TESTING AND ANALYSIS OF GRAPHENE OXIDE BASED RUBBER TYRE

An approach for responsible consumption and production of resources to achieve sustainable development

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Abstract: This research involves usage of Graphene Oxide as a filler in rubber tyre manufacturing process. The oxygen present in Graphene Oxide easily disperses in organic solvents, water and different types of matrixes like styrene butadiene rubber (SBR) which is a major component in rubber tyres. When combined the rubber tyre with ceramic or polymer matrix, the electrical and mechanical properties of the material is enhanced. The presence of Sp2 hybridization bonding network forms a very strong covalent bonding with the polymers. The testing and analysis showed that tyres made with compound containing small amount of Graphene oxide flakes exhibited outstanding wear resistance and improvement in other mechanical properties. Using the GO mixed rubber tyres reduces wear rate, this can bring production and consumer area be responsible in production and consuming resources. Implementing this researched method in tyre manufacturing will lead to less consumption of rubber, and the tyre producers become responsible producers there by we can achieve a sustainable environment.

IndexTerms - Graphene Oxide,GO,natural rubber,polymers,ceramic,production,sustainable development,styrene butadiene rubber,synthetic and composite materials,wear rate,MV.

I. Introduction

With the growing population, the growth of automobile becomes inevitable. The technology behind modernization and design improvisation helps in compact, user-friendly, and eco-friendly automobiles. However, the wheels that run the automobiles had undergone less improvisations. The idea of using graphene oxide in rubber tyre manufacturing evolved so as to sustain the usage of raw materials. This also in-turn impacts the reduction of considerable amount of worn-out tyres that accumulate as waste by product from the automobiles.

Rubber in its natural or synthetic form is a primary raw material to manufacture tyre. The rubber tyre manufacturing is tailored by chemical fillers and industrial accelerators to meet the demand of automobile industry. This can be further enhanced for its mechanical efficiency by reducing the wear and tear by the usage of a doped material in manufacturing the rubber tyre. The doped material is graphene oxide, commonly called as GO, which is an oxidized form of graphene. The manufacturing process involved is the modified Hummers method.

The composition of the compound materials involved in certain proportion or quantity the defines the quality and efficiency of the rubber tyres in the manufacturing sector. GO, when collaborated with rubber in the tyre manufacturing process improves the mechanical properties and wear resistance of tyres.

Treating graphite with strong oxides produces GO, which contains carbon, oxygen, and hydrogen in variable ratios. The graphene is an allotrope of carbon that is layered in a sheath that is distributed in a hexagonal lattice structure. Graphene is a strongest material which is a good conductor of heat and electricity. As discussed earlier, GO is obtained by using the Modified Hummers Method.

II. Method of Preparation

The method of preparation of 10 kg of rubber compound involves a mixture of 6 kg of natural rubber and 4 kg of synthetic fillers. The doped material GO is granulated into 1 nm thick flakes are added at a 0.35 % wt. Styrene Butadiene Rubber (SBR) containing 25.0 % wt is also added to the blend and stirred vigorously for 30 minutes. The GO/SBR emulsion is then co-coagulated by 1 % wt with sulphuric acid. The coagulated composite is washed with water and then dried in oven at a temperature of 50° C.

The dried composite is now compounded with the rubber ingredients and sent in to an open two-roll mill and compressed in a standard mould at a temperature of 150° C and 15 Mpa for an optimum time. The compound is then further send for mixing, profile calendaring, building, and curing. The composition involved in the preparation are tabulated in the Table 1.

Table 1 Composition of Ingredients

Component	Weight
SBR	2500 g
GO	50 g
Zinc Oxide	125 g
Steric Oxide	50 g
Antioxidant (4010NA)	75 g
Accelerator CBS	35 g

Component	Weight
Accelerator M	2.5 g
Sulphur	70 g
Fillers	1100 g

Mixing

In the process of manufacturing rubber tyre, the key ingredients involved in the preparation are subjected to a temperature of approximately 150° C in a chamber to blend the mixture continuously and homogenize the ingredients.

