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# EXPERIMENTAL INVESTIGATION OF POLYMER MATRIX COMPOSITE GEARS WITH DIFFERENT FIBRE PROPORTIONS

[1]K.Senthilnathan, [2]S.Ilayavel , [3]G.Suresh

[1]PG Student, M.E. (CAD), Sri Venkateshwara College of Engineering, Chennai (Tamilnadu).
[2]Assosciate Prof. Sri Venkateshwara College of Engineering, Chennai (Tamilnadu).
[3]Assistant Prof. Rajalakshmi institute of technology, Chennai (Tamilnadu).

**ABSTRACT**

**Nowadays Polymer gears are mostly used in power and motion transmission work under different loads and speeds. This work is intended towards enhancing the tooth wear resistance of polymer gears by inclusion of chopped strand mat (CSM) into epoxy material. As well, objective of this work is to make glass fibre reinforced polymer gears using epoxy resin with various proportions of glass fibre by changing the volume fractions such as 5% CSM, 10% CSM, 15% CSM, 20% CSM into epoxy resins. In order to validate its bending strength and wear resistance behavior of the CSM reinforced epoxy resins, all the test specimens were subjected to Fatigue wear resistance test, the test results showed that 5% and 10% CSM reinforced epoxy gears were shown very less wear rate and damages while compared with the remaining proportions.**

**Keywords: Fibre reinforced polymer, chopped strand mat (CSM), epoxy resin.**

## I. INTRODUCTION

Now a day's most of the conventional materials are effectively replaced by the composite materials because of their less weight to stiffness ratio. Among them Fibre reinforced plastic materials role played in the extensive way. In the case of plastic (FRP) - Metal Hybrid composite technology, the properties of two materials are combined in an optimistic manner resulting in synergistic effect that cannot be achieved in respective materials alone. The hybrid composite technology has a great potential in geared transmissions where plastic gears can lead to low cost, light weight, high strength and improved performance of the system. In general carbon and glass fibres are used as reinforcement in polymer gears. Most of the mechanical machine elements are manufactured with this technology due to their explicit mechanical advantage property. Even its usage is yielded in the area of manufacturing critical components (power transmission) like gears and so on. At the present time Gears are considered as one of the most critical components in a power transmission system.

Polymer composite gears finds increasing application because of low material, manufacturing cost and weight compared with metal gears even though polymer material suffers from poor mechanical strength compared with metals. Reinforced polymer offers high mechanical strength and is suitable for structural and load applications. Many research works have been performed on issues related to performance of polymer composite gears. In those articles influence of reinforcement on wear resistance, hardness of polymer gear is well discussed, and since polymer based gears are derived from metal gear design.

In conventional metal gear manufacturing processes like gear hobbing and shaping, the gear blanked are mounted with machine tool axis and obtaining concentric features in metal gears which is not difficult. When reinforced gears are used in power transmission applications and surface condition of gears plays a major role in deciding the performance.

This paper discusses the effects of wear performance and defects of polymer spur gears using epoxy resin and various proportions of chopped strand mat. Test gears were run at same speed but different load at different proportions, performance of wear rate and defects are discussed.

## II. DESIGN METHODOLOGY :

Table 1. Gear geometry calculations:

| |
|---|
| 1. PITCH CIRCLE DIAMETER |
| Module = 2mm |
| No of teeth = 48 |
| Pitch circle diameter = 96mm |
| 2. DIAMETRAL PITCH |
| Diametral pitch = No. of teeth/ pitch diameter |
| = 48/96 |
| = 0.5 |
| 3. CIRCULAR PITCH |

 

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| |
|---|
| Circular pitch = (π* pitch diameter)/No. of teeth |
| = (π*96)/ 48 |
| = 6.283 mm |
| 4. FACE WIDTH |
| Face width = 30 mm |
| 5. TOOTH THICKNESS |
| TOOTH THICKNESS = 1 mm |
| **6.** PRESSURE ANGLE = 20 ° |

III. GEAR MATERIALS AND PROCESSING:

Commercially E- Glass CSM are purchased from the market. E-Glass CSM were made from these fibres through Hand weaving machine. In this experimental investigation four proportions of polymer gears (5%, 10%, 15%, 20%) are carried out (i.e) E- Glass CSM into epoxy matrix material. Epoxy resin used as matrix materials. The density of mat is 450g/$m^2$.

