STUDY OF MECHANICAL STRENGTH OF POLYESTER-BISMUTH OXIDE POLYMER COMPOSITES

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ABSTRACT

An attempt has been made in the present study to enhance the mechanical strength of the polyester resin by adding bismuth oxide into the polyester matrix by using a simple open mould cast technique. Scanning Electron Microscopy technique was employed to study the distribution and dispersion of the additive into the matrix. Tensile and compression measurements were carried out as per ASTM standards using Universal Testing Machine. A good dispersion and distribution throughout the matrix was observed through the SEM images up to the sample consisting of 40 wt % additive, beyond which, there was formation of agglomerates within the matrix. The results reveal that, the tensile strength of the pure polyester which was found to be 16MPa has increased to 25MPa with an addition of 40% Bi_2O_3. The tensile modulus of the composites also increases linearly with increase in the additive wt% and is found to range from 1.4GPa to 2GPa. Unlike tensile strength and modulus, the compression strength of the composites increases with increase in the wt % of additive up to 40%. Further increase in the additive wt% resulted in the reduction of the compression strength of the composites. This may be due to the reason that, the presence of Bi_2O_3 beyond 40 wt% may be acting as stress concentrators leading to rapid cracking during compression loading of these samples. Thus, the addition of Bismuth Oxide has resulted in the enhancement of tensile and the compression strength of the polymer.

Keywords: Polyesters, Bismuth Oxide, Composites, Dispersion, Mechanical Strength

1. INTRODUCTION

The scientific growth and Industrial development mainly pivot on advancement in the engineering materials that are justifiable. Composite materials have now put forward over most of the common engineering materials as they consist of more than two materials in turn enhancing several properties. Over the past few decades, a polymer composite which consists of matrix and filler has become most advanced and adaptable due to its wide applications. The matrix and filler are selected based on the requirements in a particular field and are as shown in fig. 1. Thermoset polymers reinforced with several materials are becoming popular alternatives to the conventional materials in view of their mechanical properties, corrosion resistant and moreover being lightweight [1]. Polyester resins are the most widely used resin systems, particularly in the thermoset class of polymers in the composite market due to the presence of cross linking structures, good mechanical strength and once solidified cannot be reshaped. Hence, have found their place in automotive, marine, corrosion-resistant structures, building, electrical, radiation shielding applications and many more. In particular, polymer composites can also be used as shielding materials to protect from the harmful effects of ionizing radiations. Several researchers over the globe have fabricated polymer composite radiation shields and studied the shielding ability. In view of their wide applications, several efforts are being put forward by many researchers to increase the strength of the materials by reinforcing with filler or additives [2-5]. Hence, in the present study an attempt has been made to study the effect of bismuth oxide on mechanical stability of the polyester based polymer composites.

