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Characterization of Hybrid Glass Epoxy Composite Material with Combined TiO2 and Carbon Filler

K.Kalyan Krishna[1], J.Sai santhan[2], P.Lokesh Reddy[3], D.Harsha Vardhan[4]
B.Tech Student[1, 2, 3], HOD[4]
Department of Mechanical Engineering
SVIT Engineering College Anantapur, India

Abstract:
The weight to strength ratio of composite materials is very important parameter for replacing the existing material, the current work focused to examine the weight to strength ratio of newly developed hybrid composite martial of glass/epoxy with combined Titanium oxide (TiO_2) and Carbon filler. From the literature it is evident that TiO_2 and Carbon fillers individually influence mechanical properties of material which lead to present work to examine the properties with combined filler. The Glass/Epoxy composite material without filler and with 2.5%, 5% and 10% filler by weight ratio is to be prepared by hand layup technique. The Tensile, Flexural and impact tests are carrying for mechanical characterization as per ASTM standards. The newly developed composite material may exhibit better mechanical properties i.e low weight to strength ratio and it will be better substitute for existing materials.

Index Terms: Epoxy, Glass fiber, Material Properties, TiO2 and Carbon filler

I. INTRODUCTION

A composite material is a material made of two or more constituent materials with significantly different physical and chemical properties that, when combined, produce a material with characteristics different from the individual components. The lightweight composite materials can offer the impressive mechanical properties such as a high specific strength, stiffness and the relatively good energy absorbing characteristics. High performance composites are commercially used in the fabrication of aircraft, automotive and marine structures. The composite materials usually involve a matrix, such as polymers. Glass is the most common form of the reinforcing fibres because it is cheap and has good Epoxy resin is one of the excellent thermosetting polymer. The cost-to-performance ratio of epoxy resin is outstanding. Epoxy resin possess characteristics Such as high strength, low creep, good adhesion to the most of the substrate metals, Low shrinkage during curing and low viscosity. Due to these reasons epoxy resins are significantly used as a matrix material in many applications such as aerospace, structural applications, ship building and automobile industries and so on. Studies conducted during the last decade reveal that adding small amount of fillers (like TiO2 &Carbon) of nano size significantly improves the engineering properties of the polymers. Glass fiber reinforced plastic (GFRP) composite material was developed to meet the requirements of the industry for high strength materials with low weight. Titanium Oxide (TiO2) fillers exhibit excellent mechanical properties. The titanium based material offers high strength, good corrosion and oxidation resistance, it is believed that incorporation of this filler can greatly improve the mechanical, tribological properties and corrosion resistance. Influence of carbon fillers on materials improves strength like tensile, impact and flexural properties. The present study focuses on mechanical properties of GFRP laminated composites with combined filler material of TiO2 and C. The Glass/Epoxy composite material without filler and with 2.5%, 5% and 10% filler by weight ratio is to be prepared by hand layup technique. The Tensile, Flexural and impact tests are carrying for mechanical characterization as per ASTM standards. Ansam Adnan Hashim studied preparation and performance testing of nano titanium dioxide as fire retardant of high density polyethylene composite, in this work, High density Polyethylene (HDPE)/titanium dioxide (TiO2) nano-composite was prepared by melt extrusion to assess the efficiency of nano Titanium dioxide as fire retardant and to detect its effect on melting point of composite. Different weight percentages of nano TiO2 (0, 2%, 4%, 6%) were used. The Fire retardancy of prepared samples were tested according to standard methods [ASTM D 635, ASTM D4804]. The possibility of using nano TiO2 as new fire retardant for HDPE composites where the fire retardancy was improved with using nano TiO2 as filler. Sample S2 (4% wt. addition) had maximum value of fire retardancy properties (minimum rate of burning, minimum height of flame and longest the time of first drip). Iskender Ozsoy studied the influence of micro and nano-filler content on the mechanical properties of epoxy composites, In this study, the influence of micro- and nano-filler content on the mechanical properties of epoxy composites was studied. The matrix material is epoxy; the micro-fillers are Al2O3, TiO2 and fly ash added in 10 wt% to 30 wt% by weight ratio; the nano-fillers are Al2O3, TiO2 and clay added in 2.5 wt% to 10 wt% by weight ratio. The tensile strength, flexural strength and elongation at break values of micro-filler Al2O3, TiO2, fly ash and nano-fillers Al2O3, TiO2, clay epoxy composites decreased with increasing filler ratio. And the Hardness is increased with increasing filler content. S.Sivasaravanan studied impact properties of epoxy/glass fiber/nano clay composite materials, In this present investigation hybrid composites of Epoxy/Nanoclay/Glass fiber were prepared by Hand-layup technique. The glass fiber used in this present investigation is E-glass fiber bi-directional: 45˚ orientation). The wt% of nanoclay added in the preparation of sample was varied, ranging from 1wt% to 5wt%. The impact test results of nano composite materials improved with addition of nano clay in epoxy matrix. This test was performed by izod testing machine, it was found that addition of 5wt% of nano clay shown very good results compare to other percentage of nano clay. A Arockia Linson studied mechanical and thermal behavior and properties of hybrid nano composite materials, To improve the mechanical and thermal stability of the composite material by adding fiber reinforced plastic and iron oxide Nano fillers. And the Study of microstructures of the Nanocomposite material to find out the effective characterization on oxide Nano fillers with epoxy resin and fiber reinforced plastic. Discussion the adding of Nano particles have done a great job in improving of mechanical properties such as tensile strength, young's modulus, and thermal stability. T.Sornakumar studied studies on effect of nano tio2 ceramic fillers of polymer matrix composites, In this present work is to study the effect of nano titanium dioxide fillers on the properties of glass fiber reinforced plastics. The glass fiber reinforced plastic specimens were manufactured with glass fiber chopped strand mat, polyester resin and nano titanium dioxide fillers by the hand layup technique. The nano titanium dioxide fillers are incorporated in different weight ratios in the fiber reinforced plastics and the mechanical properties are evaluated. The tensile strength, flexural strength and shear strength of the GFRP improved very much with addition of nano TiO2 filler particles.