| PROPERTIES | E-Glass CSM |
|---|---|
| Density | 2.60 |
| Tensile strength | 3400 |
| Tensile modulus | 73 |
| Poisson's ratio | 0.35 |

Table. 2 Properties of E-Glass CSM

IV. GEAR MANUFACTURING

**FIGURE 1. MOULDING OF GEARS**

Chopped strand mat ( Powder bonded) is formed by binding chopped glass fibres, using spraying powder binder. The type of epoxy resin used in the present investigation is Araldite LY556 and hardener is HY951. The composite material used for this study is prepared by hand lay up method. The Epoxy resin and E-Glass fibre CSM are measured for required proportions. The fibre is chopped and added to the resin and mixed well. Initially 400gms of epoxy and 60ml of hardener is poured into a mould. The required amount of proportions is then stirred through a glass rod. The required amount of colour pigments are added to the required proportions. The mould is then kept for 6 to 7 hours. After 6 to 7 hours, the mould is then dried. A release gel made of wax is sprayed on the mold surfaces to remove a cavity from mould. Finally a desired shape is obtained.

V. TESTING OF THERMOSET POLYMER GEARS:

The schematic diagram of the gear test rig used for Conducting the performance tests are shown in figure 2. In this test rig, the test gear (GFRP) runs against metal gears. Test gear is driven using a three phase induction motor which runs at 1440rpm. The required test torque is induced through a load cell attached to eddy current dynamometer. Gear specifications and test conditions are given in table 2 and table 3. All tests were conducted under unlubricated conditions. Four gears ( 5% GFRP/A, 10% GFRP/B, 15% GFRP/C, 20% GFRP/D) were tested by subjecting it to 6.2*10^4 cycles.

For each proportions of gear, three different torques are chosen. The tooth thickness was measured by gear tooth vernier at PCD. Three different torques for each gear is chosen for measuring tooth thickness and measuring wear rate and average value for wear rate is determined. Gears were run up to 6.2*10^4 cycles. During the tests gear

 

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damages were investigated and photographs were also taken and gear defects were theoretically found.

**FIGURE. 2 PHOTOGRAPHIC VIEW OF GEAR TESTING KIT**

| | STANDARD GEAR | TEST GEAR |
|---|---|---|
| MODULE | 2mm | 2mm |
| NO OF TEETH | 48 | 48 |
| OUTER DIAMETER | 100mm | 100mm |
| FACE WIDTH | 30mm | 30mm |
| SHAFT DIAMETER | 30mm | 30mm |
| KEY SIZE | 10*5mm | 10*5mm |
| MATERIAL | Cast iron | Thermoset polymer gear |

**Table. 3 SPECIFICATION OF GFRP GEAR**

| | |
|---|---|
| TORQUE(Nm) | 1,2 and 3 |
| Rotational speed( rpm) | 1440rpm |
| Pressure angle | 20deg |
| lubricant | dry |

**Table. 4 GEAR TEST CONDITIONS**

## VI. RESULTS AND DISCUSSIONS:

### 6.1 WEAR AND PERFORMANCE OF GEARS:

In this experimental investigation , GFRP of Different volume fractions were used. Torques of 1, 2 and 3Nm were applied at 1440rpm, and the damage zones as well as the performance of the gear were investigated. Figure (3) shows the wear depth of GFRP/A, GFRP/B, GFRP/C, GFRP/D GEARS at different torque levels. All the gears were run upto 6.2*10^4 cycles at 1Nm without major damages and wear rate is low for 5% GFRP gears and will cause pitting. For 10% gears it will give improved performance and wear rate is high. For 15% and 20% GFRP gear will shows improved performance and high wear rate which will cause better improved performance of the system and will cause tooth breakage and fatigue fracture due to high loads and high reinforcement.