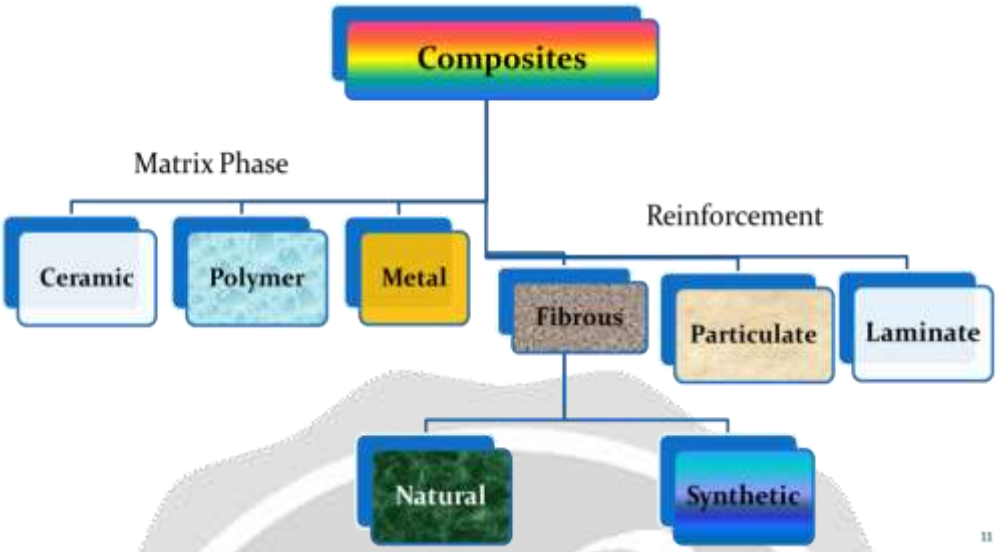

Fig-1: Types of Matrix and reinforcement – Composites

2. EXPERIMENTAL METHODS

Materials

Polyester resin belongs to the thermoset class of polymers which is prepared using Isophthalic acid, maleic anhydride, propylene glycol and styrene in the molar ratio 0.5, 0.5, 1.0 & 1.2 respectively [6]. The polyester resin which acts as the matrix, is commercially available and was procured from M/s Ashland Co. Mumbai. The additive used in the present study is the bismuth oxide and was procured from Sigma Aldrich. All the chemicals were of analar grade and used as procured.

Methods

A simple and well established open mould cast technique [7] was used to fabricate the bismuth oxide filled, polyester based polymer composites. Suitable proportions of the resin and the additive (upto 50 wt%) were weighed and then mixed mechanically. Further, ultrasonication was used for effective dispersion of the additive within the matrix. The mixture was cured in the mould at room temperature for 12 hrs and then post cured in a vacuum oven at 80^{o}C for 6 hrs. Morphological observations of the test samples were done at room temperature using Scanning Electron Microscopy technique (SEM) in order to study the distribution and dispersion of the additive within the polymer matrix. The samples were coated with a very thin film of gold to enhance the conductivity before recording the micrographs. Universal Testing Machine (Lloyd Instruments, UK) was used to study the mechanical strength of the polymer composites. Typical form of the specimens from various sections of the composite was prepared as per the ASTM standards [8], to examine the tensile and compression strength of the composites respectively.

The dimension of the samples used for the tensile and compression mode was 250mm x 25mm x 2.5mm and 150mm x 25mm x 2.5mm respectively. The test specimens were clamped in between the grips of the UTM as shown in Fig. 2. The lower grip was kept stationary, while the upper grip was moved and the automatic speed controller was attached to keep up the speed of the upper grip. On applying load, the sample was pulled in the tensile mode and compressed in the compression mode until failure.

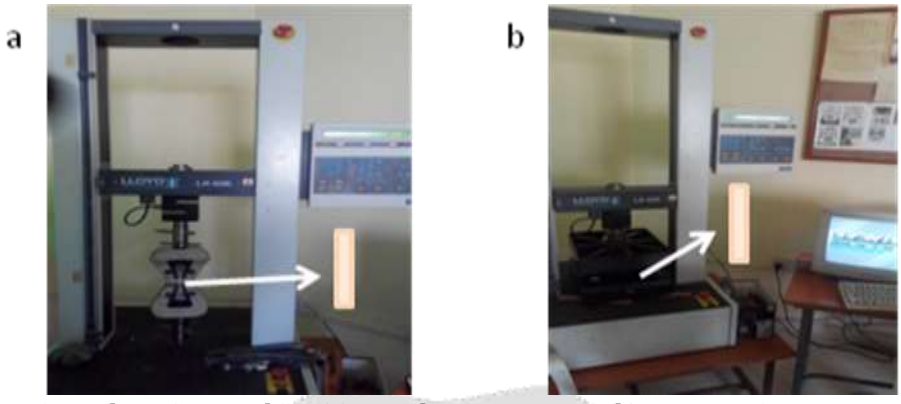

Fig- 2: Universal Testing Machine (a) Tensile measurement (b) Compression measurement

3. RESULTS & DISCUSSION

Surface Morphology

The SEM images were recorded at both low and high resolution to check the distribution of bismuth oxide in the polyester matrix and are as shown in Fig. 3. It is evident from fig. 3 (a) that, the neat polyester consists of the graded ridges with some lighter streak that departs from the ridges which is the common fracture mode being observed in the thermoset polymers. The surface morphology and distribution of the bismuth oxide filled composites are represented in the fig. 3(b-d). This clearly shows the uniform distribution and dispersion of the additive bismuth oxide in the matrix.