II.EXPERIMENTAL

Materials used:
In this study, S-glass fiber is used as a reinforcement material and Epoxy resin (LY 556) and Hardener (HY 951) is used as a polymer matrix material. Nano-Fillers such as titanium dioxide (TiO_2) and carbon, were added at 2.5%, 5% and 10% by weight ratio.

Material preparation:
Hand-layup technique is used in the preparation of composite material. Due to the economical aspect and simplicity of hand-layup technique, this technique is being used in small and medium scale industries. Hand-layup technique is a Process where in the application of resin and reinforcement is done by hand onto a suitable mould surface. The resulting laminate is allowed to cure in place without further treatment. The most popular type of open moulding is Hand layup process. The hand layup is a manual, slow, labour consuming method, which involves the following operations:

Preparation of mould: The mould is prepared by Acrylic sheet in the form of Plate.

Figure.1.Acrylic mould

The mould is coated by a release anti-adhesive agent, preventing sticking the molded part to the mold surface.

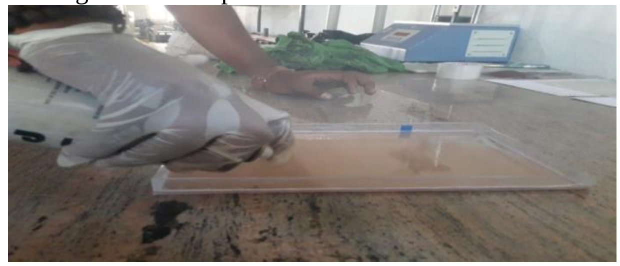

Figure.2.Spray coating to the mould

A layer of fiber reinforcing tissue is applied.
Layers of liquid matrix resin and reinforcement fibers in the form of woven fabric, rovings or chopped stands are applied. The resin mixture may be applied by either brush or roll.

