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EVALUATION OF MECHANICAL PROPERTIES ON CARBON FIBER LAMINATED VULCANIZED RUBBER

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Abstract — *Now a days, automobile industries require tyres with advanced properties. So the properties of rubber should be enhanced. To enhance the properties, rubber reinforced with adaptive materials which increase its capability. Generally some chemical additives are used to reinforce the vulcanized rubber. The effectiveness of the rubber depends on its strength and stiffness which cannot be varied beyond a certain limit by using chemical additives alone. So in this paper, carbon fiber laminates are used as reinforcing material which is extremely stronger, lighter and has properties like high strength to weight ratio, high stiffness, better fatigue and creep resistance. The specimen of composite material of rubber was fabricated using rubber as matrix, carbon fiber cluster as reinforcement, epoxy resin as adhesive and PPA-7040 as hardener in cross-ply orientation by hand lay process. Mechanical properties such as compression strength, impact strength and wear rate were obtained from the experimental investigations. The results obtained are better than ordinary vulcanized rubber with usual additives.*

Keywords*- vulcanized rubber; carbon fibers; laminates; polymer matrix composites; PPA-7040;*

I. INTRODUCTION

High performance issues are bothering more in research and development field. Because of limitations in strength of materials, there is requirement for testing of various combinations of materials which is made possible by composite materials. Different percentages of reinforcement in different production manners are testing in the field. In automobile industries, tyres require high strength, high stiffness, high life, less fatigue and creep material. Fibre reinforced composites gained popularity in presenting the material with these properties. These have additional properties like light weight and can withstand harsh conditions such as aerospace conditions, marine conditions etc. Generally jute, sisal, banana, sisal, pineapple, coir (natural fibers), carbon fibers, glass fibers, aramid fibers, polyethylene, alumina, silicon carbide (synthetic fibers) are used. Even under the large mechanical stressed, regain its original shape and size after releasing its stress obtained by vulcanization of rubber with one of the curing system such as sulphur system or peroxide system or urethane cross linkers or metal oxide system. Vulcanization is compulsory and it is at the beginning of the preparation of composite material.

Fiber reinforced composites using different types of synthetic fibers such as carbon fibers, aramid fibers, glass fibers, bassault fibers, ceramic fibers and nano technology to improve the capability of fiber reinforced composites [1-4]. Incorporation of oriented aramid fibers into the vulcanized elastomers results in substantial increase in stiffness and modulus which are suitable for pneumatic tyres and particularly in reinforcing the belts between the thread and carcass in radial tyres [5-8]. The carbon fibre cord exhibits excellent adhesion to rubber and imparts fatigue resistance when carbon fibre bundle was treated with butadiene-acrylonitile copolymer having carboxyl group and epoxy resin as a curing agent. The rate of curing of polyamides and phenolkamine depends on the properties of fiber and in case of jute as a fiber, it has better load withstanding capability at various temperatures [9-10]. In this paper, the specimen of composite material tested was fabricated using vulcanized rubber as matrix, carbon fiber cluster as reinforcement, epoxy resin as adhesive and PPA-7040 (phenolkamine) as hardener in cross-ply orientation by hand lay process.

II. EXPERIMENTAL INVESTIGATIONS

2.1 Preparation of composites

The composites perform very poorly when the load is applied perpendicular to the fibers. This paper mainly focused on improving the strength of composite material in any condition. The key factors considered are the orientation of laminates and to keep possible more number of layers in minimum thickness of composite. Cross-ply orientation was opted for anisotropic nature and optimum percentage of carbon fibers by volume. To prepare composite, firstly rubber cleaned off manufacturing oils with sand paper. Then epoxy resin and PPA-7040 were mixed in 2:1 ratio and coated over vulcanized rubber sheet of 2mm thickness. Carbon fiber sheet of 0.85mm thickness layered on rubber sheet within working time of 30min. After curing at room temperature, another layer of resin-hardener mixture is applied to the bottom layer. The required amount of pressure was applied in order to remove the air gaps between the layers to avoid de-lamination. The hand lay process was continued till required geometrical specification obtained. Give 24 hours for settling and then the pieces were cut according to required standards for testing.

2.2 Experimental testing procedures

Three types of tests were conducted on obtained composite. They are- wear test, compression test and charpy impact test. The wear test was carried out to determine whether the material was adequate for a specific wear application and to find optimised surface treatment conditions for better wear performance. Compression test was conducted to find maximum compressive stress that material can withstand without fracture. As the rubber is ductile material, compression strength was determined by the degree of distortion during testing. Charpy impact test was conducted to find the amount of energy absorbed by material during fracture. The absorbed energy is a measure of notch toughness for given material.

The wear test was conducted on pin-on-disc wear testing machine. The test specimen dimensions were taken according to machine specifications as 10mm x 10mm x 13 mm. The load was applied by using balance weighing blocks. Then the material was fixed on machine using allen key and switch on the machine. Calculate the wear rate for different times as shown in table 1 and 2. Hydraulically operated compression testing machine was used. The test specimen was prepared according to ASTMD3410 i.e., 140mm x 25mm x 25mm. The specimen should be fixed between jaws and relief valve is closed. By hydraulic action compressive stress were applied by lower jaw on the material. Visually, the material gets bulged up and cracked along its edges at 45^{o} to the horizontal on the top and bottom surfaces which proves that material undergone shear. The load values were noted for corresponding displacements of lower jaw as shown in table 3. Charpy impact equipment was used for impact test. According to ASTME23 standards, the specimen dimensions were 55mm x 10.5mm x 10.5mm and a notch of 2mm depth and 2mm width was made at the centre of the specimen using a triangular file. Now the specimen was simply supporting in condition and pendulum was released and reading obtained were as shown in table 4. Figure 1, 2 and 3 shows the testing apparatus, specimens before testing and specimens after testing for wear, compression and impact tests respectively.