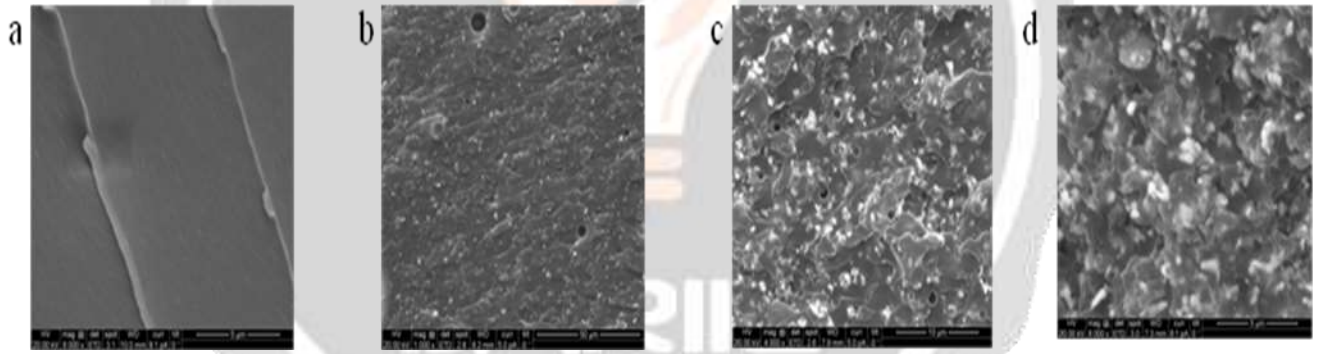

Fig-3: SEM images (a) Neat Polyester (b-d) 10, 30 & 40 wt% Bi_2O_3 filled polymer composite

It is also observed that, with increase in the additive content, there is decrease in the noticeable ridges which may be attributed to the decrease in the tension in the matrix. The presence of agglomerations is observed in the samples where the wt% of bismuth oxide exceeds 40%. These agglomerates tend to decrease the stability of the composites.

Mechanical Stability

The mechanical stability of the bismuth oxide added polyester based polymer composites was studied using a computerized Universal Testing Machine which provides the stress-strain curve on applying the load until break. Tensile tests measure how strong and stiff, a material is, in terms of tensile strength and tensile modulus. Whereas, the compression test is exactly the opposite of the tensile test, where the object is compressed between two levels until a certain load or the sample breaks [9]. The mechanical strength of the polymer composites was studied in terms of tensile strength, tensile modulus & compression strength. The effect of bismuth oxide on the tensile strength and modulus of the polyester matrix is demonstrated in fig. 4(a) and 4(b). The tensile strength increases linearly with increase in the additive content up to 40 wt% and further decreases slightly with further rise in the wt% of the additive [10] as depicted in fig. 4(a).The tensile strength of the pure polyester which was found to be 16MPa

has increased to 25MPa with an addition of 40% Bi_2O_3. This may be attributed to, with increase in the additive content, the weak interfacial area and the micro spaces increases in turn reducing the tensile strength. Whereas, as

a nced in fig. 4(b), the tensile modulus increased w b crease in the bismuth oxide wt% and is found to range 1.4GPa to 2GPa which may be due to the reason further rise in the additive reduces the matrix mobility, which inturn increases the stiffness of the composites [11]. The amount of extension at break in the composites due to the addition of load with respect to the additive content is shown in Fig. 5. Maximum elongation of 2.17mm is observed in the 40 wt% composite while the minimum of 1mm in the 10 & 30 wt% Bi_2O_3 composite.