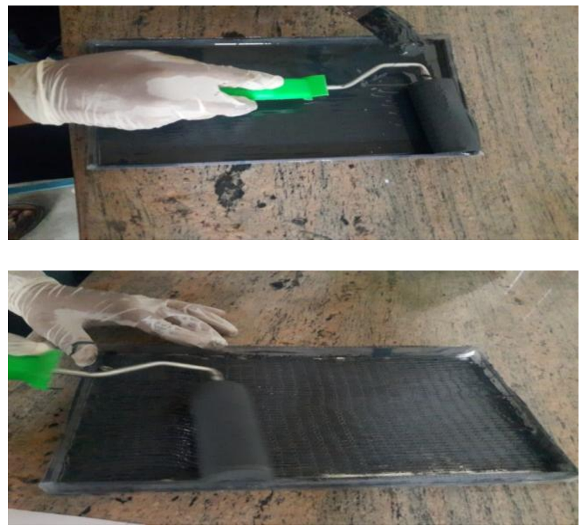

Figure.3. Hand layup Technique

After that, the part is cured for 24 hours.(usually at room temperature)

Figure.4.Material Curing at room Temperature

The part is removed from the mold surface.

Figure.5.Filler Composite Material

III.MATERIAL TESTING

As per ASTM Standards, the plate shape material is cut into corresponding profiles for conducting Tensile test, Impact test, Flexural test, Water absorption test and XRD test. Marking the dimensions in that material as per ASTM Standards.

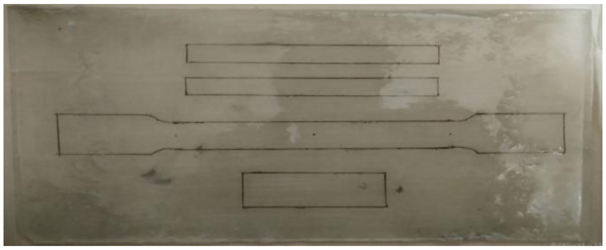

Figure.6.Marking for Cutting

Cutting the pieces for testing as per dimensional marking.

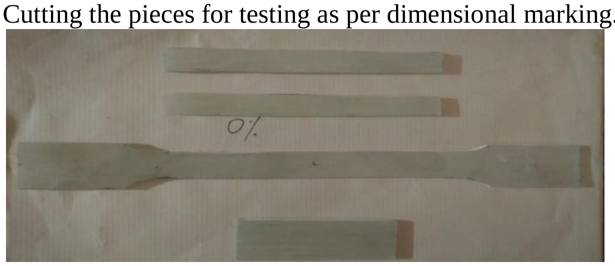

Figure.7. Cutting pieces for testing

Tensile test:

The laminate is fabricated as per ASTM standards of D638 in to the required dimensions by suing wire cut and the edges are ground to finished surface and then the testing procedure involves placing the test specimen in the testing machine and applying tension to it until it fractures. The tensile force is recorded with elongation of gauge section is recorded against the applied force.

Specimen Dimensions:
Length = 256mm
Width = 30mm
Thickness = 2mm

Figure.8. Tensile test Specimen

Flexural test:

The Flexural specimen are prepared as per the ASTM standards. The three-point flexural test is most common flexural test for the composite materials. Specimen deflection is measured by the cross head position. The test result include flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to the it until fractures and breaks.

Specimen Dimensions:
Length = 127mm
Width = 26mm
Thickness = 3mm

Figure.9.Flexural Test Specimen

Impact test:

The Impact test is carried out in a pendulum setup and standard followed is ASTM standards of D790. The centre of the specimen is made into a shape of V-Notch and it is loaded for testing the pendulum is present in the idle position and it is released and made to hit the V-Notch repeatedly until it gets fractured. The effect of Strain rate on fracture and ductility of the material can be determined by using the Impact test.

Figure.10. Impact Test Specimen

Water absorption test:

To study the behaviour of water absorption of the glass fiber reinforced epoxy composites, water absorption tests were carried out according to ASTM standard. The dimension of the material for testing is 72mm × 26mm × 3mm. Composite samples were immersed in distilled water during a time period of 48 hours. After that, check the difference between the weight of the samples of before immersion of sample in water and after immersion of sample in water.

Figure.11.Water Absorption Test Specimen

Wear test:

This test method describes a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus. Immediately prior to testing, and prior to measuring or weighing, clean and dry the specimens. Take care to remove all dirt and foreign matter from the specimens. Use non-chlorinated, non-film-forming cleaning agents and solvents. Dry materials with open grains to remove all traces of the cleaning fluids, that may be entrapped in the material. Measure appropriate specimen dimensions to the nearest 2.5 µm or weigh the specimens to the nearest 0.0001 g. Insert the disk securely in the holding device so that the disk is fixed perpendicular to the axis of the resolution. Insert the pin specimen securely in its holder and, if necessary, adjust so that the specimen is perpendicular to the disk surface when in contact, in order to maintain the necessary contact conditions. Add the proper mass to the system lever or bale to develop the selected force pressing the pin against the disk. Start the motor and adjust the speed to the desired value while holding the pin specimen out of contact with the disk. Stop the motor. Set the revolution counter (or equivalent) to the desired number of revolutions. Begin the test with the specimens in contact under load.

