Characterization of Mechanical Strength of Epoxy Hybrid Composite Reinforced with Chicken Feather Fiber and Residue Powder Extracted from Rohu Fish Scale

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***Abstract*:- Livestock waste is been used currently in various applications like textiles, crafting, decorations and even in bio-composite manufacturing. The reason for it is the abundance availability and compatible characteristics of the Livestock waste. In the current research work, the hybrid bio composite is fabricated using epoxy resin (CY-230) as matrix with hardener (HY-951) as curing agent, reinforced with varying weight percentages (wt%) of chicken feather fiber (CFF) and residue powder extracted from Rohu Fish Scale (ERP) to enhance the mechanical and physical properties of developed composite. Composite materials with their high strength to weight ratio and their diverse functionalities have attracted most of the researchers towards the advance study of the hybrid composites. The efforts are made to focus on advanced technology and uplift the use of chicken feather fiber as a Natural Biomaterial which is at present serve as a waste of poultry industry and fisheries industry to enhance the use of livestock waste in a sustainable growth of the earth and healthy environment.**

Keywords— Composites, chicken feather fiber, environment friendly

INTRODUCTION

In the past few years, the biological fibers have turn out to be an eye-catching reinforcement for many polymeric matrixes from both the ecological and economical point of view. The main source of obtaining the biological fibers is from plants, animals and minerals. The higher volume occupied by the natural fibers as compared to the synthetic ones due to their lower weight perk up the fuel efficiency and reduced emission in automobile applications [1 &2].

Chicken feather fiber is used as the reinforcement material in the current fabrication process. CFF are the waste product after processing chicken for food. In the current work various chicken's feather is used as a fiber like Kadaknath, Columbian, Guinia Fowl, RIR, Uttara Fowl, Raising Guinia, White Lagan etc. found in the Pantnagar University Poultry farm. Chicken feather is approximately 91% keratin, 8% water and 1% lipids by mass [3]. Both the fiber and quill consist of hydrophobic keratin that's why CFF shows irregular surface finish during composite fabrication. The CFF quill improves the acoustical and mechanical properties in the material [4]

Addition of CFF in the thermosetting Epoxy resin polymer helps to achieve various desired outputs because of the following characteristics [5]:-

- CFF acts as a toughening agent when reinforced in epoxy resin.
- CFF possess hydrophobic nature.
- It augments stiffness to the matrix.
- Behaves as a co monomer for the resin.
- CFF induces plasticity in the deformation zone near crack tip in order to improve its toughness.
- Acting as a free radical trap to reduce radical scission effects during fracture in highly cross linked polymers.

Any fibre can improve the impact wearing capacity but tensile strength may be decreases if the fibre tensile strength is low in compare to matrix material. To optimize or compensate the tensile strength as well as impact strength, the particulate reinforcement is required for fabrication of composite material. For this reason, residue powder extracted from Rohu Fish Scale is used to fabricate hybrid bio-composite material.

The main objective of the current research is to develop a cost effective and environment friendly hybrid bio-composite from livestock waste i.e. chicken feathers and residue powder (extracted from fish) which can provide the composite with enhanced strength or as comparably equal to the strength and other properties of available epoxy resin with hardener. The aim behind such work is to have sustainable

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development in the field of material science engineering and advance material research. Variation in the properties with varying percentage of fiber and particulate in the matrix is seriously monitored and the verdict is done to get the optimum results with maximum accuracy and precession.

MATERIALS

Specifically in the present research work, the development of bio-composite requires the matrix (as the major constituent) which is CY-230 Epoxy resin, Binding agent (Hardener) which is HY-951 of 10 wt% [6-7], Reinforcing with the various wt% of Chicken Feathers as given in fig. 1.

The different materials used for the casting of composite are described below.

