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Mechanical Characterization of Epoxy Resin Based Composite Material Reinforced with Fish Scale

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Abstract

This research work is focused on the utilization of fish scales as a natural biomaterial to improve the mechanical characteristics of epoxy resin-based composite material. The effects of addition of dried fish scale powder (DFSP) in different concentrations (0 to 12 %) to epoxy resin in the mechanical properties of the developed composite material was evaluated. The results of the study showed that the addition of dried fish scale powder as a reinforcing agent enhanced the impact strength and Rockwell hardness of the final product.

Keywords: Fish scale, composite material, impact strength, Rockwell hardness, tensile strength.

Introduction

India's fisheries sector is growing with an average annual growth rate of 7.53 %. Fish production in the country has increased from 0.75 million metric tonnes in 1950–51 to 14.2 million metric tonnes in 2019–2020. But with the increase in production, the amount of fish waste produced by the sector is also increasing. Almost two thirds of all fishes are wasted, creating serious economic and environmental issues. An yearly loss of more than Rs.15,000 crores in India's marine and inland fish sectors was reported by Mishra (2013), which represents around 25 % of total fish production.

A composite material consists of two or more separate components that are insoluble, have diverse shapes, are distinctly different from one another, and are chemically heterogeneous. The resultant substance exhibits distinct qualities compared to the individual ingredients. A composite may be referred to as a bio-composite, if it has at least one component made of renewable resources, either the matrix or the reinforcement (Verma et al., 2018). Numerous polymeric matrixes have demonstrated that plant-based fibres possess attractive reinforcement characteristics that is both environmentally and economically advantageous (Ramakrishna & Sundararajan, 2005). Since they are lighter than synthetic fibres, natural fibres take up more space than synthetic fibres (Wambua et al., 2003; Sahieb & Jog, 1999). In this study, epoxy resin is used as the matrix to create a bio-composite material along with a suitable hardener to turn the liquid into a solid. To improve the material's mechanical strength, stiffness, texture, and other qualities, different weight percentages (wt %) of dried fish scale powder was added as a reinforcement material. Kumar & Satsangi (2013) observed that properties of polymer-based composites can be easily improved by adding bio-filler. Epoxy resins can form hydrogen bonds with fish scales to increase its tensile, flexural, and hardness properties. Based on FTIR spectroscopic analysis it was found that, the creation of hydrogen bonds between the oxygen atom of the epoxy and the hydrogen atom of the polypeptide chain of fish scales at the fiber-matrix interface causes the development of this novel type of composite (Satapathy et al., 2012). Fan-Long- & Soo-Jin (2009) reported that Calcium carbonate nanoparticles could enhance cross-linking properties of epoxy resin. Freshwater fish scales can be used as reinforcement materials in polymers. They generally contain 40-55 % organic matter (collagen, fatty acids, a variety of vitamins, lecithin, calcium carbonate, etc.) and 7-25 % inorganic matter (hydroxyapatite, calcium phosphate) (Chinh et al., 2019). With this background, this study aimed to utilize dried fish scale powder to reinforce epoxy resin for improving its mechanical characteristics.

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Materials and Methods

In the present research work, the major constituent used for developing bio-composite was CY-230 Epoxy resin. Binding agent (Hardener) was HY-951. Dried fish scale powder (DFSP) at different wt % was used asthe reinforcing agent.

DFSP was prepared from fish scales collected from local fish markets. The scales were soaked in detergent for 3-4h. The scales were then washed in running water to remove odor, dirt and blood. Excess water was drained by spreading the scales in a tray and dried in a drier at 150 °C for 8-10h or until they become crispy and brittle. The scales were then ground in a grinder to make a fine homogenous powder. The powder was then sieved to remove larger particles to obtain a fine smooth powder.

400 g of epoxy resin (CY-230) was mixed with prepared dried fish scale powder in a glass beaker and stirred. After proper mixing of epoxy resin and DFSP, the beaker was placed for 25 minutes in a convection oven set at 180 °C. After 25 minutes, the beaker was kept open for allowing the temperature to drop to 40–45 °C. At 40 °C, 40 g of hardener (HY-951) was added (10 % of the weight of epoxy resin). The prepared mixture was poured into a previously greased acrylic mould and kept for 24 h undisturbed before pulling it out of the mould to get the well settled end product.

