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INVESTIGATION BEHAVIOR OF POLYMER GEAR MATERIAL

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Abstract

This work primarily focuses on the polymer matrix composite comprising Nylon 6 and Basalt fibre pooled together for the purpose of wear reduction in spur gear material. The method employed here using the Nylon 6 and Basalt fibre is employed through the Injection Moulding method, the fibres are combined in the ratio of (80:20) & (70:30). This project aims to focus on the mechanical properties such as tensile, compression, and impact test as per ASTM standards. Later Finite Element models were then developed to simulate the impact, tensile, and wear characteristics behavior of the tested material,

Keywords : Compressive Strength, Split Tensile Strength, GGBS, Metakaoline, Regression Analysis

I. Introduction

Modern aircraft engines find their compatibility to be light, reliable, and efficient to meet the global environmental problem. Many industries employ surface treatments to enhance the fatigue life of critical structural components by drastically delaying the micro-crack nucleation and proliferation under variable loads [1]. The purpose of Gears extends it to various applications in our everyday life, nevertheless, noise, vibrations, reliability & early detection of gear damage remain major apprehension in their applications. As a result, gearbox vibration condition monitoring is an apprehension in their application. As a result gearbox vibration condition monitoring is an important aspect of engineering maintenance[II]. Polymer and polymer composite gears find their suitability in applications because of the low material and manufacturing costs, minimum part weight and quite increased presentation compared with the metal gears. However polymeric materials suffer from meagre mechanical power and thermal resistance compared with metals. Reinforced polymers offer high mechanical strength and thermal resistance and are appropriate for structural/load-bearing applications. Short fibre reinforced polymers permit the fabrication of complex-shaped products economically using the injection-moulding process [III]. The standards were developed from metal gear practice in which the rating of a gear tooth is determined by either bending strength or surface durability, often referred to as wear [IV]. Since precisely moulded gears are now available, it is essential to learn more about the presentation of these gears under different operating conditions. The study of moulded gear performance is significant for economic reasons because these can be mass-produced at a fraction of the cost compared to machined gears. In general, the existing information on polymer composite gear wear is still inadequate and the existing gear surface temperature forecasts need further study to be used for realistic applications [V]. However, applications of polymer gears remain incomplete due to a lack of performance information and design customaries. It is well acknowledged that polymer gears are very susceptible to temperature variations however a thorough understanding of this sensitivity and of how their mechanical properties debase with increasing temperature is lacking in the literature. Understanding their thermo-mechanical behavior relics is very challenging because of the severe non-linearity and high factual-life sensitivity to tiny changes in polymer gear temperature[VI]. Symmetric gears (same pressure angle at both the drive and coast sides of the tooth profile) are used in bi-directional load/motion diffusions. Asymmetric gears (different pressure angles at the drive and coast sides) are more appropriate than conventional symmetric gears for uni-directional load transmission purposes. However, the consumption of asymmetric gears for the engineering application is incomplete due to the difficulty in manufacturing asymmetric gears through predictable techniques such as milling, shaping, and hobbing. Since powder metallurgy and the injection moulding manufacturing process demand only a single/ few die(s) for mass production, asymmetric gears can be contrived economically as symmetric gears[VI]. Modified asymmetric gear geometry to diminish localized loading and to steady the bearing contact for the significant reduction in transmission error optimized the asymmetric gear teeth design to reduce dynamic loads [VII]. Nowadays most manufacturing industries are using composite material to reinstate their traditional materials. in recent times in automobile industries composite material has been used for many reasons. The gears used in the automobile transmission system which is prepared by cast iron can be replaced by using the composite material with the combination of Nylon 6 [V] and E-glass. The noise will be condensed by using the composite material [2]. The fatigue life can be improved by replacing the cast iron material and also the wear rate can be reduced by using the composite material[III]. Thus Gear performance is significantly prejudiced by the interacting surface conditions. on the other hand, very few attempts have been made to recognize the effect of the mating surface condition[VIII].

