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Mechanical and dry sliding wear characterization of epoxy–TiO_2 particulate filled functionally graded composites materials using Taguchi design of experiment

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ABSTRACT

Titania (TiO_2) reinforced homogeneous and functionally graded epoxy composites are developed by simple mechanical stirring and vertical centrifugal casting technique respectively. Investigations on mechanical and wear characteristics of TiO_2 reinforced homogeneous epoxy composites and its functionally graded composite materials developed for tribological applications are presented. The effect of various operational variables, material parameters and their interactive influences on specific wear behaviour of these composites has been studied systematically. A series of test are conducted on a pin-on-disc machine with three sliding velocities of 105, 209 and 314 cm/s under three different normal loading of 20 N, 30 N and 40 N. Out of all samples 20 wt.% epoxy–TiO_2 epoxy graded composites exhibited lowest specific wear rate TiO_2 particle additions on epoxy graded composites have a dramatic effect on the flexural strength, tensile modulus and impact strength in comparison to homogeneous composites. Scanning electron microscope (SEM) observations also indicate that in homogeneous composites TiO_2 particles are peeled off from the matrix to form holes while in graded composite materials under same experimental conditions the TiO_2 particles remain quite intact to the matrix.

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1. Introduction

Polymer composites containing different fillers and/or reinforcements are frequently used for applications like automotive parts, gear assemblies used inside home appliances etc. in which friction and wear are critical issues. In particular, they are now being used as sliding elements, which were formerly composed of metallic materials only. Composites constituted of functionally graded materials (FGMs) are attracting wide attention worldwide. Criteria for graded material classification include the geometry of the gradation, distinguishing whether the gradation goes throughout the bulk or only affects the coating, and also the function of the gradation. The main feature of a graded material is that it is used to produce components having deliberately introduced transitions in microstructure and/or composition which ultimately caters the need of functional requirements that vary with location within the part [1]. Numerous techniques for synthesizing functionally graded materials are available as of today however synthesis of such a material is possible only if there is a precise control on chemical composition and fabricability exists for such a material [2]. Graded materials are also designed for example to reduce internal stresses [3] or for applications.

TiO_2 (Titania) is a conventional filler material and is used extensively for developing new materials. It has a strong potential as coating material with linear coefficient of thermal expansion of $9.4 \times 10^{-6}\,K^{-1}$ and an elastic modulus of 283 GPa [4]. Inaguma et al. has recently successfully fabricated Al based FGM containing TiO_2 nanoparticles by a centrifugal mixed particle method and came with the observation that TiO_2 particles were distributed on surface of FGM ring. Also the hardness on surface of the FGM ring they manufactured was higher than that on inner part because of dispersion hardening [5].

TiO_2 has also been used in combination with hydroxyapatite for developing biomaterials for implants because of its favourable biological effects and improved corrosion resistance [6–8]. TiO_2 is also frequently and successfully used to reinforce Al_2O_3 wear resistant coating on metal substrate. Seifried et al. has prepared thick ceramic films in the systems Titania and Titania/silica consisting of nanocrystalline grains between 15 and 45 nm by a modified Chemical Vapour Deposition (CVD) method [9]. In addition to it, various other studies related to wear mechanism of TiO_2 on different substrates like stainless steel [10], grey cast iron [11] are also reported. Nanostructured and conventional Al_2O_3–3 wt.% TiO_2 coatings were deposited by atmosphere plasma spraying and the tribological properties of both coatings against a silicon nitride ball were examined in the temperature range from room temperature to 600 °C by Lin and his fellow researchers [12]. Multifunctional arc ion plated

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