Analyzing the Life Prediction of Spur Gear based on Vinyl Ester with Different Fibre Proportion

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Abstract. The gear is an essential part of every mechanical power transmission system, as well as most industrial rotating machinery. Gears may grow to dominate as the most effective mechanism for transmitting power in future machines due to their high degree of durability and compactness. The vinyl ester resin have high strength and low frictional of porous carbon material. The Vinyl ester resin is used as a reinforced material in plastic gear. In this work, Vinyl Ester and Glass fiber composite material with different proportions were equipped for strengthen cast plastic gear. The spur gear pair was used as the test gears, and the glass transition temperature and fatigue tests were used to determine the gear's life span. Finally, the composite gear has to be analyzed.

1. Introduction

Industrial gears are used in a variety of settings. They're utilized in everything from textile mills to the aviation sector. They are the most extensively utilized means of electrical transmission. They alter the mechanical shaft's and the rotation axis' rotational speeds [1]. They are the ideal medium for minimizing energy loss and attaining great precision in high-speed machinery, such as an automotive gearbox. They're in charge of converting the prime mover's input into a lower-speed, higher-torque output. Power is transmitted with a high velocity ratio using toothed gears. They are exceedingly tight at the place of contact at this period [2]. When a set of teeth is in use, it is subjected to two forms of cyclic stresses. Both of these strains may not reach their pinnacle at the same time. However, gear tooth failure is caused by the combined action of both of these, with bending fatigue generating fracture at the root of the tooth and contact fatigue causing surface failure [3]. When loads are applied to the surfaces of the bodies, they bend elastically near the contact point. The areas with the most of the lines bunched together have the highest stresses [4].

Pitting and scoring are the most common surface failures caused by contact fatigue. Tiny particles are removed from the surface of the tooth due to the intense contact forces that exist between mating teeth. Pitting is caused by a fatigue failure of the tooth surface [5]. The hardness of a gear tooth is the most important factor in its resistance to pitting. Pitting, or surface fatigue failure, occurs when a pair of teeth transfers power and is produced by numerous repetitions of high contact stress on the gear tooth surfaces. Contact fatigue causes gear teeth to break down. Even a little reduction in stress at its source results in a large increase in exhaustion [6,7].

Using superior materials, heat treatment and carburization to harden surfaces, and shot peening to boost surface polish, among other things, has improved gear design for many years. By changing the pressure angle, utilising asymmetric teeth, changing the geometry of the root fillet curve, and so on, additional attempts have been made to increase the durability and strength [8]. Some study has also been done employing stress redistribution techniques, which involve putting stress alleviating elements into the stressed zone, with the goal of reducing root fillet stress in spur gear. This also guarantees that current gear systems are interchangeable [9,10]. The trials that employed a combination of circular and elliptical stress alleviating characteristics yielded greater outcomes than those that used only circular stress relieving elements.

A stress-relieving feature in the shape of an aerofin is tested in this study. For analysis, a finite element model with a three-tooth segment is used, and a stress relieving feature of varying sizes is placed on gear teeth at various points [11]. In mechanical power transmission systems, gearing is one of the most important components. The contact between the mating teeth is where power is transferred between
gears. Meshed gears' teeth flanks are subjected to high contact pressures during operation, and as a result of the repeated stresses, damage to the teeth flanks, as well as tooth fracture at the root of the tooth, is one of the most common reasons of gear failure [12]. The gear's dependability is determined by the tooth's fatigue failure. However, by incorporating stress-relieving elements into the gear, the sites of stress concentration may be reduced, extending the gear's life. The best stress relieving qualities of several shapes are added to spur gears with involute profiles, and the best among them is offered [13,14].

2. Materials and Methods

The most frequent form of gear is spur gear. They are used to transmit rotational motion between parallel shafts and are typically cylindrical in form with teeth that are straight and parallel to the rotation axis. To achieve very large gear reductions, several spur gears are sometimes employed at the same time. Spur gears are employed in a variety of equipment, however they are not utilized in automobiles since they make a lot of noise. Similar to cams, gear teeth are mated against each other to provide rotational motion.

The tooth profiles are considered to have conjugate action when they are intended to create a consistent angular-velocity ratio during meshing. A geometric link between the geometry of tooth profiles and conjugate action may be created, as stated in Law of Gearing: "In all positions of the contacting teeth, a common normal to the tooth profiles at their point of contact must pass via a fixed location on the line-of-centers known as the pitch point." Any two curves or profiles that engage and satisfy the rule of gearing are known as conjugate curves. When one curved surface pushes on another, a point of contact (point c) is formed where the two surfaces are tangent to each other and the forces are equal at all points. Fig. 1 shows the diagram of Spur gear.

In mechanical clocks, the cycloidal gear profile is a kind of toothed gear. The epicycloid and hypocycloid curves, which are created by a circle rolling around the outside and inside of another circle, respectively, are used to create the gear tooth profile. One advantage of cycloidal teeth over involute teeth is that cycloidal teeth do not wear out as quickly as involute teeth. As a result, cycloidal teeth are sometimes used in gears that transmit a great amount of power. Because cycloidal teeth have broader flanks than involute teeth, cycloidal gears are stronger for the same pitch than involute gears. For cast teeth, they are the best option. In cycloidal gears, contact is made between a convex flank and a concave surface, whereas in involute gears, contact is made between the convex surface and the concave surface.
The cycloidal wear is reduced as a result of this situation, however the change in wear is minimal. In cycloidal gears, interference does not exist at all. Although cycloidal gears have benefits, they are overshadowed by the involute gears’ greater simplicity and flexibility. The involute gear profile is the most often used gearing system. The profiles of the teeth of an involute gear are involutes of a circle. The involute of a circle is the spiraling curve produced by the end of an imagined tight rope unwinding itself from the stationary circle known as the base circle. Involute gear construction involves a single instantaneous contact between a pair of teeth. As the gears spin, the location of this contact point shifts across the various tooth surfaces.