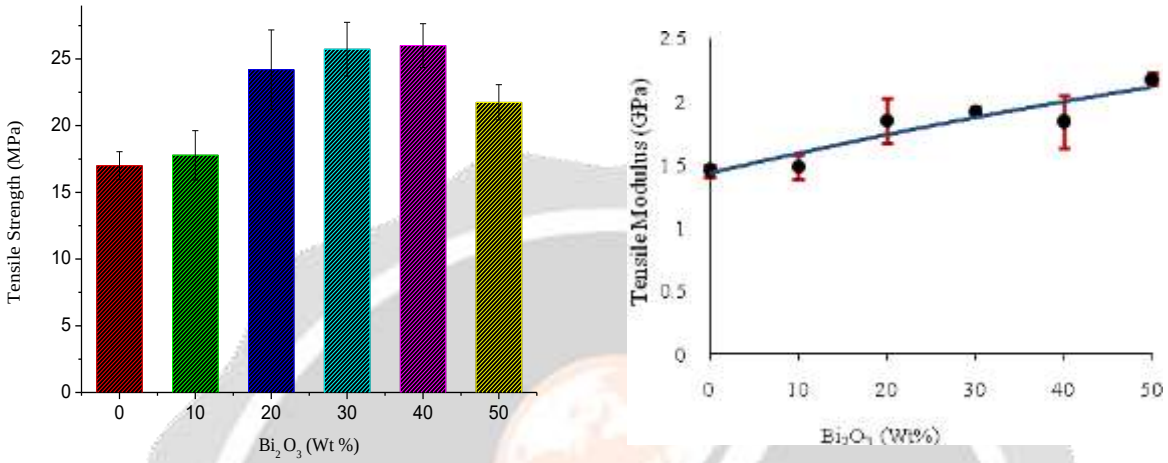

Fig- 4: (a) Tensile strength of the polymer composites (b) Tensile Modulus of the polymer composites

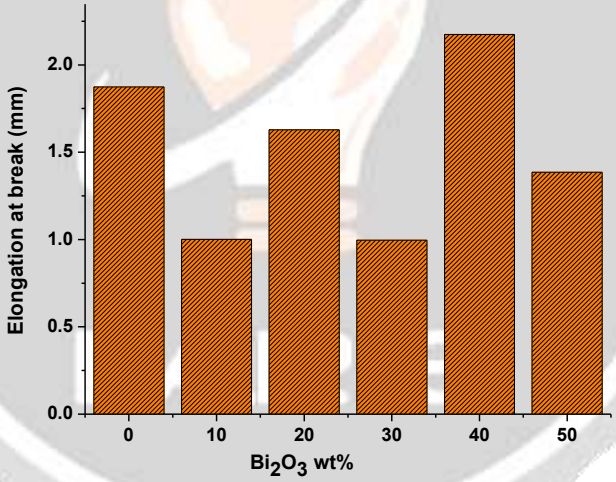

Fig- 5: Elongation at break with respect to the Bi_2O_3 content of the polymer composites

Fig. 6 reveals the compression strength of the composites. It is found that, the compressive strength of the pure polyester resin is 3.5MPa and has been increased to 22MPa by the addition of 40 wt% of Bi_2O_3 into the polyester matrix. Further increase in the additive content lowers the strength of the composite which may be due to the fact that, the presence of Bi_2O_3 beyond 40 wt% may be acting as stress concentrators leading to rapid cracking during compression loading of these samples and consequently lowers the mechanical properties [11]. In addition, the formation of voids and agglomerates may also decrease the stability of the composites [12].

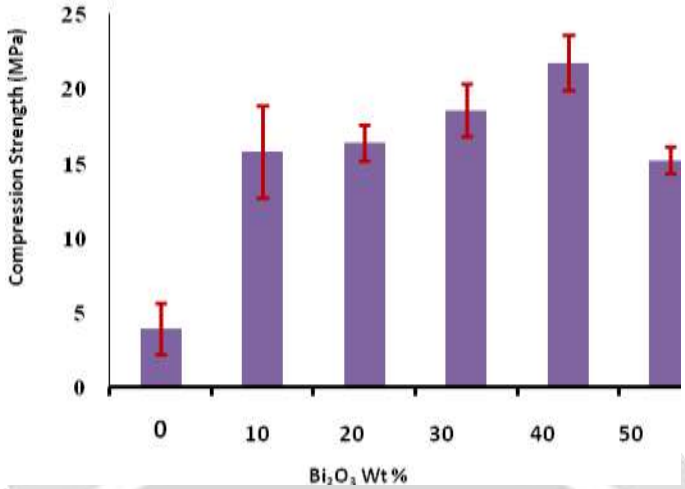

Fig-6: Variation of compressive strength of the composites with respect to the Bi_2O_3 wt%

4. CONCLUSIONS

In the present experimental investigation, bismuth oxide filled polyester based polymer composites were fabricated and their mechanical strength was analysed. Bismuth oxide particles are found to be distributed uniformly within the polyester matrix. With increase in loading of the additive above 40 wt%, the particles tend to agglomerate forming big clusters within the matrix hindering the property of the material. A noticeable effect of addition of bismuth oxide on the mechanical strength of the polymer composites is observed. The tensile and compression strength of the composites is found to increase with increase in the additive content upto 40 wt%. Further increase has decreased the strength the material. Hence, in the present study, 40 wt% can be optimized as the limiting factor for further applications.

5. ACKNOWLEDGEMENT

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