

Evaluation of Mechanical Properties and Wear Characterization of Polymer Composites under Varying Temperature Conditions: A Review

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Abstract: Due to several favorable properties in structural applications composites nowadays forms familiar group while selecting the type of materials recommended for particular applications. In addition to this, the glass fibre reinforced epoxy composites, like any other fibre reinforced polymer composites, offer many advantages over the conventional structural materials. These materials have good corrosion resistance, good toughness and good insulation property. These properties have encouraged their use in several Civil Engineering applications, Aerospace Engineering, Transport and Marine Engineering. The performance of the composites can further be improved by adding fillers to them. The work aims at using E-waste Rubber as a filler material. The present work includes the processing, mechanical characterization and study of the wear behaviour of a series of such Rubber filled glass-epoxy composites. The work further assesses the wear behaviour of the prepared specimens upon thermal aging.

Keywords: E-Waste, rubber particles, wear behaviour, thermal aging

1. INTRODUCTION

Composites form complex structures as they are merged with two or more materials mixed with macroscopic scale which are highly insoluble with one another. The matrix material must have the load transferring ability where as fiber dominates the quantitative absorption of energy when it is applied in the form of load externally [1-5]. Composite materials have replaced metals in various engineering applications owing to their numerous advantages, like high strength/weight ratio, low cost, low density, better stealth properties, etc. Due to these advantages, there is an increasing demand for use of these materials in defense applications like naval ships, warplanes, armor vehicles and re-entry vehicles. In addition to this composites find their applications in automotive and aerospace industries such as bushes, gears, seals, cams, shafts etc. The most common types of reinforcement used in polymeric matrix composites (PMC) are strong and brittle fibers incorporated into a soft and ductile polymeric matrix. In this case, PMC are referred to as fibre reinforced plastics (FRP's). Composites in civil engineering applications have been steadily increasing. This is primarily due to the ever-increasing demand for materials, which are characterized by high strength-to-weight and stiffness-to-weight ratios at an effective installed or life cycle cost. The advantageous properties of fibre reinforced polymer (FRP) includes, high strength-to-weight ratio, and corrosion and fatigue resistance create an interest in engineers; the most economical choice depends on the cost of material, production cost, life cycle cost, and material properties. Weight savings and performance, naturally, play a major factor in the choice of materials. A combination of good mechanical properties and relatively low cost makes glass fibre attractive choice for the marine structures. The glass fibres reduce the quantity of water absorbable material and thus, the water sorption of FRC should be less compared to that of the matrix polymer. In-plane shear properties of both carbon and glass fibre composites were comparable and inter laminar shear properties of E-glass composites were observed to be better than the carbon composite because of the better nesting between the E-glass fabric layers. In industry, particularly materials working in places under wear effects are desired to resist wear. The wear resistance of materials determined by the result of laboratory experiments. In this study, the wear behaviour of a E-glass-fibre-reinforced composite with epoxy resin planned to investigate under various loads, speeds and sliding distances. Understanding the tribological behaviour of fabric reinforced polymer composites is an essential element in the design of sliding components. Thus, the aim of the present work is to study of sliding wear behaviour under different loads/ velocities of E-glass fibre composites.

