Thermo Mechanical Behavior of Wool Noil Reinforced composite with Unsaturated Polyester Resin

V. M. Patil[1], Sunil K. Agrawal[2]
1- College of Engineering & Technology North Maharashtra Knowledge City, Jalgaon
2- Department of Textile Engineering, College of Engineering & Technology, Akola
Email: Patil.vilas@rediffmail.com

Abstract

In the present work composite was prepared by reinforcing wool noil with Unsaturated Polyester Resin (UPR) using varying fiber weight fraction of 3, 6, 9, 12 &15%. The mechanical properties (tensile, flexural & impact test), thermal properties (TGA, DSC analysis), morphological properties were investigated. The results clearly indicate that up to 12% loading of fibers the tensile, flexural & impact strength increases and from 12 % onwards starts reducing whereas Thermo-gravimetric analysis also shows distortion last till maximum temperature 4120 C & % weight loss of material is almost nearest to lowest for 12 % fiber loading where as in DSC glass transition temperature (Tg) is highest in case of 15% loading & melting temperature (Tm) & heat absorbed is also nearest to highest in case of 9 % loading of fibers. The SEM test was conducted and clearly seems the presence of fibers & their dimension, bonding, morphological structure of composites in Images.

Keywords: UPR (unsaturated polyester resin), Wool Noil, DSC, TGA, SEM.

I. Introduction

Natural fibers are an attractive research area as a reinforcing material for polymer composite. Natural fibers are eco-friendly and renewable, lightweight, high flexibility, high specific properties, biodegradability and non-abrasive to processing characteristics, and lack of residues upon incineration, with little problem of moisture absorbency. Wool Noil is a waste generated at comber unit. “Noil” term used to describe a short fiber. Generally wool noil is used in cushion as filler material or for making carpets. Pure wool used for apparel purposes & waste in Wool Processing Noil being cost effective can be utilized as for making value added product like composites. Here, we use this as a reinforcing agent to strengthen the composite material. Considerable research has been conducted with natural cellulosic fibers as a source of reinforcement for composite but very little work being conducted as natural protein fibers although the physical properties of wool noil fiber supports for good tensile strength and elongation. [1] Layth Mohammed et al., examined the summary of various surface treatments applied to natural fibers and their effect on natural fiber reinforced polymer composites properties. The applications of natural fiber reinforced polymer composites in automobile and construction industry and other applications are demonstrated. It concluded that chemical treatment of the natural fiber improved adhesion between the fiber surface and the polymer matrix which ultimately enhanced physic-mechanical and thermo-chemical properties of the natural fiber reinforced polymer composites. [2] Nihal Sokmen, they mention that Natural cotton, bamboo and wool fibers were used as reinforcement agents in a polyurethane-based matrix to improve the sound absorption and thermal conductivity properties of the composite. . At higher frequencies, increasing the bamboo or wool fiber content decreases the sound absorption coefficient for the composite. Adding cotton, wool or bamboo fibers to polyurethane foam does not result in a significant change in the thermal conductivity of the material. The best thermal conductivity value was observed with a composite including 4% cotton fiber. [3] Sivaraos, S.T. Leong, Y. Yusof, C.F. Tan, Their work focuses on determination of tensile properties of stone wool fiber reinforced high density polyethylene composites by two methods: experimental and finite element analysis Significant improvement of tensile properties was observed and recorded from the composites. [4] Cheng et al studied the mechanical and thermal properties of chicken feather reinforced polylactic acid composites. They reported that the addition of chicken feather as reinforcement into polylactic acid enhanced the tensile moduli and thermal stability of composites as compare to polylactic acid. [5]

II. Materials & Methods

2.1 Materials

Wool Noil fibers (Comber waste in spinning process) were used as reinforcement material, fineness & average length of fibers are 17.5 micron & 73mm.Unsaturated polyester resin (UPR) of Espol brand .Density & Viscosity of resin are 1.314g/cc & 460cps.

UPR is thermosetting polymer hence for require to use Hardener & accelerator for curing. MEKP (methyl ethyl ketene peroxide) & Cobalt Octane were used as hardener & accelerator respectively. MEKP is colorless liquid with density of 1.1709g/cc.

2.2 Fabrication of Composites.

Hand layup method was used to fabricate composite by reinforcing wool noil fibers into unsaturated polyester resin (UPR) Matrix. Composites were prepared by using various fiber weight fractions i.e. 3, 6, 9, 12 & 15 weight % by randomly aligned sheet of fibers.