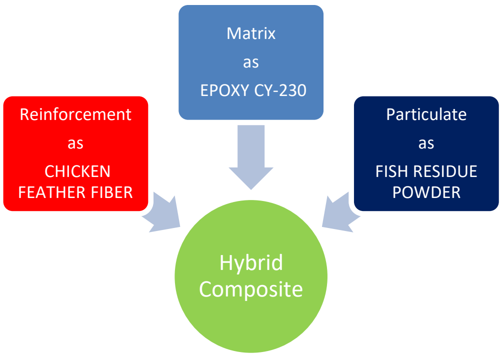

Fig. 1: Constituents in hybrid composite

A. Chicken Feather Fiber (CFF)

Chicken Feathers are the waste product from the processing of chickens for food. Chicken feather initiates from free renewable livestock bio-waste. CFF can be considered as a waste by product that is serious causal to environmental pollution due to the disposal problems. Basically there are two main feather disposal methods that is, a burning and burying. But both of them have negative effect on the environment. Chicken feather is approximately 91% keratin, 8% water and 1% lipids by mass [8]. Both the fiber and quill consist of hydrophobic keratin that's why CFF shows irregular surface finish during composite fabrication. Different types of chicken feathers used as a fiber were taken from various chickens available at Pantnagar poultry farm.

Chicken Feathers are cleaned and washed properly by Alkali treatment using NaOH (Sodium Hydroxide) solution. Chicken feather fibers were soaked in 5% concentration of NaOH with distilled water for 6-8 hours at 30°C and then thoroughly washed with running water (sieving method). It was then dried in the natural light for 24 hours [9]. The processing of feathers using alkali solution helps to remove dirt, impurity, stickiness, blood contamination and the oily part from the feathers. The dried Chicken feathers are cut into small fibers (less than 5mm) pieces one by one. The rashes and barbs are removed and only the barbicels and hairy part is used as fiber. The sharpened scissor is used for proper sizing of CFF. Ones the rashes are removed the feathers are further cut into smaller size.

B. Residue powder extracted from Rohu Fish Scale (ERP)

ERP is the white colored micro sized particle which was extracted from the Rohu fish scale. The various laboratory reactions were performed in the development of ERP. The developed ERP contains varying percentages of elements like calcium, sodium, and oxygen etc. in compound form which shows better compatibility with Epoxy.

FE-SEM analysis was conducted to identify the presence of Silica powder and other minerals in the extracted powder from Rohu fish residue. The success of the process was clearly visible through the results obtained after composition analysis through FESEM. The output revealed that the certain percentage of silica powder was present in the extracted powder kept under investigation. From the table 1 (a-d) it can be noted that along with silica other elements like Carbon, Oxygen, Sodium, Calcium, and Phosphorous etc. were also present in the obtained powder. The reinforcing use of the extracted powder as particulate in CFF filled epoxy based hybrid composite has improved the cross linking reactivity and bond strength of the composite. The presence of multiple charged elements (like Na +1, Ca +2, P +3, C +4, O -2 etc.) has amended the proper mixing and thus strengthens the developed hybrid composite. Certain compounds like calcium carbonate (CaCO3), silica oxide (SiO2), sodium hydroxide (NaOH) etc. were also diagnosed. CaCO3 increases the thermal stability and the cross linking density as compared to neat epoxy [10]. SiO2 in epoxy resin improves the modulus of elasticity by 10-20% and toughness by 25-30%. Therefore it can be undoubtedly concluded that the ERP is a very prestigious material as a reinforcing particulate for epoxy resin.