2. REVIEW OF LITERATURE

Few papers were discussed about development and validation procedures for predicting the tensile and flexural strength and also the wear behavior of polymer matrix composites. Literature revealed that the flexural and tensile properties of unidirectional composites and also to study of the relationship between them. This model predicts higher strength in bending than in tension. The new model provides an explanation for the different strengths in bending and tension which is consistent with the progressive, noncatastrophic failure process which is often observed in bending tests of unidirectional composites. Therefore it is common for flexural strengths to be higher than tensile strengths for the same material. Conversely, a homogeneous material with defects only on its surfaces. Kocaoza et al discussed the tensile characterization of glass FRP bars. The characterization of fibre reinforced polymer (FRP) bars for concrete reinforcement is necessary for design purposes as required by structural engineers, and for quality control/optimization purposes as required by bar manufacturers. For the samples specifically tested coating might have an effect on the tensile strength of FRP bars. A coating using fillers seems to increase the tensile strength slightly. Lassila et al determined flexural properties of unidirectional E-glass fibre-reinforced composite (FRC) with polymer matrices of different water sorption properties. It is observed that Flexural strength of specimens with 45 vol% fraction E-glass fibres varied from 759 to 916MPa in dry conditions. Water stored specimens showed flexural strengths of 420–607 MPa. Dehydration of specimens recovered the mechanical properties. Decrease of flexural properties after water immersion was considered to be mainly caused by the plasticizing effect of water and the decrease depends on water sorption. The main significance of this work is to use of polymers with low water sorption seems to be beneficial in order to optimize the flexural properties of FRC. Srinivasan et al. have revealed the study of Mechanical behaviour and damage evolution of E-glass vinylester and carbon composites subjected to static and blast loads. Fibre based composites have found extensive applications in various fields. In this study, two different fibre materials, namely, E-glass and carbon, with different fibre architecture are chosen. These composites were subjected to quasi-static and high strain rates of loading utilizing different testing methodologies. In quasi-static testing, the tensile, compressive and shear properties were studied using existing ASTM standard testing procedures and the results are reported. Based on the experimental study, it is observed that the carbon fibre composites tend to achieve sudden destructive damage whereas E-glass fibre composites tend to sustain progressive damage, under dynamic loading. Christopher Wonderly et al aimed to make comparison of mechanical properties of glass fibre/vinyl ester and carbon fibre/vinylester composites. Glass and carbon fibre composite laminates were made by vacuum infusion of vinyl ester resin into biaxially knitted glass and carbon fibre fabrics. The carbon fibre laminates proved mechanically superior under loading conditions where the strength is mainly fibre dominated, the glass fibre laminates were equally strong or stronger under loading conditions where the strength is mainly resin dominated. Both composites exhibit excellent properties and are considered suitable for use in large ships. The relatively poor transverse properties of the carbon fibre composite would require more elaborate joint design. Since the carbon fibre composite has higher specific strengths, lower density, as well as considerably higher stiffness, a carbon fibre ship could be built significantly lighter than a glass fibre ditto of the same strength and or stiffness. Pekka and Vallittu carried out the study of Flexural properties of acrylic resin polymers reinforced with unidirectional and woven glass fibres. The aim of this study was to describe and test a novel system to use polymer-preimpregnated reinforcing fibres with commonly used multiphase acrylic resins. A 3-point loading test was used to measure transverse strength and flexural modulus of the materials and ultimate strain at fracture was calculated. Cross-sections of test specimens were examined with a SEM to evaluate degree of impregnation of fibres with polymer matrix. Quantity of fibres in test specimens was determined by combustion analysis. This paper concluded that novel glass fibre reinforcements may considerably enhance flexural properties of multiphase dental polymers, which is due to proper impregnation of fibres with polymer matrix. Hasim Pihitli reflects towards an experimental investigation of wear of glass fibre–epoxy resin and glass fibre–polyester resin composite materials. In this paper, the effects of resin content on the wear of woven roving glass fibre–epoxy resin and glass fibre–polyester resin composite materials have been examined. Furthermore, composite materials are experimentally investigated under different loads and speeds by using a block-on-shaft wear tester. Glass fibre–epoxy resin composites generally showed higher resistance and minimum wear if we compare with glass fibre–polyester matrix resin composites materials. The weight loss of all composite specimens generally increased with the sliding distance at the constant sliding speed, with 0.39 m/s, when the applied load was increased from 5 to 10 N. For this reason, the weight loss of glass fibre– epoxy resin composites less depends on the sliding distance. Hasim Pihitli and Nihat Tosun dealt about the investigation of the wear behaviour of a glass-fibre-reinforced composite and plain polyester resin. In industrial applications, the increase in the use of composite materials means that it is necessary to know their behaviour under working conditions. It is observed that the wear resistance of the fibreglass-reinforced composite specimens is much more than the plain polyester. The load applied on the specimens is more effective on the wear behaviour of the specimens than the speed. Because of increasing of temperature together with the applied load, the thickness of the brittle layer on the specimen surface has increased. These layers have broken out from the specimen surface. The broken pieces have increased the wear by acting as an abrasive medium between the shaft and surface. Tayeb and Gadelrab presented the study of friction and wear properties of unidirectional oriented E-glass fibre reinforced epoxy (EGFRE) composite. Friction and wear experiments were conducted

in the normal direction of the fibre orientation against a cylindrical counter face using a pin-on-ring technique for different sliding surface conditions. It is observed that Reductions of about (62-88) % in friction and (30-75) % in wear rate were achieved, again depending on the value of applied normal load and speed. The increase in either load or speed decreases the friction coefficient and wear rate for all cases tested. David et al revealed about the Analysis of how thermal aging affects the long-term mechanical behaviour and strength of polymer–matrix composites. The use of polymer–matrix composites for aeronautical applications with a long service life led to examining the couplings between thermo mechanical loading and thermal aging effects. Thermal aging gives rise to complex phenomena on molecular scale that can considerably alter the mechanical properties and reduce the lifetime of composite materials. Barjasteh et al studied on Thermal aging of fibreglass/carbon-fibre hybrid composites. Thermal oxidation of a unidirectional carbon-fibre/glass-fibre hybrid composite was investigated to determine oxidation kinetics and degradation mechanisms. The layer did not grow appreciably after four days of exposure, and even exposures of 1 year at 180c and 200c caused no significant thickening. Thus, the oxidized surface layer effectively functioned as a passive layer, arresting the diffusion of oxygen and protecting the bulk epoxy from further oxidation.