Different mechanical tests were performed at the Dynamics Lab, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar. Izod Impact testing machine (Model: AE.ICT.O, 2014) was used to perform the Izod or Charpy test to measure the impact energy and strength of the constructed composite at 34 °C and 58 % RH. Rockwell hardness testing device was used to determine the Rockwell hardness of the composite. A 1/4-inch ball indenter was used to measure hardness using the scale L. Ultimate tensile strength (UTM) and percentage elongation of DFSP filled composite were determined by a universal testing machine (ASI Sales Pvt. Ltd., model AMT-SC). Test was conducted as per ASTM D882-12 standard. The specimens were positioned between the jaws of the universal testing machine (UTM), which was set to 10 mm width and 100 mm length. Three samples of from each group were taken. The specimen gauge length was taken as 25 mm with rate of separation of the gripping jaws as 4 mm/min. Tensile tension was gradually applied to the two ends of the specimen.

Results and Discussion

The impact of adding DFSP in different percentages on the composite's impact strength and impact energy are shown in Table 1. Maximum impact strength of 1943 kJ/m^2 was noted when DFSP was added at 8 %. The addition of dried fish scale powder increased the composites' impact strength from 1216 J/ m^2 (0 wt%) to 1943 J/ m^2 (8 wt%), after which it decreased to 1387 J/ m^2 (10 wt%).The impact strength of composite material was significantly different in different composites with DFSP at different wt%. Gopi et al. (2016) found best results with 10 wt% of fish scale, after which impact strength started decreasing significantly. Impact strength and impact energy of DFSP reinforced composite increased and the major reason for this hike must be proper mixing of the scale powder

Table 1. Effect of addition of DFSP on impact strength of epoxy-based composite

% of DFSP	Geometric Dimension (In mm)			Area (mm^2) T*B	Energy (J)	Energy/Thickness (J/mm)	Impact Strength (J/ m^2)
	L	T	B				
0	61.01	7.99	13.01	103.94	0.1253	0.0156	1216
2	61.00	8.02	13.06	104.74	0.1427	0.0177	1372
4	60.79	8.09	12.70	102.74	0.1648	0.0203	1604
6	60.80	8.07	12.80	103.29	0.1899	0.0235	1838
8	60.02	7.90	13.00	102.70	0.1996	0.0252	1943
10	60.00	8.20	12.52	102.66	0.1424	0.0174	1387
12	60.01	7.98	12.95	103.34	0.1231	0.0154	1191

throughout the mixture and also smaller particle size of the scale powder particles (Li et al., 2015). Fourier Transform Infrared (FTIR) spectroscopy investigation has revealed that fish scales can establish hydrogen bonds with epoxy resins at the fiber-matrix interface between the oxygen atom of the epoxy and the hydrogen atom of the polypeptide chain of the fish scale (Satapathy et al., 2012). However, at higher weight percentages of filler material, due to agglomeration, these forces weaken and are insufficient to create the necessary bond between the matrix and the filler (Bansal, 2016), which accounts for the declining values of impact strength and impact energy at 10 and 12 weight percentages of DFSP.

Table 2 shows how the weight percentage of DFSP in an epoxy-based composite affected the values of Rockwell hardness. When the weight % of DFSP reached 8 (147.17 HRL), the composite's hardness peaked and was 12.51 times greater than the hardness of neat epoxy (130.80 HRL). According to Kumar et al. (2019), a compression or pressing stress is produced during the hardness test. The matrix and solid filler phases would consequently be pushed and crushed together. Thus, even if the interfacial connection is inadequate, the interface can transfer pressure more effectively. Same results were observed in the present study.

As shown in Fig. 1, tensile strength of the composite decreased with increase in the wt% of DFSP. The uneven and large particle size of DFSP, which was unable to withstand the stress distributed equally throughout the matrix, could be the evident rationale for the loss in tensile strength. Similarly, Sekhar et al. (2012) observed decrease in tensile strength, when feather fibre was added. As a result, it can be stated that the addition of DFSP to epoxy is unacceptable in terms of tensile strength. Composite of epoxy alone along with and hardener had the highest tensile strength (33 MPa).

