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Enhancement of mechanical and specific wear properties of glass/carbon fiber reinforced polymer hybrid composite

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Abstract

Mechanical components are subjected to friction and wear necessitating evaluation of tribological properties of polymer based composites. The wear properties of composites depend on the material, operating conditions and on the stacking sequence in hybrid composites. In this article, evaluation of the mechanical properties and optimum parameters for minimum specific wear rate of the hybrid composite were determined. The Hybrid composite was fabricated by hand-layup method with stacking sequence $[CG_3C]_S$ of glass and carbon fiber. The results revealed that the flexural strength and tensile strain are improved through hybridization. The wear properties of the hybrid composite was evaluated by DUCOM three body abrasion tester with different operating conditions such as applied load and sliding distance. Box–Behnken design of experiment was used to perform the experiments. Response Surface Methodology (RSM) was employed to model and optimize the parameters for minimum specific wear rate of hybrid composite. The predicted value for minimum specific wear rate of $16.8511\times10^{-3} mm^3/Nm$ was applied load of 33N and sliding distance of 1221m for hybrid $[CG_3C]_S$ which was in close agreement with experiment.

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Keywords: glass/carbon composites, hybrid composites, specific wear rate, response surface;

1. Introduction

The fiber reinforced polymer composites are increasingly being used for tribological applications in industrial equipments and automotive components such as bearing, gears and cams etc. Composites are preferred as they are considerably lighter and have satisfactory mechanical properties where as tribological properties of composites are inferior in comparison to conventional materials [1–3]. However, it has been possible to improve mechanical

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properties of composites through hybridization [4–6]. The addition of fillers or fibers such as carbon fiber in glass fiber reinforced polymer composites improves mechanical properties such as tensile and flexural strength[7–10]. Hybridization can also be applied to improve the tribological properties of fiber reinforced polymer based composites. Wear has been found to be influenced by the properties of the material, operating conditions and stacking sequence of laminating layers for hybrid composites. Thus optimization of operating conditions such as sliding distance and applied load can result in improvement of wear properties. Through response surface methodology, independent parameters can be optimized for modeling of desired response[11,12].

Czél and Wisnom [9] investigated unidirectional glass and carbon hybrid composites and found the failure type of composites to be influenced by the thickness of carbon layer. Onal et al. [13] have reported of flexural strength to depend on volume fraction of carbon fiber in hybrid glass carbon composites. Sudheer et al. [14] have reported that the mechanical properties and wear resistance were improved by means of graphite filler. Yousif [15] reported that glass fiber reinforced polyester composites displayed improved frictional and wear resistance when the glass mat was parallel to the sliding direction than in perpendicular direction. The effect of glass/carbon sequence of hybrid composites on mechanical properties such as tensile and flexural strength along with tribological properties has not been carried out in many instances. Therefore, in this article, the mechanical and tribological properties of plain glass, plain carbon and a hybrid composite having symmetrical sequence $[CG_3C]_S$ were evaluated. By means of Box–Behnken design of experiments the tests were performed and the optimum condition for minimum specific wear rate was determined using response surface methodology. The MINITAB 17 software has been employed to develop a model and find optimum conditions for minimum specific wear.

2. Experimental Work

2.1. Materials

The Polymer used was Diglycidyl ether of Bisphenol A type epoxy resin having density 1.16 g/cm^3 branded as Lapox L-12 having tensile strength of 110 Mpa and tensile modulus of 4.1GPa and Triethylene tetra amine hardener branded as K-6 from Atul Industries, India. Bidirectional 2×2 twill woven roving carbon fiber of areal weight 200 gsm and density 1.76 g/cm^3 were obtained from Soller Composites having tensile strength of 3.53 GPa, tensile modulus of 230 GPa. The bidirectional plain woven E-glass fiber of 360 gsm and density 2.52 g/cm^3 were procured from Owens Corning, India having tensile strength of 3.1 GPa and tensile modulus of 76 GPa.

2.2 Fabrication of composites

The composites were fabricated by reinforcement of glass and carbon fibers with epoxy polymer by hand lay-up method. The hybrid composite contained six layers of glass fibers and four layers of carbon fibers. The two plain composite each contained ten layers of glass and carbon fiber respectively. The ratio of epoxy to hardener was 10:1. By using a roller voids and air bubble were removed. During preliminary curing, a load of 10 kg for 24h at room temperature was applied. The hybrid is symmetrical with stacking sequence $[CG_3C]_S$ where G represents plain woven bidirectional E-glass fiber and C represents 2×2 twill woven bidirectional carbon fiber. Specimens were obtained by cutting to dimensions of test specifications. Then post curing was done at 140 ^{O}C for 6 hours before testing [16].

3. Results and Discussions

3.1 Tensile Strength

Tensile strength and modulus were evaluated according to ASTM D3039-76 standard using Instron 3370 Universal Testing Machine (UTM) with gauge length of 150 mm and cross head speed of 2 mm/min for specimen dimensions of 250 mm (length) × 25 mm (width) × 3 mm (thickness).