TABLE 1 (A): ERP COMPOSITION AT SPECTRUM 1 (THROUGH FESEM AT 685 CTS)

Element	Weight %	Atomic %
C	8.86	14.05
O	44.73	53.62
Na	24.00	19.89
Si	2.78	2.53
P	4.20	2.58
Ca	15.43	7.33
Total	100.00	

TABLE 1 (B): ERP COMPOSITION AT SPECTRUM 2 (THROUGH FESEM AT 1515 CTS)

Element	Weight %	Atomic %
C	9.43	14.46
O	46.40	53.72
Na	28.71	23.00
Si	2.61	2.40
P	2.22	1.32
S	1.90	1.09
Ca	8.72	4.01
Total	100.00	

TABLE 1 (C): ERP COMPOSITION AT SPECTRUM 2 (THROUGH FESEM AT 1515 CTS)

Element	Weight%	Atomic %
C	2.82	5.65
O	34.33	52.60
Na	6.36	6.65
Si	2.69	2.59
P	1.37	1.07
Ca	52.42	31.44
Total	100.00	

TABLE 1 (D): ERP COMPOSITION AT SPECTRUM 3 (THROUGH FESEM AT 1515 CTS)

Element	Weight %	Atomic %
C	10.16	16.10
O	40.59	48.67
Na	28.45	23.55
Si	2.47	2.32
P	4.63	2.85
Ca	13.70	6.50
Total	100.00	

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RESULTS AND DISCUSSIONS

The systematic fabrication and processing of various composite's samples with varying weight percentages of CFF in epoxy resin are based on the results of mechanical tests performed at the Dynamics Lab, Collage of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar.

Experiments showed that the neat epoxy has the weight density of 1132.08 kg/m^3 i.e. 1.56% less than the theoretical density (1150 kg/m^3). From fig. 2 it can be seen that the addition of CFF in epoxy resin decreases the weight density of the prepared composite as chicken feather is lighter in weight (density = 800 kg/m^3 approx.) as compared to pure epoxy. Also the decrease of 3.79% in density is recorded from 0 (i.e. 1132.08 kg/m^3) to 5 wt% (i.e. 10893.12 kg/m^3) of CFF in fabricated composite. The density at 7 wt% of CFF in epoxy resin is 1078.51 kg/m^3. Almost 5.19% decrease in density was recorded during the total composites development from 0 to 7 wt% of CFF. The main reason for the linear decrease in the density was due to commutatively adding of CFF in epoxy that decreases the specific weight of the prepared composite.

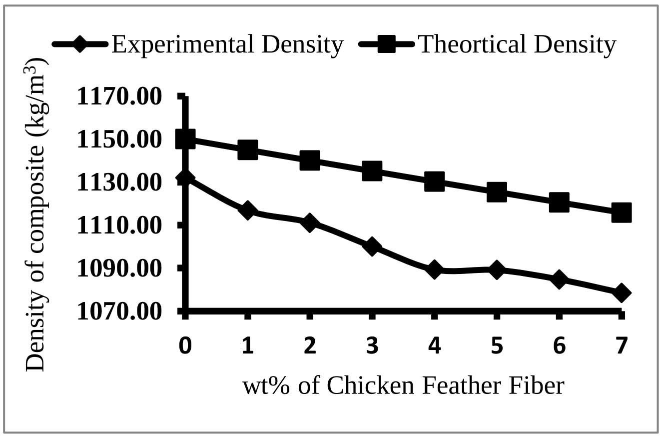

Fig. 2: Effect of wt% of CFF on density of composite

Izod impact test was performed using Impact testing machine. The results of impact test are given in table 2. It shows variation in impact strength and impact energy of the composite with increase in wt% of CFF and it is observed that the maximum Impact strength is occurring at 5 wt% (i.e. 1880 J/m^2).

TABLE 2: EFFECT OF WT% OF CFF ON IMPACT ENERGY, IMPACT STRENGTH AND ENERGY/ THICKNESS OF EPOXY BASED COMPOSITE

% of CFF	Geometric Dimension (In mm)			Area (mm^2)	Energy (J)	Energy/ Thickness (J/t)	Impact Strength (kJ/m^2)
	L	T	B	T*B			
0	60.0	8.00	12.7	101.6	0.1253	0.0157	1.23
1	60.0	8.00	12.7	101.6	0.1360	0.0170	1.34
2	60.0	8.00	12.7	101.6	0.1400	0.0175	1.38
3	60.0	8.20	12.7	104.14	0.1485	0.0181	1.43
4	60.0	7.20	12.7	91.44	0.1590	0.0221	1.74
5	60.0	7.90	12.7	100.33	0.1886	0.0239	1.88
6	60.0	8.00	12.7	101.6	0.1666	0.0208	1.50
7	60.0	7.20	12.7	91.44	0.1250	0.0174	1.48