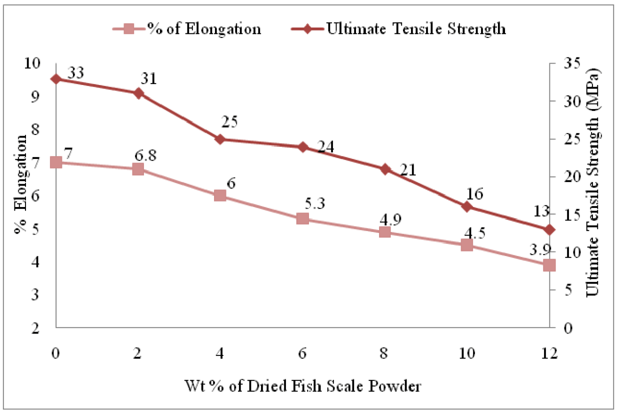

Fig. 1. Effect of addition of DFSP on ultimate tensile strength (MPa) and percentage elongation of epoxy resin-based composite

From the analysis of data of mechanical tests performed on DFSP reinforced composite, the following observations were made. The developed composite's impact strength and Rockwell hardness increased as the percentage of DFSP in the epoxy resin increased. At 8 wt% DFSP, the maximum impact strength was obtained i.e. 1943 J/m^2, which is 59.78 % higher than the control with neat epoxy resin. The maximum value of Rockwell Hardness (i.e. 147.17) was obtained at 8 wt% DFSP, which was 12.51 % higher than the control sample. Tensile strength of the composite was decreasing with increase in the wt% of DFSP. Control sample of epoxy alone had the highest tensile strength (33 MPa).

Table 2. Effect of addition of DFSP on Rockwell Hardness of the epoxy-based composite

% of DFSP	Hardness Value (in HRL) R1	R2	R3	R4	R5	R6	R7	Avg.
0	130.79	131.45	130.97	130.85	129.98	131.01	130.95	130.85
2	135.10	136.41	136.00	136.40	135.37	135.92	136.21	135.91
4	139.23	138.54	139.84	139.67	139.57	139.73	139.29	139.41
6	142.77	143.00	143.01	143.20	142.88	143.03	143.05	143.00
8	147.3	146.11	146.34	148.90	147.57	147.02	146.96	147.17
10	130.13	128.93	131.00	130.91	129.72	128.82	129.77	129.89
12	127.46	129.09	128.00	126.97	126.12	127.56	126.08	127.32

Use of fish scales as a bio-filler in composites can be initiated as one of the solutions for the problem of fish waste disposal and a way to put them into good use. Dried fish scale powder (DFSP) has very minute, brown particles and have excellent compatibility with epoxy resin. The microstructure of hydroxyapatite and calcium carbonate present in fish scale powder forms hydrogen bond with epoxy resin and can improve its mechanical characteristics. The reinforced particles prevent dislocation, which helps to prevent plastic deformation and therefore increases tensile strength and hardness. Particles should be equally distributed throughout the matrix and should be small enough to achieve effective reinforcement. The epoxy resin-based composite added with fish scales can be used in automotive coatings due to its mechanical strength, great adhesion to metals, and heat resistance. These features facilitate better protection of vehicle body from corrosion and it is eco-friendly too. DFSP incorporated composite materials can be used as protective coatings to aircrafts to extend its lifespan. This material can also be used in construction work as paints, sealers and primers, which will increase their longevity, as it is highly adhesive and non-corrosive. In addition, it can be used to fabricate carriers of oil and gas, and also in marine industries because it possesses good resistance against alkalis, seawater, wine, vegetable oil, gasoline etc. and also comes with low cost, good mechanical properties and high specific strength. This can replace fragile glass table tops due to higher impact strength. DFSP reinforced composite material sheet can be an alternative for ceramic wall tiles as it is light in weight. A thin covering of this composite material prior to solidification can also be applied on any surface to get a smoother and even surface. This composite could be a reliable material to replace plastic frames and false ceiling due to its light weight and high adhesiveness property.

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