The test is stopped when the desired number of revolutions is achieved. Tests should not be interrupted or restarted. Remove the specimens and clean off any loose wear debris. Note the existence of features on or near the wear scar such as: protrusions, displaced metal, discoloration, micro-cracking, or spotting. Re-measure the specimen dimensions to the nearest 2.5 µm or reweight the specimens to the nearest 0.0001g, as appropriate. Repeat the test with additional specimens to obtain sufficient data for statistically significant results.

Figure.12.Pin-on Disc Setup for Wear Test

IV. RESULTS AND DISCUSSION:

Effect of filler on Tensile Strength:

This test is carried out on a universal testing machine.

Figure.13.Specimen Placed in UTM for tensile test

After the test is completed, the fracture occurs as shown in the figure.

Figure .14. Fracture occurs on UTM

The tensile strength for the GFRP laminated test specimen is shown in the table.

TABLE.1. TENSILE TEST VALUES

FILLER %	ULTIMATE BREAKING LOAD	AREA	ULTIMATE TENSILE STRENGTH
0%	16920	60	282
2.5%	8950	60	149
5%	14620	60	244
10%	18810	60	314

The table shows the value of tensile strength varies from 149 to 314 N/mm². The adding of 5wt% and 10wt% surface functionalized of combined fillers produced the significant improvement in the tensile strength.

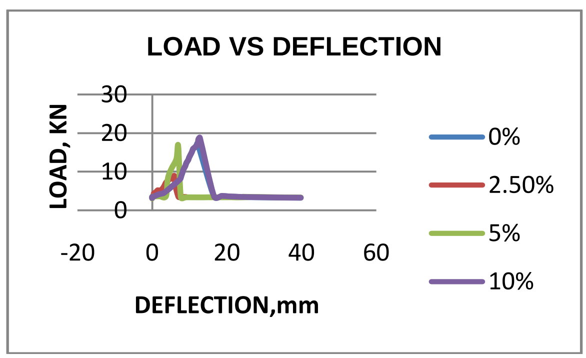

Figure.15. Load vs Deflection graph for Tensile test

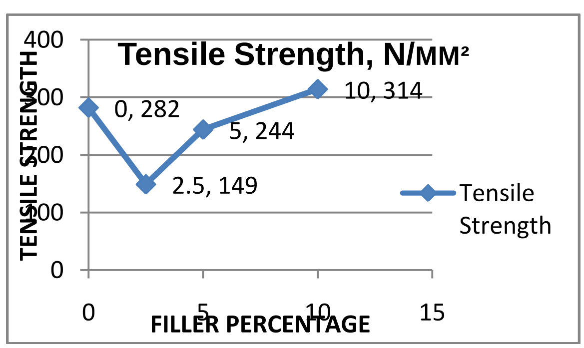

Figure.16. Tensile Strength Graph

Effect of filler on Flexural Strength:
This test is also carried out in a Universal testing Machine.

Figure.17. Specimen Placed in UTM for Flexural test

The sample is placed on two supporting pins a set distance apart and a third loading pin is lowered from above at a constant rate until sample failure.

Figure.18.Bending Occurs on UTM

The flexural strength for the GFRP laminated test specimen is shown in the table.

TABLE .2. FLEXURAL TEST VALUES

FILLER %	FLEXURAL BREAKING LOAD	FLEXURAL STRENGTH
0%	3.79	4858.97
2.5%	3.45	4423.08
5%	3.85	4935.90
10%	3.75	4807.69

It can be observed that the bending load bearing strength of composite increases with the addition of filler in 5%. The addition of TiO2 and C as the filler material to glass/epoxy composite makes the material harder than normal glass/epoxy composite, this leads to bear more bending load than the normal composite material. Basically the glass epoxy composite itself is a brittle material and further addition of TiO2 and C as filler made the material still harder and hence the bending strength increased with addition of filler content.

