength-to-weight ratio using graphene, which will lead to the production of components for windmill blades or airplanes which is displayed in Fig. 2. creation of portable sensors using nanocomposites that sound an alert when strong winds cause the windmill's blades to flex, signalling the windmill to be turned off before significant damage is done. Polymer nanocomposites with magnetic characteristics (Srivatsan et al., 2018) are used in oncology to make tumour cells more visible during magnetic resonance imaging (MRI) scanning.

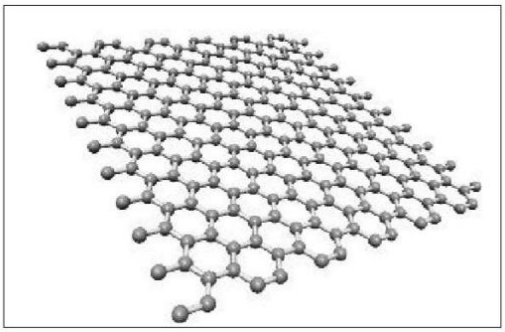


Fig. 2: Structure of Graphene

Methodology

In order to create GO-N and GO-GFN nanocomposites, different weight fractions of graphene oxide nano powder (0, 0.02, 0.03, 0.04, and 0.05 wt%) must be dispersed throughout the nylon-6 matrix. The Central Institute of Plastic Engineering and Technology, CIPET, Chennai, uses a melt mixing procedure to create the nanocomposite pellets. Using a metallic die, the specimens were injection molded at 265°C. In order to examine mechanical characteristics including hardness, flexural strength, and tensile strength, samples were cut from specimens. Tribological investigation was performed on the polymer nanocomposites that exhibited superior mechanical properties (Jaluria, 2018). To investigate the wear resistance potential of synthesized nanocomposites, tribological research was performed on the graphene oxide infused nylon (GO-N), graphene infused glass filled nylon (GO-GFN), glass filled nylon (GFN), and nylon (N) systems. The purpose of the mechanical test was to determine the ideal weight percentage of GO that significantly improves the mechanical properties of glass-filled nylon and nylon systems. According to ASTM G99, wear testing is carried out using a pin on a disc tribometer. Fig. 3 displays the tribological analysis flowchart. Wear loss, frictional force, and coefficient of friction were examined and linked to mechanical characteristics. During this phase, the composition of a nanocomposite system with improved mechanical and tribological properties was determined.

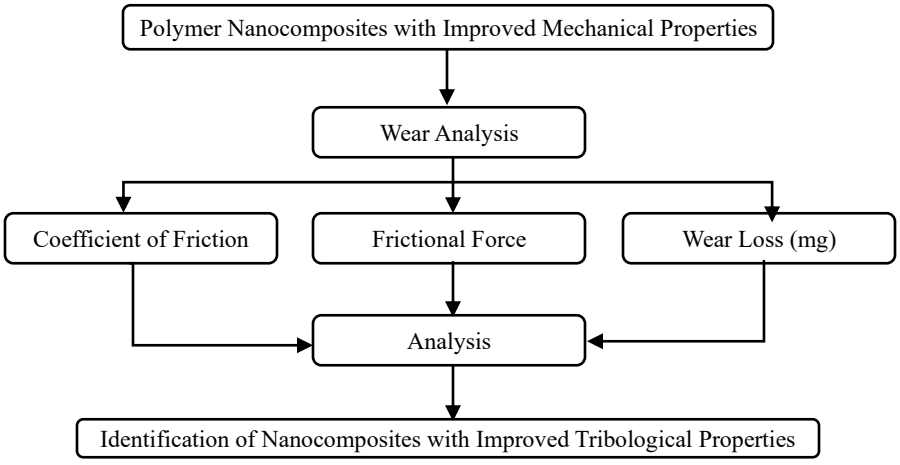


Fig. 3: Tribological Analysis on GO-N and GO-GFN Nanocomposite Systems

The composition that offers improved properties is chosen for use in engineering applications based on mechanical studies and tribological analysis. The goal of the study was to evaluate the potential of a polymer system with an ideal GO content for creating engineering-related gears and bearings (Mamalis, 2005).

Experimental Results

Fig. 4 and 5 show the XRD spectra obtained for graphene oxide reinforced glass filled nylon nanocomposites and 0.03 weight percent graphene oxide reinforced nylon. Plotting the Braggs angle 2theta in the X-axis and the peak intensity in the Y-axis creates the X-ray diffraction curve.

