Mechanical Characterization, Fabrication and FTIR Spectroscopic Analysis of Fish Scale Reinforced Epoxy Composites

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Abstract: This paper describes the processing and characterization of a new class of epoxy matrix composites reinforced with short fibers obtained from the scales of a fresh water fish (Labeo rohita). The functional groups involved in the formation of the resulting composite are identified. Fourier Transform Infrared (FTIR) spectroscopic analysis shows that the formation of hydrogen bonds occurring at the fiber-matrix interface between the oxygen atom of the epoxy and hydrogen atom of the polypeptide chain of fish scale is responsible for the formation of this new class of composites. These composites possess improved micro-hardness and exhibit tensile and flexural strengths marginally different from those of neat epoxy. These composites are expected to find applications as potential materials for conveyor belt rollers, pipes carrying pulverized coal in power plants, pump and impeller blades and also as low cost housing materials.

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1 Introduction

Recently the critical discussion about the preservation of natural resources and recycling has led to the renewed interest concerning biomaterials. Because of increasing environmental consciousness and demands of legislative authorities, use and removal of traditional composite structures, usually made of glass, carbon or aramid fibers being reinforced with epoxy, unsaturated polyester or phenolics, are considered critically [1]. Over the years, many researchers have also reported on the performances due to the poor interfacial bonding between the hydrophilic natural fibers such as sisal, jute and palm fibers and the hydrophobic polymers [2]. But in spite of this, there has been a growing global attention on natural fibers primarily because they are environment friendly and are of very low cost. Bio-fibers like animal whiskers and poultry feather are also recently drawing attention of researchers [3]. But the potential use of fish scale fiber in composite making has not been explored so far.

Fish is one of the most abundantly available aqueous species and its scale, regarded as a waste material, can be gainfully converted to value added products. Although some earlier works studied fish body scales to strengthen their role in fish taxonomy [4], the available reports on fish scale research are relatively less. Ikoma et al. [5] have studied the micro structural, mechanical, and bio-mimetic properties of fish scales from Pagrus major. However, reports available on composites using fish scale are rare. Against this background, the present investigation is undertaken to study the possible utilization of fish scales in polymer composites.

2 Experimental Details

2.1 Materials

Epoxy LY 556, chemically belonging to the ‘epoxide’ family is used as the matrix material. The mature fish scales of Labeo rohita are washed in water to remove adhering dust and soluble surface impurities. The scales are allowed to dry in sunshine for two days and are then kept in an oven at 70°C till they become crispy. The dried scales are then cut into short flakes of dimension, approximately 6-8mm in length and 1mm in width. These flakes are used as the reinforcing phase.

2.2 Composite Fabrication and Characterization

The low temperature curing epoxy resin and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. The dried flakes of fish scales in four pre-determined weight proportions (0, 5, 10 and 15 wt %) are reinforced with random orientation into the epoxy resin. The castings are put under load for about 24 hours for proper curing at room temperature. Specimens of suitable dimension are cut using a diamond cutter for physical and mechanical characterization. Micro-hardness measurement is done using a Leitz micro-hardness tester. The tensile test is performed in the universal testing machine (UTM) Instron 1195. 3-point bend test is performed on these samples to evaluate the flexural strength as per ASTM standard (D2344-84).

2.3 FTIR Spectroscopy

Fourier Transform Infrared (FTIR) spectroscopy is an analysis technique which detects characteristic functional groups in molecules of any matter [6]. On interaction of an infrared light with the matter, chemical bonds stretch, contract and bend and as a result, each functional group tends to absorb IR radiation in a specific wavelength range regardless of the structure of the rest of the molecule. Based on this, functional groups present in the composite are identified. In the present work, spectroscopy is performed using a FTIR spectrophotometer interfaced with IR microscope operated in reflectance mode (Perkin Elmer Spectrum RX-1).

3 Results and Discussion

3.1 Mechanical Properties

The tensile strengths of the composites with fiber content of 5 wt%, 10 wt% and 15 wt% are recorded as 66 MPa, 63.65 MPa and 62.36 MPa respectively where as that of neat epoxy is about 70 MPa. However, the incorporation of flakes results in only marginal improvement in the flexural strength. The hardness values of the composites with fiber content of 5 wt%, 10 wt% and 15 wt% are recorded as 42.4 Hv, 42.95 Hv and 43.75 Hv respectively. For hardened neat epoxy, this value is found to be 41.75 Hv. It is thus seen that the hardness is improved by the incorporation of fish scale short-fibers.