The purpose of this test was to confirm and validate the dependability of the Batch A-08 product lines. If the test parameters were fulfilled, a mean lifecycle to failure of at least 102 cycles would be established and verified. Furthermore, product performance at temperature extremes (35 C, 120 C), throughout and after a considerable number of life cycles, is necessary to confirm the MTTF, according to test practice. The gear lifespan test was carried out in accordance with industry standards. Three test samples were employed in each composition, at varying torques, to allow a fair test result (2 N-m to 4 N-m). The Gear analyzing test rig was utilized for this experiment. The test was carried out on several vinyl ester resin fiber compositions.

The product lifecycles (MLTF) test started on 1st March, 2017, and the test was completed on 3rd March, 2016, for an actual test duration of 10 continuous test hours for 3 consecutive days. During the course of the product life test (MLTF), Gear tooth failure took place at 105th cycle. As a result, the MLTF value (No. of lifetime cycles) was calculated. The MLTF of batch A-08 product line is 105 to 106 for products operated at various torques. The testing team feels that the figures in this report may be interpreted as a conservative estimate of product lifespan because the Glass Transition Temperature (Tg) was used as the failure criteria.

3. Results and Discussions

Transition Temperature of the VE88F12 gear is comparable to that of the Torque 3.0 Nm spur gear pair. The Glass Transition Temperature of a spur gear pair with a torque of 3.5 Nm is lower in the VE96F04 gear than in the VE88F12 gear.

Table 1. Percentage Reduction in Weight of the Gear (Deformation)
No.of cycle=6.2*10^4cycles

| S.No. | % OF GLASS FIBER | LOAD APPLIED (kg) | MOTOR SPEED (rpm) | INITIAL WEIGHT OF GEAR (gm) | FINAL WEIGHT OF GEAR (gm) | REDUCTION IN WEIGHT OF GEAR (gm) |
|-------|------------------|-------------------|-------------------|-----------------------------|---------------------------|--------------------------------|
| 1     | 5                | 1                 | 400               | 235                         | 233                       | 2                              |
| 2     | 5                | 2                 | 400               | 254                         | 250                       | 4                              |
| 3     | 10               | 1                 | 400               | 264                         | 261                       | 3                              |
| 4     | 10               | 2                 | 400               | 272                         | 271                       | 2                              |
| 5     | 15               | 1                 | 400               | 300                         | 293                       | 7                              |
| 6     | 15               | 2                 | 400               | 317                         | 307                       | 7                              |
| 7     | 20               | 1                 | 400               | 324                         | 310                       | 14                             |
| 8     | 20               | 2                 | 400               | 333                         | 329                       | 4                              |
Fig. 2 and 3 plot the Glass Transition Temperature ($T_g$) Vs Total number of rotations. The Glass Transition Temperature of VE88F12 gear grows with time and finds equilibrium in the instance of the spur gear pair with Torque 3.0 Nm depicted in Figures. The Glass Transition Temperature of VE96F04, on the other hand, immediately climbs once rotation begins, peaks, and then steadily lowers until it achieves equilibrium.

![Fig. 2 Glass Transition temperature (Torque 3.0 Nm)](image1)

![Fig. 3 Glass Transition temperature (Torque 3.5 Nm)](image2)
In the case of the Torque 2.0 Nm spur gear pair in Fig. 3, the Glass Transition Temperature (Tg) progressively increases over time, achieves equilibrium quickly, and remains stable for a long period. According to these findings, the link between the Glass Transition Temperature and the rotation time varies depending on the gear type. Because the Glass Transition Temperature is thought to be about equal to the quantity of tooth wear, it is assumed that the tooth wear of a spur gear pair with a torque of 2.0 Nm occurs in a consistent volume per revolution.

The average value of the Glass Transition Temperature during operation was employed as an indicator to measure the fatigue life of plastic gears since they are impacted by heat. The average Glass Transition Temperature shows the amount of fatigue work done by the test gears while in use.
The fatigue life of VE88F12-particles varies depending on their median grain sizes. In comparison to VE96F04 and VE88F1260, VE88F125 has a longer life at low temperatures. As a result, the smaller the VE88F12-particle's median diameter, the better. Furthermore, when compared to comparable gear pairs, the VE88F125's fatigue limit is around 8°C greater.

The fatigue life of the VE88F12-particle varies somewhat depending on the median grain diameter. The fatigue life of a spur gear pair with a torque of 3.5 Nm, on the other hand, is almost the same as that of a spur gear pair with a torque of 3.0 Nm.

4. Conclusion
Following a review of the literature on composite spur gear, a research of weight reduction and stress distribution in composite spur gear was carried out. As a result of these findings, we may deduce that stress-induced deformation and spur gear weight produce superior outcomes. The following conclusions have been formed based on the above-mentioned experimental findings and discussions: Because the theoretical mesh is a point contact in the case of a Torque 2.0 Nm spur gear pair, the contact pressure is considerable. As a result, the VE88F12-particle's low frictional feature influences fatigue life.

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Conflict of Interest
The authors declare no conflict of interest.

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