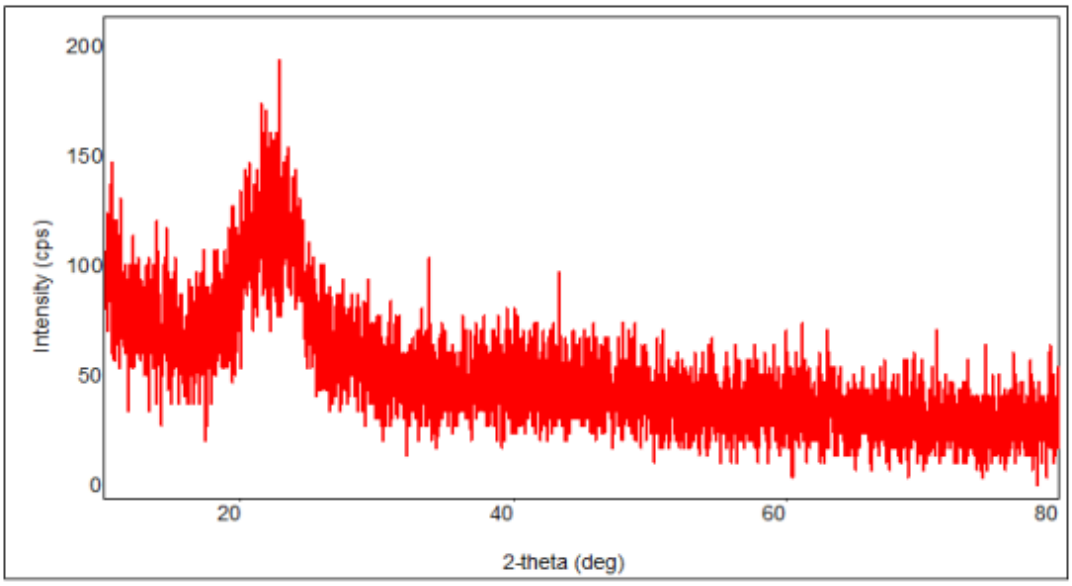


Fig. 4: XRD Pattern for 0.03wt% GO-N Nanocomposite

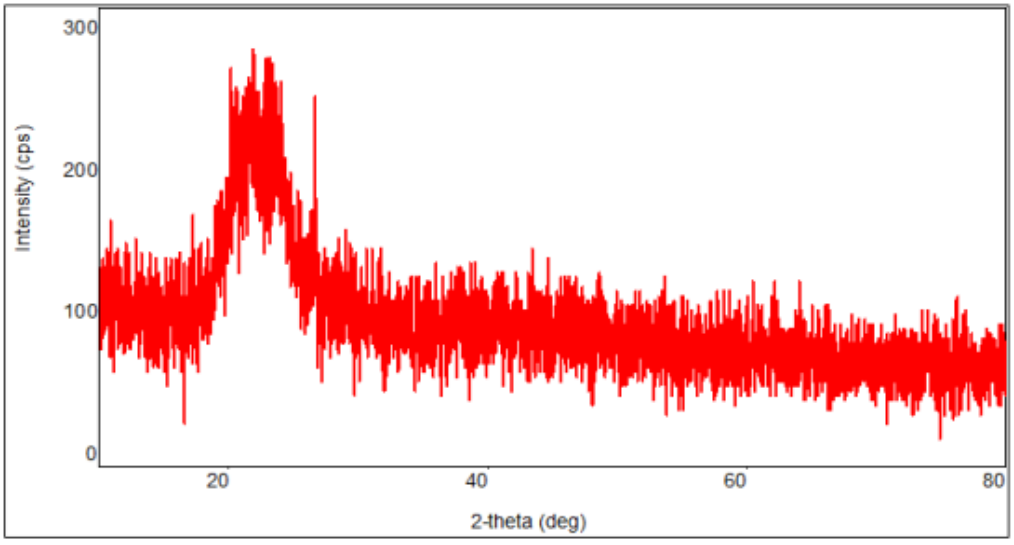


Fig. 5: XRD Pattern for 0.03wt% GO-GFN Nanocomposites

The entire vibrational band generated is utilized to validate the manufactured nanocomposites' molecular structure. The FTIR spectra of nylon are shown in Fig. 6. The generated vibrational band exhibits medium-strength asymmetric CH2 stretching at 2925 cm-1 and N-H stretching at 3080.4 cm-1.