**DEFORMATION OF GEARS:**

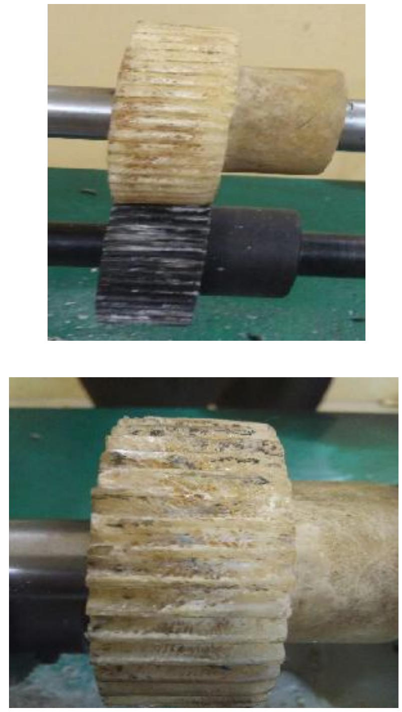

**FIGURE 3 DEFORMATION OF GEARS FOR 5%: BEFORE WEAR AND AFTER WEAR**

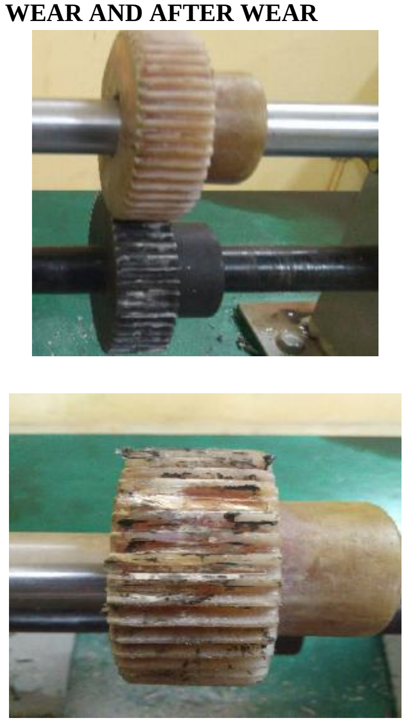

**FIGURE 4 DEFORMATION OF GEARS FOR 10%: BEFORE WEAR AND AFTER WEAR**

**FIGURE 5 DEFORMATION OF GEARS FOR 15%: BEFORE WEAR AND AFTER WEAR**

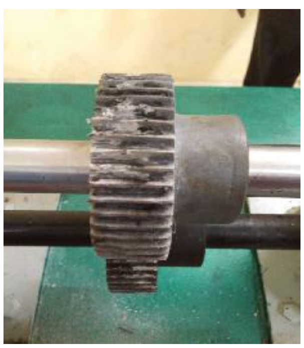

**FIGURE 6 DEFORMATION OF GEARS FOR 20%: BEFORE WEAR AND AFTER WEAR**

**TABLE 5. WEAR RATE ANALYSIS TABLE**

| S.No | % of glass fibre | Load applied(KN ) | INITIAL WEIGHT OF GEAR(gm) | FINAL WEIGHT OF GEAR(gm) | WEAR RATE (gm) |
|---|---|---|---|---|---|
| 1. | 5 | 1 | 245 | 243 | 2 |
| 2. | 5 | 2 | 274 | 270 | 4 |
| 3. | 5 | 3 | 290 | 284 | 6 |
| 4. | 10 | 1 | 272 | 269 | 3 |
| 5. | 10 | 2 | 275 | 269 | 6 |
| 6. | 10 | 3 | 325 | 317 | 8 |
| 7. | 15 | 1 | 325 | 320 | 5 |
| 8. | 15 | 2 | 320 | 313 | 7 |
| 9. | 15 | 3 | 324 | 315 | 9 |
| 10. | 20 | 1 | 308 | 305 | 3 |
| 11. | 20 | 2 | 315 | 312 | 3 |
| 12. | 20 | 3 | 333 | 330 | 3 |

## VII. CONCLUSION:

Glass fibre reinforced polymers of different gears were prepared by hand lay up technique. Wear performance of GFRP were studied and the following conclusions are made. Polymer composite gear can fail in two ways: one by fatigue and another by wear.

- All the composite gears can be tested into number of cycles.
- 5% composite gear shows less wear rate because of less content of fibres.
- 10% composite gear gives better wear rate because of fibre content is high.
- Pitting will cause in 10% gears due to repletion of high contact stresses.
- 15% and 20% composite gears give more wear rate compared to 5% and 10%.
    - The possible reason for that is high content of fibres gives improved performance of the system. Due to high content of fibres, it will cause tooth breakage and fatigue failure.

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