# INVESTIGATION OF GEAR PERFORMANCE OF (MLNGPs) AS AN ADDITIVE ON POLYAMIDE 6 (PA 6) SPUR.

By

**Esraa Mahmoud Ahmed Mohamed Afifi.**

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
**MASTER OF SCIENCE**
IN
**MECHANICAL DESIGN AND PRODUCTION ENGINEERING**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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**Title of Thesis:**

**"INVESTIGATION OF GEAR PERFORMANCE OF (MLNGPs) AS AN ADDITIVE ON POLYAMIDE 6 (PA 6) SPUR."**

**Key Words:** Polyamide 6 (PA 6), Multilayer Nano Graphene Platelets, Gear Performance.

**Summary:**

The aim of his study estimated the effects of (MLNGPs) as an additive on Polyamide 6 spur gear performances. These include strength, elastic modulus, thermal stability, dynamic mechanical analysis, moisture absorption, and wear characteristics. The nanocomposites gear was made by melt mixing method and injection molded into thick flanges. The wear experiments were performed using test rig under external torques of 13 and 16 Nm with different concentration 0.1, 0.3 and 0.5 wt% MLNGPs. The result showed tensile strength increased30%, Vickers micro hardness value increased up to 25%, storage modulus E' is increased up to 37% and glass transition temperature is increased up to 14%. On the other hand TGA result shows that the $T_{onest}$ increased up to 7.5% and Td increased up to 2%, and wear decreased by 35% at 16 Nm and 54% at 13 N.m

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Finally, I wish to acknowledge and express my deep gratitude to all those who helped me in presenting this work.

# Dedication

I sincerely dedicate this work to my mother, father and my husband…...

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# Nomenclature

| | |
|---|---|
| NGPs | Nano Graphene Platelets |
| MLNGPs | Multi Layered Nano Graphene Platelets |
| CNTs | Carbon Nanotubes |
| SWNTs | Single Walled Carbon Nanotubes |
| MWNTs | Multi Walled Carbon Nanotubes |
| SEM | Scanning Electron Microscope |
| TEM | Transmission Electron Microscopy |
| HRTEM | High Resolution Transmission Electron Microscopy |
| XRD | X-ray Diffraction |
| DMTA | Dynamic Mechanical Thermal Analysis |
| TGA | Thermal Gravimetric Analysis. |

# Abstract

Over the past decades, the polymer and their composite are chosen to replace metallic material owing to their easy manufacturability, transmit power quietly without lubrication, less weight to power consumption, low operating noise, low cost and durable. Polymer composites have been increasingly applied as chemical industries, structural materials in aerospace, automotive industries and mechanical devices such as photocopier machines, printers, automatic teller machines, food processor and windshield wiper drive.

Now molded plastic gears provide substitute to metal in lightly loaded drives. They transmit power quietly and often without lubrication in numerous applications, furthermore decrease the quantity of parts and oppose chemicals in numerous applications. Before, polymer gears were restricted to 0.25 hp due to varieties in properties and uncertainties about how they react to natural conditions such as moisture, temperature and chemical. Now, better molding controls combined with design practices that more accurately encompass environmental factors have boosted plastic gear drive capacity to 1.5 hp. Using reinforcement this is standout amongst the most practices to enhance the gear performance.

This study investigated the effects of multilayer graphene nanopelatelets (MLNGPs) as an additive on polyamide 6 (PA6) spur gear performances. These include strength, thermal stability, dynamic mechanical Thermal analysis, moisture absorption, and wear characteristics. The nanocomposites gear was made by melt mixing method and injection molded into thick flanges. CNC milling machine used to produce PA6/MLNGPs spur gear. The wear investigations were performed at a speed of 1400 rpm under torques 13 N.m and 16 Nm with different concentration 0, 0.1, 0.3 and 0.5 wt% MLNGPs using test rig. The result showed that 0.3% of MLGNPs is the optimum concentration. Tensile strength increased up to 30%, Vickers micro hardness value increased up to 25%, storage modulus E’ is increased up to 37% and glass transition temperature is increased up to 14%. On the other hand TGA result shows that the $T_{onest}$ increased up to 7.5% and Td increased up to 2%, and wear rates decreased by 35% at 16Nm and 54% at 13 Nm.

# Chapter 1 : Introduction.

The thermoplastic polymer gear is selected to substitute another metallic in lightly load drives because of the economic gains and their technical advantage. Thermoplastic gears are widely used in mechanical devices such as photocopier machines, printers, automatic teller machines, food processor windshield wiper drives, and even watches. Comparison with metal gear, The polymer gear are able to transmit power quietly, without lubrication application, low specific gravity material, low noise operating, and opposes chemicals in many applications. However, considerations such as; working environment, strength, weight, elastic modulus, thermal expansion, moisture absorption and friction characteristics must be precisely considered when deciding to replace metal with polymer. Despite the advantages of using plastic instead of metal it has drawbacks like strength lower than metal. For instance, bending strength, range in (12000: 450000 PSI), dependent upon specific material. This means larger gears to carry the same load. Gear teeth deflect more under load because they have lower elastic modulus and mesh stiffness. Strength and stiffness change generally with temperature extremes and exposure to water and chemicals. For example, the elastic modulus of plastic drops as much as 60% with a 900° F temperature rise, whereas the modulus of steel remains nearly constant. Nylons lose as much as 50% of their modulus due to it absorb moisture. Gear dimensions also variation with environmental conditions. The thermal expansion coefficient for unreinforced plastics is three to twenty times that of metals. However, certain reinforced plastics offer thermal expansions close to that of metals. The thermal effects of molding, particularly gating and cooling, affect the long term dimensional stability of gears.

## 1.1. Objective of this study

The main study estimated the effects of multilayer graphene nano platelets (MLNGPs) as an additive on polyamide 6 (PA6) spur gear performances. This study includes thermal stability (TGA), dynamic mechanical thermal analysis (DMTA), strength, elastic modulus, moisture absorption, and wears characteristics. The nanocomposites gear was made by melt mixing method and injection molded into thick flanges. Spur gear produced by using CNC milling machine. The wear investigations were performed at speed of 1400 rpm and under torques 13N.m and 16 N.m with different concentration 0, 0.1, 0.3 and 0.5 wt. % MLNGPs using test rig.

## 1.2. Overview of the thesis

**The thesis is divided into six chapters:**

1. **Chapter one**: An introduction of polymer and its application and the objective of this study.

2. **Chapter two**: Includes presents a review of related research topics covering areas in polymer gear reinforcements and the different way to study the gear performances.

3. **Chapter three**: Discuss the polymer gear behavior and graphene as reinforcement and different technique of dispersion and the types of test rig.

4. **Chapter four**: Describes the experimental setup and techniques used in the investigation of gear performance of MLNGPs as an additive on polyamide 6 spur gear.

5. **Chapter five**: Discusses the results of the experimental work and the interpretation for the results. The results of characterization of the produced nanocomposites will be demonstrated in this chapter.

6. **Chapter six**: Includes the main general discussions are given in this chapter, which is followed by a conclusion and findings from the work and provides suggestions for future work.