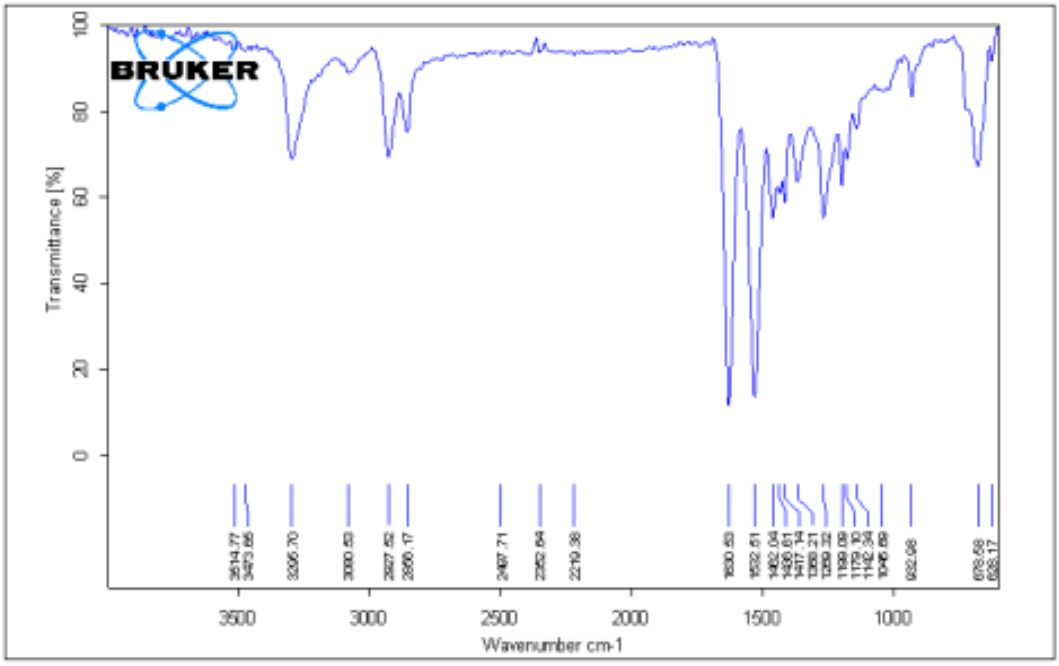


Fig. 6: FT-IR Spectra of Nylon

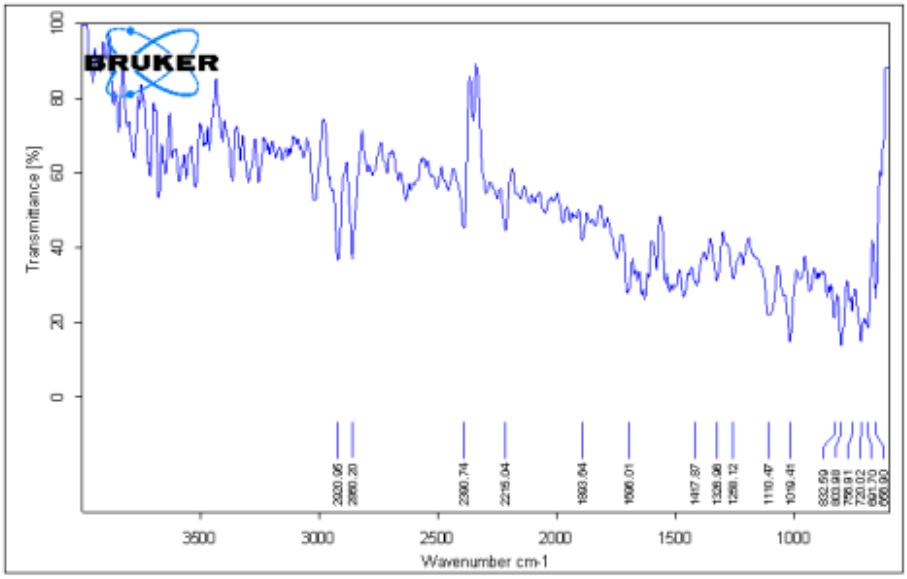


Fig. 7: FT-IR Spectra of Glass Filled Nylon

(Fig. 7) The mechanical and physical properties of the GO-GFN polymer nanocomposites are significantly impacted by the infusion of graphene oxide at a lower concentration of 0.03 weight percent. This was supported and confirmed by a number of characterization studies, including ray diffraction, Fourier transform infrared spectroscopic studies, scanned electron microscopy, and transmission electron microscopy. The mechanical and thermal stability of the GO-

GFN infused with 0.03 weight percent graphene oxide was demonstrated by dynamic mechanical analysis and thermogravimetric analysis performed on the produced GO-GFN nanocomposites.

Conclusions

Graphene oxide is used in the current work at a maximum weight concentration of 0.05wt%. Higher concentrations of graphene oxide, such as 1 weight percent, 2 weight percent, and 3 weight percent, can be employed in the future as inclusions for nylon and glass-filled nylon, and the impact of these concentrations on mechanical and tribological properties can be investigated. A very thorough evaluation based on non-destructive testing methods is advised because the fabrication of the components involves blending, injection moulding, and subsequent machining processes, which frequently result in the formation of voids at the micro and macro level. These voids may alter the components' properties when subjected to cyclic loading processes. A set of GO-GFN gears can be made, used in portable lathe gear box configurations, and their performance assessed.

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