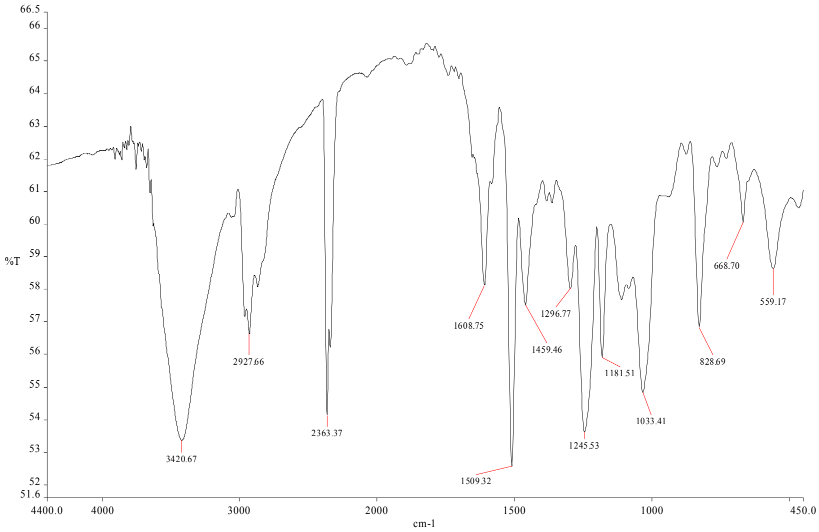

Figure 1. FTIR spectra of epoxy resin

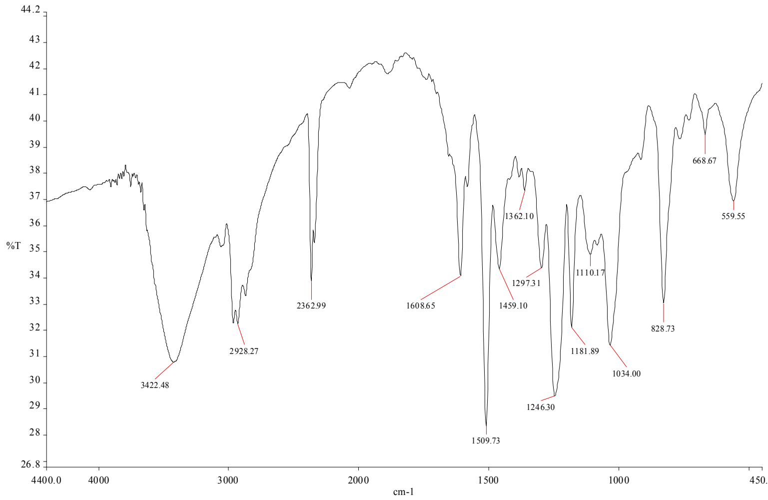

Figure 2. FTIR spectra of epoxy- fish scale composite

3.2 FTIR Spectroscopy

The main constituent of the fish scale (Labeo Rohita) is an organic protein called keratin [5]. The functional groups present in the raw fish scale as obtained from the FTIR spectroscopic analysis are identified as C – H in methyl, N – H in amine, C – N in amide and H – bonding in amide linkage. Similarly, Figure (1) presents the spectra of epoxy resin which reveal the presence of different functional groups such as benzene, ether, epoxide, alcohol etc. The IR spectra for the fish scale reinforced epoxy composite are given in Figure (2). This gives us an idea of the rearrangement of the functional groups during composite formation. On comparing Figures (1) and (2), it can be seen that the IR peaks are almost similar but in case of Figure (2), these are laterally shifted towards lower frequency region. Moreover the peak at 3422 cm^{-1} is relatively shorter and wider in Figure (2) as compared to Figure (1). This leads to the conclusion that the hydrogen bonds are formed between the oxygen atom of the epoxy and hydrogen atom of the polypeptide chain of fish scale. This is schematically illustrated in Figure (3).

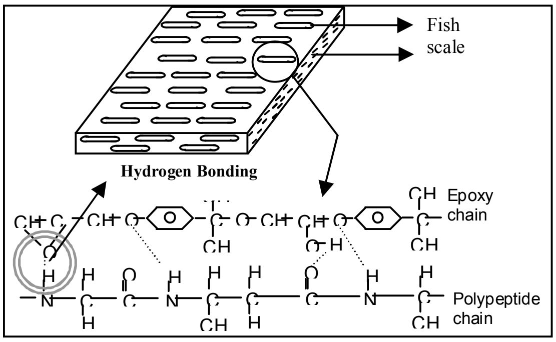

Figure 3. Chemical bonding between elements of epoxy matrix and the poly-peptide chain of the fish scale in the composite

The newly formed hydrogen bonds between O---H in the composite leads to weakening of all other bonds present in epoxy due to stretching of bonds. This phenomenon is supported by the lateral shifting of respective IR peaks in the composite. Since all the hydrogen atoms of polypeptide chain cannot take part in this hydrogen bond formation with oxygen atoms in epoxy chain, the interface between the epoxy body and the scale does not exhibit high strength.

4 Conclusions

Successful fabrication of epoxy matrix composites reinforced with flakes of fish (Labeo rohita) scale is possible. The FTIR spectroscopic analysis shows that the formation of hydrogen bonds occurring at the fiber-matrix interface between the oxygen atom of the epoxy and hydrogen atom of the polypeptide chain of fish scale is responsible for the formation of this new class of composites. This study opens up a new avenue for utilization of a bio-waste like fish scale.

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