II. Material Selection

The nylon 6 [V] have superior mechanical properties such as high tensile strength, good impact strength, and high wear resistance characteristics. The basalt fibres have a tensile strength of 2050mpa and young's modulus of 85 mpa. The basalt fibres withstand up to 8500 C. In this project basalt fibre and nylon6 were taken for production as it has high wear resistance[III].

III. Manufacturing Methods

In practice, VARTM is manufactured by placing alternative layers of metal and fibre/prepreg in the mould through the hand lay-up method. Later the structure is cured at desired temperature and pressure or by using an autoclave. But, there is a lot of chance of the presence of blow holes or bonding failures in this method also these fabrication processes were expensive and suit for limited specimens. To maintain high accuracy in bonding at low cost, we prepared our specimens under the VARTM process, the speciality utilized by Manufacturing Technology Lab,
Anna University. Basalt fibre drilled sheets of 300X300mm and the same size as three layers of basalt Fibre are stacked in such a way that the top and bottom consist of basalt with alternate natural fibre sheets. Polyester resin and HY5/3 hardener in a 1:10 ratio combination are used as a binding agent to achieve the required basalt through a cold mould set up by VARTM. the mentioned combination is squeezed through a vacuum gun into the stacked die with 5 bar pressure and allowed to cure for around a day. From the obtained plate, the required test specimens as per ASTM standards were cut by using an abrasive water jet machining set-up.

IV. Impact test:

The Izod impact test is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This test is carried out on the samples made as per the ASTM D256 standard. The absorbed energy by the specimen is noted until a fracture takes place during testing.

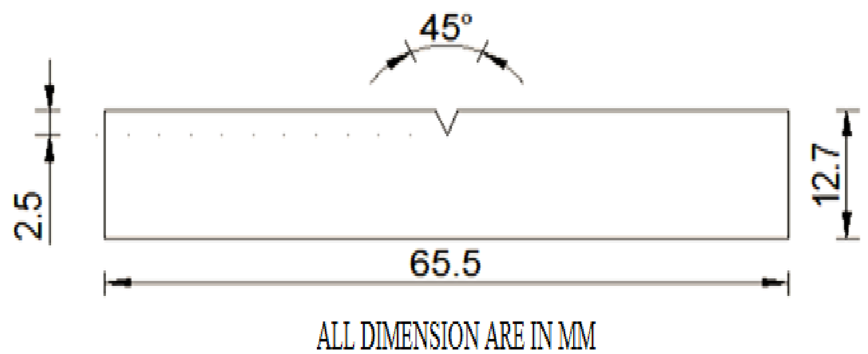

Fig. 1. IMPACT TEST SPECIMEN

Table 1: Impact test results

S.No	80:20 (in joules)	70:30 (in joules)
1	10	7
2	9.0	8.
3	9.0	9

V. Tensile Test

Material strength can be found by testing the material in tension or compression. Test specimens are prepared according to ASTM D638 standard, each specimen having 30 mm width and 280 mm gauge length, as shown in Figure. The specimen is loaded in a computer-controlled Universal Testing Machine (ASE – UTN 10) until the failure of the specimen occurs. Tests are conducted on composites of different combinations of reinforcing materials and ultimate tensile strength and ductility are measured. Simultaneous readings of load and elongation are taken at uniform intervals of load. The tensile test is carried out at room temperature. The uniaxial tensile test is conducted on the fabricated specimen to obtain information regarding the behavior of a given material under gradually increasing stress-strain conditions.

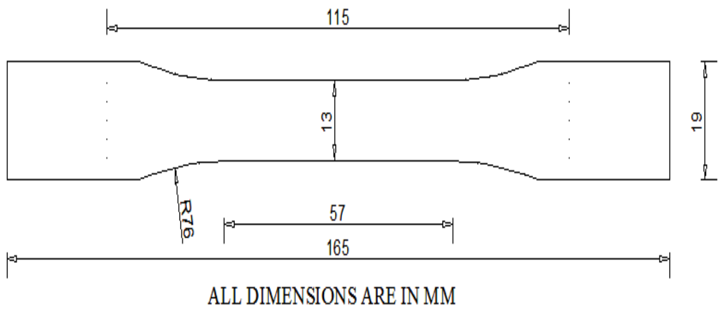

Fig. 2. The ASTM D-638 standard specimen for compression testing

Table 2:Tensile tests results.