Also the impact strength is continuously increasing with wt% of CFF in epoxy resin till 5% and then suddenly falling to 1480 J/m^2 at 7 wt% of CFF. Experimentally it is determined that the impact strength of neat epoxy resin (CY-230) with hardener (HY-951) sample is 1230 J/m^2. The major reason for this hike is the flexible nature of the fibers. The fibers when added into the epoxy forms layers and absorbs energy just like fabrics. Table 1 lists the elaborative results obtained during Impact testing performed at 290C atmospheric temperature and 49% RH.

The tensile strength of CFF filled epoxy resin composite is experimentally determined using 25kN servo controlled Universal Testing Machine (UTM) at fixed cross head speed of 1mm/min under displacement control mode. An ISO standard ISO 527-2/1B/50 is followed in specimen preparation for tensile testing. From fig. 3 it can be observed that, with increasing weight percentage of chicken feather fiber in Epoxy resin, the tensile strength of the composite is unceasingly decreasing. Also the maximum tensile strength of epoxy resin (CY-230) with hardener (HY-951) was observed to be 30.14 MPa.

The clear justification for the decrease in tensile strength on adding CFF in epoxy matrix could be the poor strength of fiber itself. Another reason is the irregular shape of the fibers due to which the strength of the composite decreases as they become unable to support the stress transferred from the matrix. The same trend of decreasing tensile strength with emu feather fiber was diagnosed by [11]. So, it can be concluded that the addition of chicken feather fiber into epoxy is unacceptable from strength point of view.

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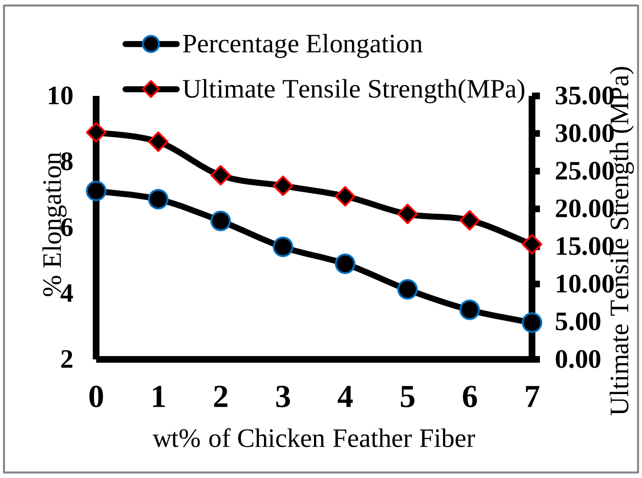

Fig. 3: Effect of CFF wt% on ultimate tensile strength (MPa) and percentage elongation in epoxy resin based composite

To compensate the tensile strength, the residue powder extracted from Rohu Fish Scale (ERP) is used to increases the tensile strength. The maximum impact strength of CFF composite is found in 5 wt% of CCF reinforced composite. Therefore, to obtain maximum impact wearing capacity as well as tensile strength, the 5 wt% of CCF reinforcement is fixed to fabricate hybrid composite with various wt % of ERP.

The different wt% of ERP in 5 wt% CFF filled hybrid bio-composite sample are tested and results are shown in fig. 4. The maximum tensile strength (i.e. 30.83MPa) was observed at 3 wt% ERP which is 70.71% greater than 0 % ERP sample. Also the percentage elongation was rising with increasing wt% of ERP till 3% (% elongation at 3% ERP was 5.78). Later with increasing wt% of ERP, percentage elongation decreases down to 3.5% which shows its brittle characteristic. The increase in ultimate tensile strength might be due to the better interfacial bonding and matrix-reinforcement cross linking as shown in SEM micrograph and XRD analysis. This also enhanced the toughness characteristics of the hybrid composites.