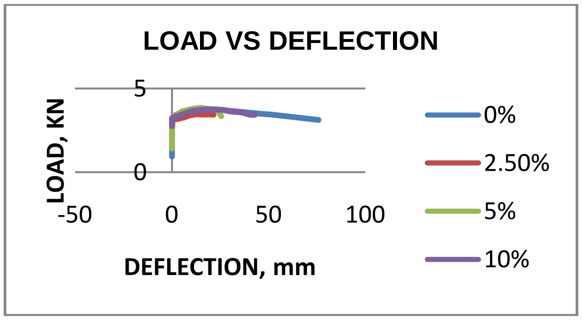

Figure.19. Load vs Deflection Graph for Flexural Test

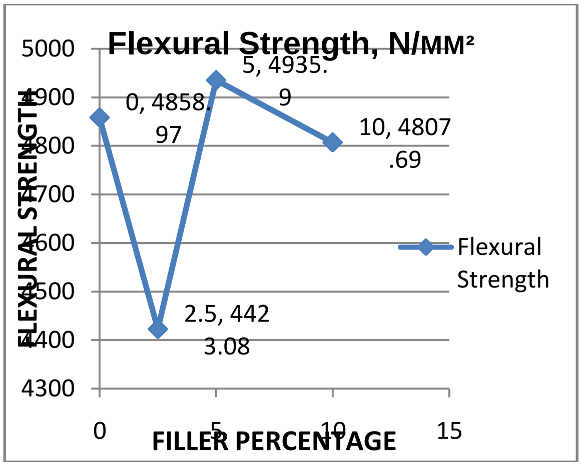

Figure.20.Flexural Strength Graph

Effect of filler on Impact Strength:
The specimen is placed in a testing machine.
The apparatus consists of a pendulum of known mass and length that is dropped from a known height to impact a notched specimen of material. The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after the fracture (energy absorbed by the fracture event). It is observed that Impact toughness value for unfilled glass composite is more than filled composite.
The value of the impact strength for the samples with different wt% of TiO2 and Carbon is shown in Table

TABLE.3. IMPACT TEST VALUES

FILLER %	FORCE (J/M)	IMPACT STRENGTH
0%	10	143.1334
2.5%	2	65.29698
5%	8	147.6056
10%	4	86.81047

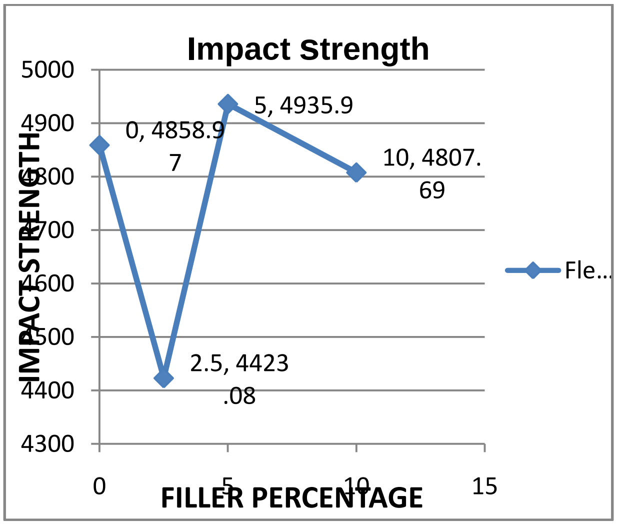

Figure.21.Impact Strength Graph

Water Absorption Test: Composite samples were immersed in a distilled water during the time period of 48 hours. After that, check the difference between the weight of the samples of before immersed in water – specimen weight and after immersed in water – specimen weight.