Profile Calendaring

The homogenized mixture is now subjected to the calendar, which is a set of multiple huge cylindrical roll. The rollers squeeze the mixture into thin sheets. A layer of fabric sheet is sandwiched between the top and bottom layers of thin sheets. With the help of steel cords, the calendars produce body plies and belts of the tyre structure.

Building

Tyre building is a process of assembling all the components onto a tyre building drum. Manually operated tyre building machine (TBM) is used for this process. Typical the TBM operations include the first-stage operation, where inner liner, body plies, and sidewalls are wrapped around the drum, the beads are placed, and the assembly turned up over the bead.

Curing

In this process, by applying pressure to the green tyre in the mould, the tyre achieves a final shape. The tyre is wrapped around an inflated tube and pressed in the mould under high pressure and temperature condition for the desired time. After the curing the rubber tyre, other additional processes like size measurement and visual inspection and testing is done before it is send for packing and dispatching.

III. Testing and Analysis

After the manufacturing process, GO additive rubber component and the tyre that is manufactured is subjected to the testing laboratory. In the laboratory, the tyre is tested for the wear and rubber properties. These test results are compared with the standard parameters to understand the quality. In this research project, the GO/Rubber tyre undergoes six different type of tests done at different stages of tyre manufacturing. The rubber compound after compounding undergoes Mooney viscosity and Oscillating Disc Rheometer. The final tyre was tested for tensile strength, ultimate elongation, adhesion test, hardness shore "A", and abrasive wear rate test.

Mooney Viscosity (MV)Test

To understand the viscosity of the rubber compound with the GO additive, the compound is subjected to the Mooney viscosity test. Viscosity of rubber compound plays an important role in deciding its processing behaviour. In the tyre manufacturing process, the rubber compound undergoes different types of processing before it is heated up or vulcanized into its final product. The viscosity of a rubber compound that is ready to manufacture tyre is determined in a Mooney shearing disk viscometer. The viscosity of the compound is indicated by the torque required to rotate the disk embedded in a rubber/compound specimen, which is enclosed in the die cavity under standard conditions. GO added rubber compound showcased perfect ability to process it for calendaring, extruding, and moulding in the tyre manufacturing process. process. The compound also exhibits good results when comparing the results with the standard ISI values.

MV-Oscillating Disc Rheometer (ODR) Test

The rubber component with the GO additive is subject to undergo curing is tested for its physical characteristics of the material. This is always recommended to maintain the consistent quality of compounded rubber, as the rubber tyre is made in batches. If there are any variations found, the batch variations need to be taken care to eliminate any aberrations. Each batch on testing can be classified into a Pass/Fail criterion depending upon the quality control limits. By this method, one can easily monitor the consistency of each rubber compound every day.

Tensile Strength

To understand the tensile strength of the rubber tyre with GO additive, the specimen of the manufactured rubber tyre is subjected to stress by applying tensile load in the Universal Testing Machines (UTM). The sample material undergoes stress, the elastic limit increases with the decrease in the cross-section area. During this increase in stress with the added load, the atomic bonding tends to bind the atoms together with the closely packed atomic structure. By further application of the tensile load across the cross-section area of the sample, the stress increases and the sample breaks. The value at which the sample breaks is calculated as the ultimate tensile strength. The ductility values are read from the test. The researched value is analyzed with the standard values and the sample, in this case, rubber tyre with GO additive shows better tensile strength.

Ultimate Elongation at Break

The rubber tyre with GO additive is subjected to UTM to understand the ultimate elongation at break point. To understand the mechanical property in terms of elongation, the consider the direction in which the strain is induced by applying the external force and the rate at which the force is applied to the specimen. The sample is stretched extremely long by the application of external load. This in turn applies extreme force on the sample. The maximum stress stretches or elongates the sample and the maximum elongation point is read. The research values are compared with the standard values and the sample exhibits optimal elongation value. According to ISI standards the elongation should be minimum 300% to have the perfect ductility and elasticity.