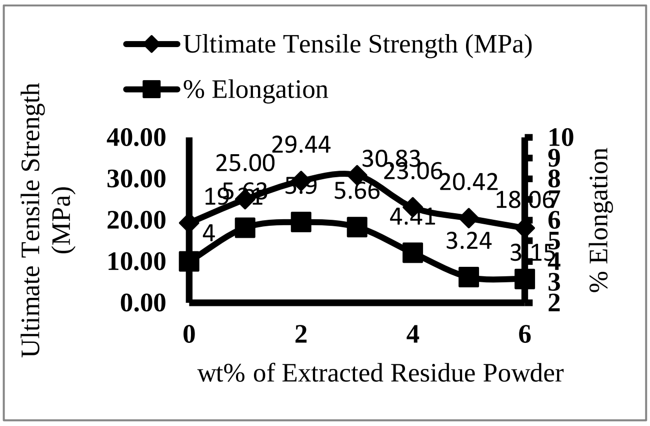

Fig. 4: Effect of ERP wt% (with 5wt% CFF) on ultimate tensile strength and percentage elongation on hybrid composite

The variation in impact strength and energy is shown in fig. 5. The optimum composition obtained was the hybrid composite with 3 wt% ERP. The impact strength (i.e. 1908.2 J/m^2) which was enhanced by 4.08 % as compared to composite with 0 wt% ERP (i.e. 1856.3 J/m^2) and 54.72% as compared to neat epoxy. The increase in impact strength might be due to the proper blending of ERP and better cross linking between the matrix and the reinforcing agents. The decrease in the impact properties after 3 % ERP composition may be due to fiber break-off (as shown in SEM micrograph with 4% ERP), presence of voids or dimples.

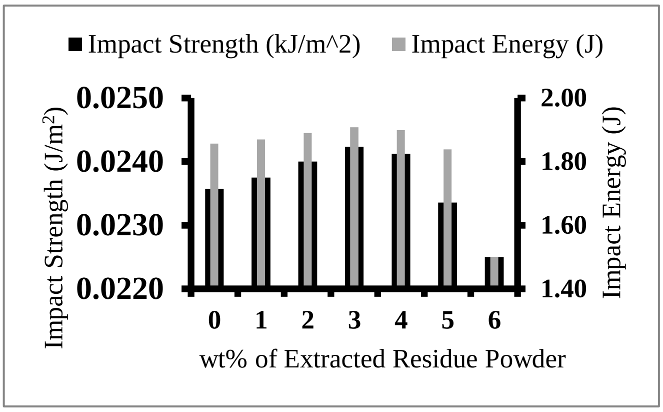

Fig. 5: Effect of ERP wt% (with 5 wt% CFF) on impact strength and impact energy

Fig.6 (a) shows the SEM image of the tensile fractured surface of the hybrid composite (with 1 wt% extracted residue powder from Rohu fish as particulate and 5wt% CFF in epoxy resin matrix). The unidirectional river line shows the brittle fracture. The proper accumulation of the chicken feather is visible with dispersed residue part. The Shiny squared region shown in figure signifies the clear separation of bonding which leads to sudden brittle fracture. The powdered particulate is non-uniformly mixed and it has hurdled the river lines and the insufficient filling of particulate around the matrix leads to early failure. Feather's reinforcement near point of failure, matrix flow and minute voids are visible in 500X magnification.

Fig.6 (b) shows the SEM image of the tensile fractured surface of the hybrid composite (with 2 wt% extracted residue powder from Rohu fish as particulate and 5wt% CFF in epoxy resin matrix). Here we can observe the improved contamination of ERP and Fiber. Hackles and ribbons are moving in different planes therefore it leads to better impact and compressive strength. Proper bonding between the matrix with fiber and the ERP is visible which shows good tensile strength behavior of the composite. Certain voids and randomly oriented fibers (shown in enlarged view) occurred using hand lay-up technique is seen and these could be the cause of material failure. Therefore improvement can be made in mixing method. The shiny views are due to sudden brittle fracture.