3. MATERIALS AND METHODS

The main materials used are, Glass fiber (360 gsm), Epoxy resin (araldite GY250) and E-waste rubber as a filler material. Glass fiber is a material consisting of numerous extremely fine fibers of glass. It is most commonly used as reinforcement material because of its exceptional properties. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle. Here type of glass fibre used is E-glass, The main compositions of E-glass (electrical insulators) are the oxides of silica, aluminum and calcium. The glass fiber is also regarded as calcium alumino borosilicate glass. Epoxy is the cured end product of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resin is relatively low molecular weight pre polymers capable of being processed under a variety of conditions. In this work, non-degradable waste material which is used as automobile tires but after prolong usage this rubber tires are dumped directly on the ground which are non bio- degradable. In this aspect our work is concerned about preparing finely powdered E-waste rubber having grain size of 150microns is used as a filler material. This powdered sample collected is as shown in Fig.1. The die arrangement for preparing composites and pressing arrangements are shown in Fig 2.



Fig.1 E-waste rubber powder



Fig.2 Die arrangement

As per the calculations 16 no. of layers of 250x250 sized glass fiber was cut. The required amount of Epoxy resin was weighed. Calculated amount of powdered filler was added. The different percentages of wollastonite used are: 1%,3%, 5%, 7%. The resin hardner proportion ratio of 10:1 was mixed and thoroughly stirred. By using Hand layup technique the glass fiber

along with resin was compressed and cured in the die for 24hours. The fabricated and cured samples of both woven and chopped specimens are shown in fig 3 and 4 respectively.



Fig.3 woven sample

Fig.4 chopped sample.

4. TESTING OF COMPOSITES

Tensile strength testing;

The tensile test is generally performed on flat specimens. The commonly used specimens for tensile test are the dog-bone type and the straight side type with 14 end tabs. The tensile experiments were performed according to ASTM standard D3039 .

Flexural test;

The short beam shear (SBS) tests are performed on the composite samples at room temperature to evaluate the value of flexural strength (FS).

It is a 3-point bend test, which generally promotes failure by inter-laminar shear. The SBS test is conducted as per ASTM standard (D2344- 84) using the same UTM.

Wear test;

For many industrial applications of glass fibre reinforced composites, information about their tribological behaviour is of great importance. Therefore, this work presents an experimental study of the wear behaviour of E-glass epoxy composites when rubbed against different sliding contacts under various normal loads, sliding velocities, and sliding distances. Most of the previous studies concentrate on the wear and friction properties of polymeric composite material. On the other hand, surface temperature is another equally important parameter in studying tribological behavior of polymeric composite. It has been indicated that in most polymeric composite, high stiffness and low thermal conductivity results in high temperature at the sliding contact during friction and beyond a certain critical temperature, wear rates were found to be increased very sharply. The increases in the use of the composite materials mean that it is necessary to know their behaviors under working conditions. The wear resistance is an important parameter and its experimental behaviour must be known. Many studies about the sliding wear mechanism of glass fibre polyester composites have been carried out. When epoxy resins are reinforced with high strength glass-fibres, the product obtained is used in structural applications requiring high strength and low weight. Glass-fibre–polyester composites are of relatively low density and they can be tailored to have stacking sequences to provide high strength and stiffness in the directions of high loading . Many studies reported that the wear resistance with polymer sliding against steel improved when the polymers are reinforced with glass or Aramid fibres. However, the behaviour is affected by factors such as the type, amount size, shape and orientation of the fibres, the matrix composition and the test conditions such as load, speed and temperature [6,7,8]. The wear resistance of materials is determined in the laboratory experiments. In this study, the wear behaviours of woven glass fibre, composite materials are planned to investigate under different loads, speeds and sliding distances.

Effect of thermal aging;

The increasingly widespread use of polymer–matrix composites (PMCs) in aircraft structures raises the problem of their service life, in particular in harsh environments (temperature, oxidizing environment, etc.). The use of polymer matrix composites for aeronautical applications with a long service life led to examining the couplings between thermo mechanical loading and thermal aging effects. Thermal aging gives rise to complex phenomena on molecular scale that can considerably alter the mechanical properties and reduce the lifetime of composite materials. In addition to thermo mechanical stresses, the composite structures will therefore be subjected to physical and chemical aging effects which may degrade the material and

alter the residual performance of the structure. Herein, the term aging denotes changes in physical and chemical properties with respect to a reference point, generally taken at the end of the cure cycle [9]. The glass transition temperature (T_g) is determined using low temperature DSC.

5. CONCLUSION

This paper concluded that novel glass fibre reinforcements may considerably enhance flexural properties of multiphase polymers which is due to proper impregnation of fibres with polymer matrix. Glass fibre–epoxy resin composites generally showed higher resistance and minimum wear if we compare with glass fibre– polyester matrix resin composites materials. It is observed that reductions of about (62-88) % in friction and (30-75) % in wear rate were achieved, again depending on the value of applied normal load and speed. The increase in either load or speed decreases the frictional coefficient and wear rate for all the cases tested. Thermal aging gives rise to complex phenomena on molecular scale that can considerably alter the mechanical properties and reduce the lifetime of composite materials.

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