Adhesion Test

To understand the adhesion property of the rubber tyre with the GO additive that is sandwiched with the fabric layer, the specimen is examined in laboratory conditions with H-test. The adhesive property of the specimen depends on the phase interphase and the mutual adhesiveness of the rubber and the fabric material that is interlined for reinforcement purpose. The H-test, the force required to tear the rubber compound and the fabric material is read. The bond strength of the specimen is found to be strong when comparing with the minimum ISI standard of 8 Kgs.

Abrasive Wear Rate Test

To understand the wear rate of the rubber compound with the GO additive, the specimen is subjected to physical wearing conditions. In tyre industry the biggest concern is life of tyre as it wears out with time and according to physical conditions it is in. The longevity and the worn-out rate is read, the material loss is reduced due to the presence of GO in the rubber compound. The abrasive wear rate test is done to check the percentage loss of material for a duration of two minutes on the wear rate testing machine. Samples are made from the compound in the dimension 15x8mm cylinders, the wear is measured in terms of loss of the compound. The standard material loss for bicycle tyre is 10%, this may vary for different type of tyres.

IV. Results and Observations

The research performed on the rubber tyre with the addition of GO exhibits remarkable results. The standard laboratory tests at various conditions to analyse the physical and mechanical properties demonstrate that the usage of GO in the rubber manufacturing benefits the tyre industry.

Table 2 Test Report

Parameters	Unit	Standard	Observed
Tensile strength	Kg/cm^2	81.5 MIN	88.6
Ultimate Elongation at break	%	300 MIN	348
Tension set	%	10 MAX	6
Adhesion test	Kgs	4 MIN	8

CGS units: Kg = kilogram, cm = centimeter, % = percentage

Tensile Strength

The ISI standard that is defined for the rubber compound used for manufacturing rubber tyres is, 81.5 Kg/cm^2. The researched result demonstrates that the tensile strength of the rubber compound with the GO addition is 88.6 Kg/cm^2. The increased tensile strength by 8.7 Kg/cm^2 compared to the minimum standard ISI value shows that the rubber compound has remarkable load bearing capacity.

Ultimate Elongation

The ISI standard that is defined for the rubber compound used for manufacturing rubber tyres is, 300 %. The researched result demonstrates that the ultimate elongation at break of the rubber compound with the GO addition is 348 %. The increased ultimate elongation at break by 14 % compared to the minimum standard ISI value shows that the rubber compound more ultimate elongation at break than the minimum standard elongation. This showcase that the GO added rubber compound shows good resistance to wear, and increased toughness property. This can be interpreted as the longevity of the rubber tyre.

Tension Set

The ISI standard that is defined for the rubber compound used for manufacturing rubber tyres is, 10 %. The researched result demonstrates that the tensile set is 6 %. In this test, the compound is stretched to 150 % for 15 minutes and kept at rest for an hour at room temperature and then final change is observed. It was observed that there was 40% decrease in change in length as compared to standard limit.

Adhesion Test

The ISI standard that is defined for the rubber compound used for manufacturing rubber tyres is, 4 Kgs. The researched result demonstrates that the adhesion property of the rubber compound with the GO addition is 8 Kgs. The increased adhesion to twice the minimum standard ISI value shows that the rubber compound has good adhesion. This showcase that the GO added rubber compound shows that it has good bonding with different dissimilar material or fabric layers. This can be interpreted as best suit for automated manufacturing process.