Fig.6 (c) shows the SEM image of the tensile fractured surface of the hybrid composite (with 3 wt% extracted residue powder from Rohu fish as particulate and 5wt% CFF in epoxy resin matrix). The Smother river lines

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show the brittle behavior at the hackle zone. Improved toughness can be observed. Ribbons and hackles are moving in different planes and therefore improved impact strength can be detected. Though the powder particulate is non uniformly distributed but it is increasing the bond strength between the matrix and the particulate as the extracted powder composed of multiple charged elements as been seen through FE-SEM analysis. It seems to be the most appropriate combination for the composite development. Here minute air voids and plucking off of matrix which can be seen at 180x zoom could be the appropriate reason for material failure.

Fig.6 (d) shows the SEM image of the tensile fractured surface of the hybrid composite (with 4 wt% extracted residue powder from Rohu fish as particulate and 5wt% CFF in epoxy resin matrix). Here the proper parting zone i.e. crack initiation zone, crack propagation zone and fracture zone is visible. We can observe from the SEM image that at higher accumulation of fiber and the particulate, the matrix shows enhanced bonding but the breaking of fiber and over accumulation of particulate leads to comparative decrease in the mechanical strength of the composite.

Fig.6 (e) shows the SEM image of the tensile fractured surface of the hybrid composite (with 5 wt% extracted residue powder from Rohu fish as particulate and 5wt% CFF in epoxy resin matrix). The decrease in the mechanical strength occurs due to stress concentration at the voids area and visibility of dimples at the fracture zone. The de-bonding of matrix with the fiber and the particulate may be scrutinized due to generation of dimples and fiber break-off near brittle Fracture zone. At 2000x magnification it was very well observed that the ERP is contaminated at one place and thus leads to material failure. Therefore with higher particulate % the strength starts decreasing.

Fig.6 (f) shows the SEM image of the tensile fractured surface of the hybrid composite (with 6 wt% extracted residue powder from Rohu fish as particulate and 5wt% CFF in epoxy resin matrix). Here we can observe that at higher concentration of mixture, the chemical reaction between the matrix and the particulate is showing improper bonding and reactivity decreases. The clear hackles and ribbon zones are visible and therefore reduce the strength of the composite. Accumulation of powder at one place and the generation of micro cracks are visible from the SEM image, which could also be the reason for sudden and brittle fracture at low loads. Therefore reduces bonding attraction and load bearing strength. So finally we can conclude that the 6 wt% ERP in 5 wt% CFF is the saturation state for the current epoxy based hybrid composite fabrication.

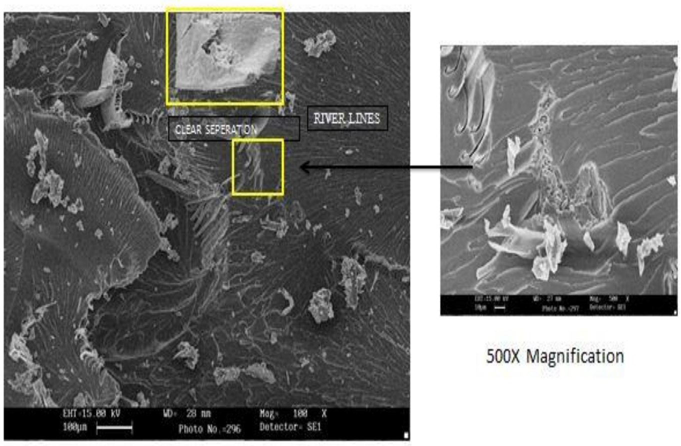

Fig.6 (a): SEM image of hybrid composite with 1 wt% extracted residue powder and 5 wt% CFF in epoxy resin at 100X magnification