Tensile Test	Ultimate Braking Load KN	Elongation in %	Yield Stress (KN/MM2)
1	5.68	8.33	0.121
2	4.43	10.00	0.1336
3	6.3	6.66	0.099
4	4.48	11.22	0.058
5	7.25	8.66	0.025
6	6.25	6.55	0.044

VI. Flexural Test

The flexural specimens are prepared as per the ASTM D790 standard. The 3-point flexure test is the most common flexural test for composite materials. Specimen deflection is measured by the crosshead position. Test results include flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks. The specimen was used for conducting the flexural test. The tests are carried out at a condition of an average relative humidity of 50%. A graph is drawn for each sample between the force and the displacement in the flexural test. It shows that sample C has higher flexural strength [9] than other samples.

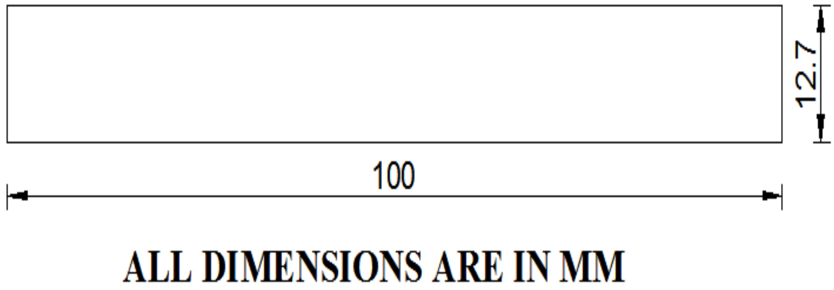

Fig 3. FLXTURAL TEST SPECIMEN

Table 3: Flexural test results

Flexural Test	UltimateBreak Load Kn	max disp mm	Ultimate stress KN/MM2
1	0.480	3.8	0.010
2	0.498	4.55	0.009
3	0.625	3.306	0.012
4	0.655	308	0.014
5	0.587	4.5	0.008

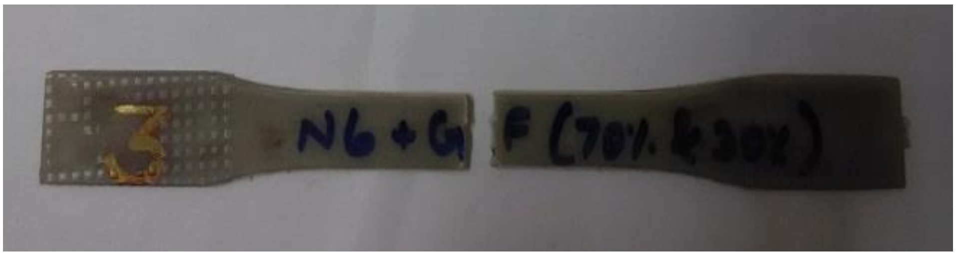

Fig. 4. Tensile Specimens (after testing)

Fig. 5. Compression test specimen after failure

Fig. 6. Impact test specimen after failure

VII. Morphological Analysis using SEM

In general, SEM is used to observe the topography and morphology of a specimen. A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The fractured surfaces of impact test specimens are analyzed using SEM. The samples were taken for the SEM Analysis as they have large variations in the mechanical test results as well as variations in the composition and melting temperature.