Abrasive Wear Rate Test

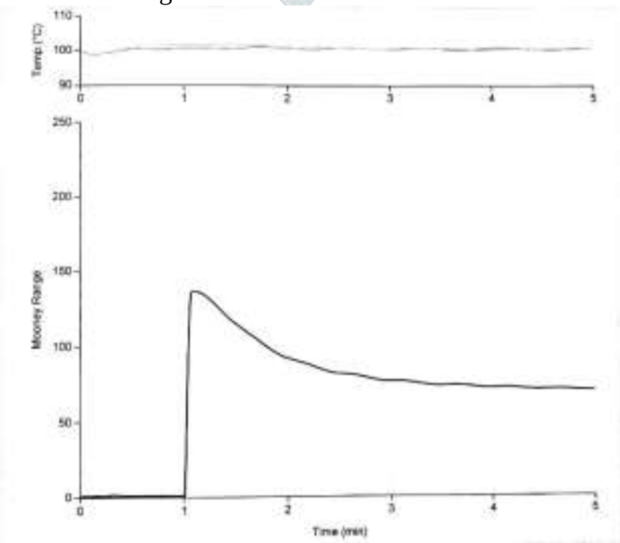
The ISI standard that is defined for the rubber compound used for manufacturing rubber tyres is, 10 %. The researched result demonstrates that the abrasive wear rate of the rubber compound with the GO addition is 8.7 %. The reduced abrasive wear rate of 13 % shows that the rubber compound is subjective to less wear and loss of material loss is minimum.

MV Test

The rub time report for the MV Mooney viscosity test shows that the viscosity of the rubber compound with GO is under the ISI standard range of 250. The test was performed for five minutes with the temperature of 1000 C. Initially, at the range of 0-1 minute, the MV viscosity value is zero, the range increased to 136.60 at the time it reached 1 minute. Later the viscosity dropped to 70.4 at the end of the test, i.e., the fifth minute. The test was ceased at the fifth minute, the temperature of the compound was 100.70 C.

The test observation is indicated in Fig. 1. This positive demonstration shows that the rubber compound with GO addition is well suited for manufacturing rubber tyres.

Figure 1: MV PROPERTIES



MV ODR Test

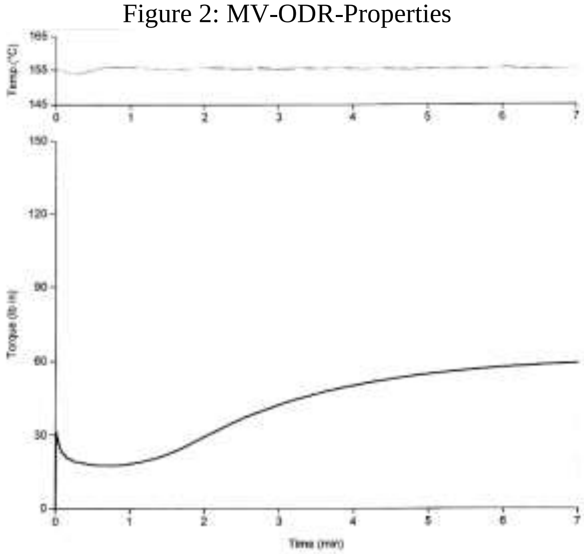
The mechanical property of the rubber compound with the GO additive was observed at 1550 C for seven minutes in the MV Oscillating disc rheometer. The test observation is indicated in Fig. 2. The standard torque limit is 150 lb in, whereas the observed torque at zero minute is 31.4 lb in, the torque dropped at the first minute to 17.6 lb in and then gradually increased and reached up to 59.1 lb in at the seventh minute. The mechanical properties, such as, optimum cure, thermoplasticity, cure rate, and end temperature were observed.

The observed values show significant increase in the mechanical properties of the GO added rubber compound, the properties elucidate that the GO added rubber compound is perfectly suited for rubber tyre manufacturing. The following table shows the observed mechanical properties and the values.

Table 3 Derived Mechanical Values of MV-ODR Test

Parameters	Units	Observed Values
Optimum Cure	minutes	65.9
Thermoplasticity	-	13.8
Cure Rate	m^{-1}	25.7
End Temperature	˚C	155.5

Figure 2: MV-ODR-Properties



V. Conclusion

In conclusion, adding GO in the manufacturing of rubber tyre reduces the wear rate by 13 % when comparing with the non-GO added rubber tyre. Considering the large-scale manufacturing and consumption of rubber tyre with GO additive, the reduced wear can be interpreted as a responsible production with reduced consumption of the natural resources, where rubber being the key ingredient in manufacturing rubber tyres. This can be seen as a supporting step to achieve the Sustainable Development Goal 12 "Responsible Consumption and Production" which was framed by the United Nations Organization to transform our world.

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