Figure 1. Testing apparatus for wear, compression and impact tests respectively

Figure 2. Specimens before testing for wear, compression and impact test respectively

Table 1. Wear rate for the composite specimen

Load (Kg)	Wear rate (mg/hr)		
	30 min	45 min	60 min
2	2	2.66	3
3	4	4.66	5
4	6	6.66	7

Table 2. Wear rate for the rubber specimen

Load (Kg)	Wear rate (mg/hr)		
	5 min	10 min	15 min
2	252	330	404
	5min	7 min	10 min
3	384	462.85	608
	1 min	2 min	5min
4	630	1080	1260

Table 3 Maximum compressive load for composite and vulcanized rubber specimens

	Composite specimen		Vulcanized rubber	
S no	Stroke (mm)	Load applied (N)	Stroke (mm)	Load applied (N)
1	1	7000	1	7400
2	2	39000	2	9400
3	2.5	59000	3	13300
4	3	74000	4	20200
5	3.5	82000	5	29600
6	4.5	93000	6	49300

Maximum compressive strength = maximum compressive load / resisting area
= 93000 N / (147mm x 22mm)
= 28.757 Mpa

Table 4. Charpy impact test results for composite and vulcanized rubber

Trails	Composite (Joules)	Vulcanized rubber (Joules)
1	11	5
2	12	5
3	13	5
4	12	5
average	12	5

Figure 3. Specimens after testing for wear, compression and impact test respectively

III. RESULTS AND DISCUSSIONS

The maximum compressive strength of composite specimen is 28.757 MPa. This specimen is able to withstand a maximum compressive load of 93,000N at 34.6% reduction in total thickness. The Charpy test revealed that the composite specimen is able to absorb 12 Joules of energy i.e, more than two times of the vulcanized rubber test specimen (5 Joules). From this Wear test, it was revealed that the wear rate of the composite specimen was almost negligible when compared to vulcanized rubber (as wear rate 7mg/hr<<<1260mg/hr).

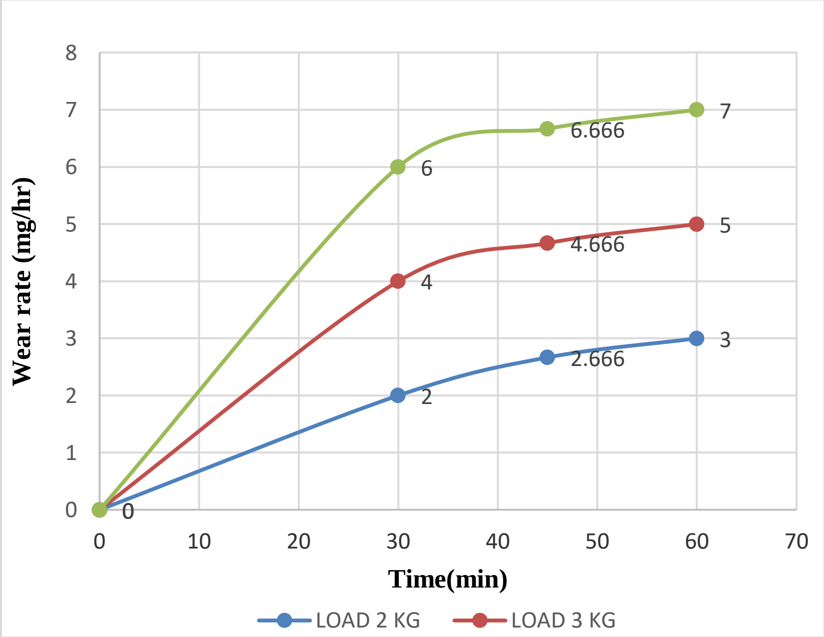

Figure 4. Wear test performance graph

The Test was conducted at 300rpm with a load of 4kg for 5minutes, 3minutes and 1minute. Then load changed to 3kg and test conducted for 10minutes, 7mintues and 5minutes. Then load changed to 2kg, the test conducted for 5minutes, 10minutes and 30minutes. At a load of 4 kg, there is more wear rate than 2kg and 3kg. As rubber has a high coefficient of friction there is more wear rate.

IV. CONCLUSIONS

Turbo-static carbon fibers tends to increase tensile strength of the composite and on heat treatment, meso-phase derived carbon fibers have high young's modulus. The testing of composite material in hydraulically operated compression testing machine revealed that the material behaviour is superior to the vulcanized rubber. As the matrix is ductile in nature and reinforcement is brittle in nature, resultant composite is intermediate in nature. The Charpy test revealed that the impact energy of the composite specimen is more than two times of Vulcanized rubber's impact energy. Ductile fracture appears on specimen after testing. The material was able to absorb near 99.3% of kinetic energy during test. Wear test revealed that the wear rate of the composite specimen is almost negligible when compared to vulcanized rubber.

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