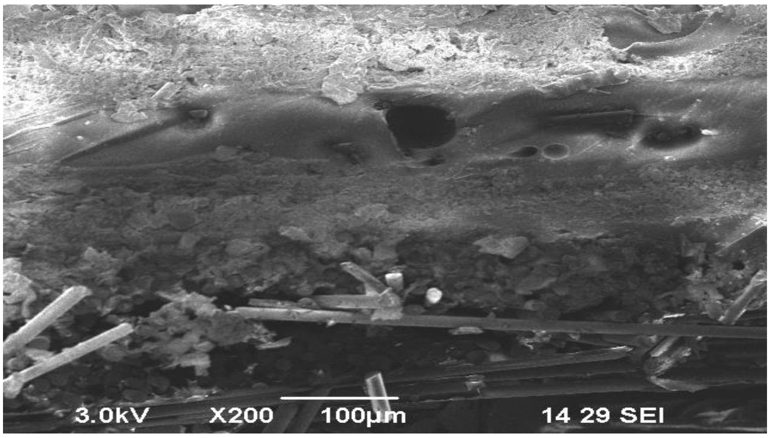

Fig. 7. SEM IMAGE **(A)**

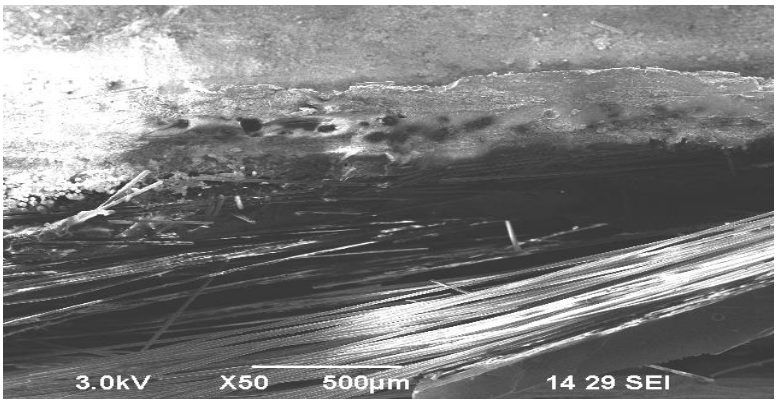

Fig. 8. SEM IMAGE **(B)**

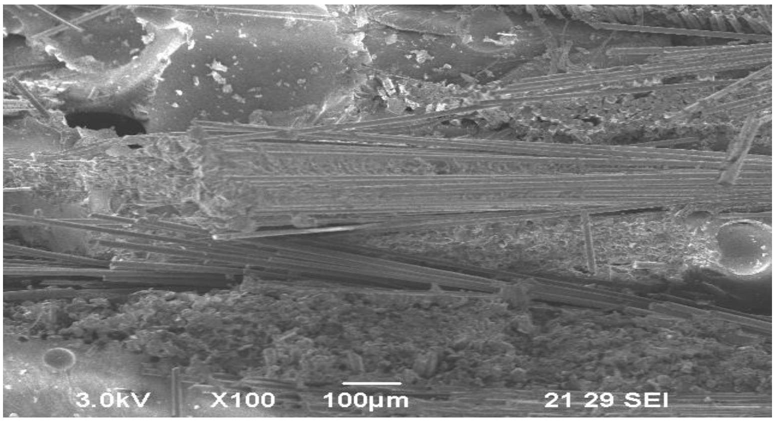

Fig. 9. SEM IMAGE **(C)**

The SEM image shown in the above diagram is taken from the ZEISS testing machine having 100Xresolutionand 0.6. In the SEM image, the fibre direction is uniformly distributed. The void of the image is under the control limit. The morphology of the image is clearly distributed. The fibre orientation is clearly shown in the image A

In the SEM image B, the fibre in some places is delaminated due to loading pressure and the properties of the mixture are evenly distributed in the SEM image C also the fibre is delaminated in some places due to loading pressure and the properties of the mixture is evenly distributed

VIII. Conclusion

- The project has focused on the alternate gear material. The material has been taken from nylon 6+ Basalt fibres.
- The Tensile test properties, as well as the Flexural strength, increased considerably. The Compression properties also increased.

- The SEM Result has concluded that the morphology properties are evenly distributed in fibre and matrix. The fibre in some places is delaminated due to loading pressure.
- The FEM Result was also done. The actual and theoretical calculations were also determined.

Conflicts of Interest:

There is no conflict of interest regarding the paper.

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