TABLE.4. WATER ABSOPRTION TEST VALUES

FILLER %	BEFORE IMMERSED IN WATER-WEIGHT	AFTER IMMERSED IN WATER - WEIGHT	MASS OF WATER ABSORBED GRAMS
0%	9.95	9.97	0.02
2.5%	10.13	10.14	0.01
5%	10.52	10.55	0.03
10%	11.17	11.2	0.03

Effect of filler on Wear rate:

Wear tests for different number of specimens was conducted by using a pin-on disc machine The pin was held against the counter face of a rotating disc with wear track diameter 200 mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under the normal load of 490KN and a speed of 130rpm. Wear tests were carried out for a total sliding distance of approximately 30mm under similar conditions as discussed above. The surfaces of the pin samples were slides using emery paper (200 grade) prior to test in order to ensure effective contact of fresh and flat surface with the steel disc. The samples were weighed (up to an accuracy of 0.0001 gm using microbalance) prior to and after each test. The wear rate was calculated from the height loss technique and expressed in terms of wear volume loss per unit sliding distance.

TABLE.5. WEAR TEST VALUES

Filler (wt%)	Speed (rpm)	Time (sec)	Initial Weight (gm)	Final Weight (gm)	Weight Loss (gm)
0%	130	60	2.23	2.19	0.04
2.5%	130	60	2.53	2.49	0.04
5%	130	60	2.24	2.21	0.03
10%	130	60	2.65	2.63	0.02

TABLE.6. WEAR RATE FOR TEST SPECIMENS

FILLER (wt%)	WEAR RATE (mm²)	WEAR RESISTANCE (m/mm²)	SPECIFIC WEAR RATE (mm²/KN-m)
0%	26.4	0.0398768	0.0538775
2.5%	26	0.0394788	0.0530612
5%	25.33	0.0384615	0.0516938
10%	25	0.0378787	0.0513247

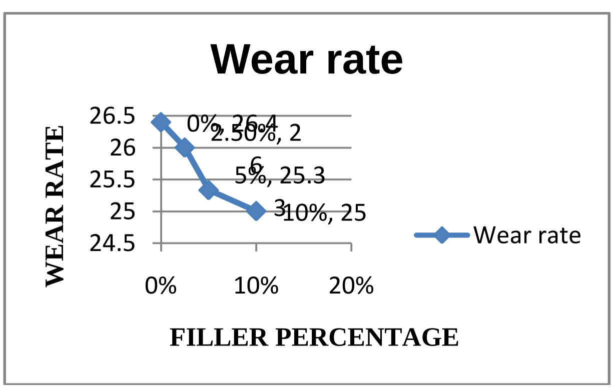

Figure.22. Wear Rate Graph

Weight to Strength Ratio:

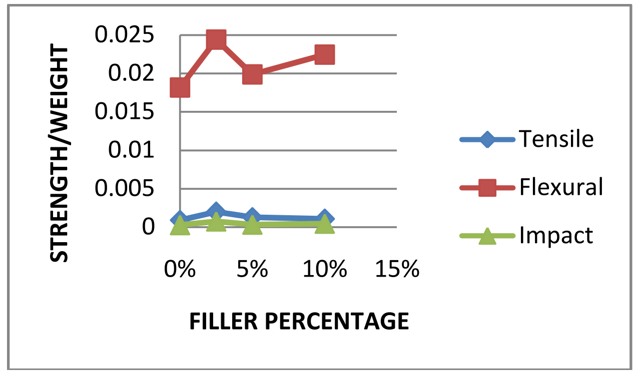

Figure.23.Weight to Strength Ratio Graph

V. CONCLUSION:

Developed hybrid glass epoxy composite material with combined Titanium oxide and Carbon filler by Hand Layup Technique with the newly developed material is subjected to characterization and the following conclusions are drawn from the work.

- In Tensile loading, it is evident that percentage increase of filler content will increase the tensile strength gradually and Young's modulus is observed that the maximum value is at 5% of filler addition.
- In Flexural testing, the percentage increase of filler content will increase the flexural strength gradually.
- For Impact, the percentage increase of filler content will reduce the impact strength gradually. Impact toughness value for unfilled glass composite is more than filled composite. TiO2 and Carbon filler material makes material harder and brittle which is the reason for reduction in impact toughness value.
- The water absorption is more with increasing filler content is compared with the unfilled composite.
- In Wear testing, the percentage increase of filler content will reduce the wear rate and the minimum wear rate is occurred at 10% of filler addition.

From all the above results, finally conclude that,

5% of filler is best suitable for flexural load applications than tensile load and Impact load applications.

10% of filler is best suitable for tensile load applications than flexural load applications. And also this percentage filler shows very good results with less wear rate and it is also suitable for Eroding environmental conditions.

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