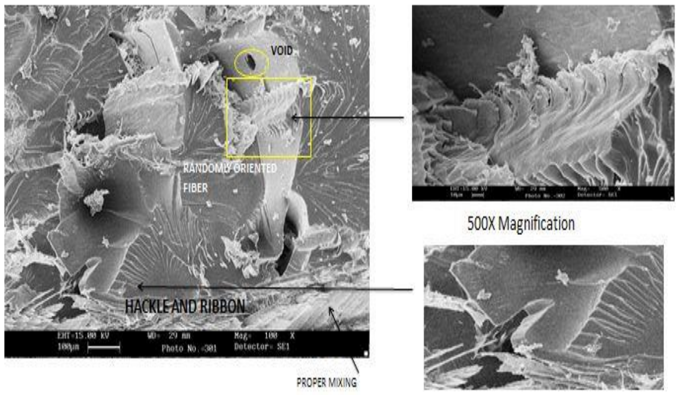

Fig.6 (b): SEM image of hybrid composite with 2 wt% extracted residue powder and 5 wt% CFF in epoxy resin at 100X magnification

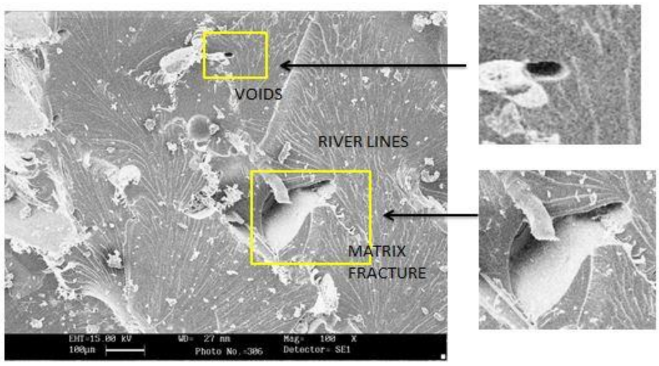

Fig.6 (c): SEM image of hybrid composite with 3 wt% extracted residue powder and 5 wt% CFF in epoxy resin at 100X magnification

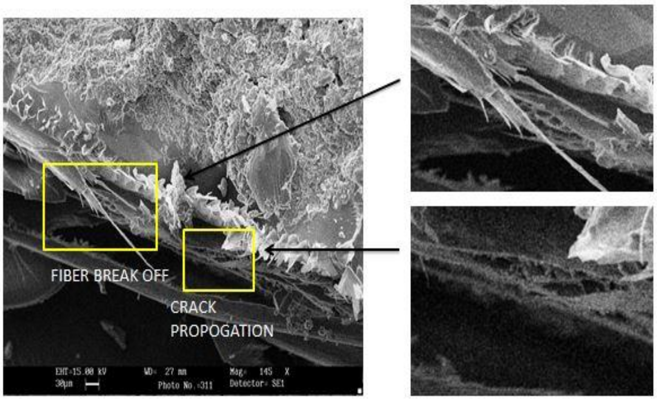

Fig.6 (d): SEM image of hybrid composite with 4 wt% extracted residue powder and 5 wt% CFF in epoxy resin at 100X magnification

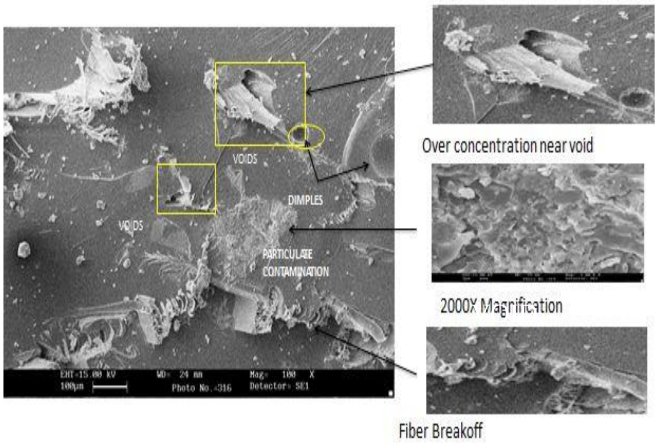

Fig.6 (e): SEM image of hybrid composite with 5 wt% extracted residue powder and 5 wt% CFF in epoxy resin at 100X magnification

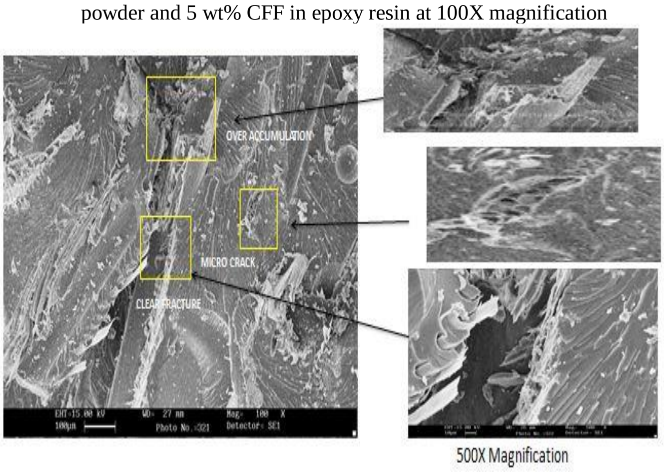

Fig.6 (f): SEM image of hybrid composite with 6 wt% extracted residue powder and 5 wt% CFF in epoxy resin at 100X magnification

The results obtained for X Ray Powder Diffraction test performed at IIC, IITR under 290C atmospheric temperature and 51o RH are given in table 3. The powdered form of the sample is used for XRD testing. Here the output curve displays counts in ordinate axis and two theta scale in abscissa. The variation in gallery spacing (d) with thread angle (2Q) signifies the crystalline or amorphous nature of the sample put under investigation. The sharp and steep peak shows the crystalline nature whereas the smooth and less steep peak shows the amorphous nature of the material.

TABLE 3: XRD CHARACTERIZATION OF VARIOUS ERP COMPOSITIONS IN HYBRID BIO-COMPOSITE

Designation	Counts at Peak	Gallery Spacing “d” (in A)	Thread Angle “2Q” (in degrees)
ERP 1	980	4.57	19.41
ERP 2	1070	4.50	19.56
ERP 3	1048	4.36	19.70
ERP 4	1025	4.34	19.51
ERP 5	1080	4.77	18.58
ERP 6	880	4.75	18.67

From the obtained XRD spectra, it can observe that the curve between 170 to 220 thread angles has the smooth trend that shows the non crystalline nature of the CFF and ERP filled, epoxy based hybrid composite. The decrease in gallery spacing and the increase in thread angle together results in the better interface bonding between the matrix and the reinforcing materials. The minimum value of Gallery Spacing between 2-4 wt% of ERP shows the optimum cross linking characteristic of the developed hybrid composite which results in better tensile strength and impact strength.

CONCLUSIONS

Fabrication mechanical characterization of epoxy based composites was performed in the present research work. Among all the Epoxy Resin based composites developed with varying weight percentage of chicken feather fiber reinforcement i.e. 0 wt% (control sample) to 7 wt% of CFF, the 5 wt% of CFF in cured epoxy resin was the most appropriate composition based on the output results of impact strength and for hybrid bio-composite development with extracted powder from Rohu fish by varying wt% of particulate from 0 wt% (i.e. 5 wt% CFF) to 6 wt% of reinforcing particulate the 3 wt% of particulate gave the most optimized results during the entire investigation of hybrid composite characterization. The entire paper helps to get the deep knowledge about the material used, methods adopted, process required for complete development of material, its testing procedure and the systematic standardization.

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