A glass sheet mold was used for casting the composites having dimensions 220x220x4mm. a mould release spray was applied at the inner surface of mold for quick & easy release of the fabricated composite sheet. The cast of each sheet cured in room temperature for 24 hours with approximately 50kg of load.

Dimension of Specimens cut as per the ASTM standards, the percent weight fraction of fibers are being nomenclature as D1-3% (fiber weight), D2- 6%, D3- 9%, D4- 12% & D5-15%.

2.3 Testing & Characterization of composites

The composites made by wool noil fibers & UPR were tested for Mechanical & Thermal behavior.

2.3.1 Tensile Test

The Tensile test is performed on universal testing machine (UTM) Instron H loks model. The standard test method was applied as per the ASTM D 3039-76. With crosshead speed of 10mm/min. the length of specimen was used 125mm & three specimens of each sample were tested & average value of Tensile strength, Young modulus & elongation at break is reported.

2.3.2 Flexural Strength

The flexural strength with specimen size 120x13x40mm were tested by using three point bend test in UTM 201 machine in accordance with ASTM D 2344-84.the test was conducted using load of 10 KN at 2 mm / min. rate of loading ,the flexural stress was found out by using equation

$$Tm = \frac{(3fl)}{(2bt^2)}$$

Where Tm is flexural strength in kg/cm, f is breaking load in kg, l is span length in cm, b is width of specimen in cm ,t is thickness in cm .three specimen of each composites were tested & average value are reported.

2.3.3 Impact Strength

The Impact strength calculated by ASTM D 256 machine ,specimen size was 90x13x4mm.impact strength are designed to measure the resistance to failure of material to a suddenly applied force such as collision ,falling object or instantaneous blow. The test measures the impact energy or energy absorbed prior to fracture.

2.3.4 Thermo gravimetric analysis (TGA)

Thermal stability of composites was assessed by thermo gravimetric Sgimadzu 50 apparatus. TGA test was carried out on 1 to 10 mg sample placed in aluminum cell 28 c to 500 c in nitrogen atmosphere at flow rate of 50 ml/min. & temperature rate of 10c/min.

2.3.5 Differential Scanning Calorimetriy

The DSC technique gives results of heat flow measured & plotted against temperature .The area under the peak is directly proportional to the heat evolved or absorbed by the reaction & the height of curve is directly proportional to ratio of reaction. Which help us to identify or assessed the thermal ability of composites, DSc test was carried out on Heat flux type of Shimadzu DSc-60 instrument at flow rate of 50ml/min .in nitrogen atmosphere with Aluminium cell at 1mg to 50mg sample weight with temperature rate 10^o c/min.

2.3.6 Scanning Electron Microscopy

The SEM results are useful to identify the reinforced material as well as it reflects the surface morphology and interfacial properties of the composites.

III. Result and Discussions

3.1 Mechanical Properties

The tensile, flexural and impact properties of UPR and wool noil fibre reinforced composite are given in table 1.

3.1.1 Tensile Properties

Table 1, shows the tensile strength and modulus of UPR and wool noil fibre reinforced composites. The tensile strength and modulus were found to be increased with increasing wool noil fibre content up to D4 (wool noil fibre loading up to 12 weight%). The tensile strength and modulus are found to be maximum up to 12% loading and seems nearly equivalent to plain UPR but the tensile modulus is higher in D4 where as it has been drastically reduced in D5 (wool noil fibre loading up to 15 wt%) as well as in plain UPR.

3.1.2 Flexural Properties

Table 1 depicts, The flexural strength and modulus were increased with increasing fibre loading percentage up to D4 (i.e. up to 12 wt % of fibres) and onwards i.e at 15 wt % of loading, the strength and modulus started decreasing where as if we compare flexural strength of D4 with plain UPR then UPR is having higher flexural strength but modulus has decreased drastically.

3.1.3 Impact Properties

Table 1 depicts, the impact strength and energy absorbed was showing similar trend of tensile and flexural properties. The impact strength is highest in D4 as well as highest in energy absorbed as compare to other weight % loading of wool noil fibre with UPR & plain UPR.

Table.1 Mechanical testing results of composites

Composite	Tensile Strength (Kg/Cm^2)	Tensile Modulus MPa	Flexural Stress(Kg/Cm^2)	Flexural Modulus MPa	Impact Strength(J/mm)
D1 3%	366.35	2279.5	584.13	968.37	0.175
D2 6%	272.61	6534.3	490.15	1981.79	0.156
D3 9%	399.23	3498.38	598.15	2140.62	0.190
D4 12%	423.08	6066.9	628.61	2974.54	0.21
D5 15%	328.02	1197.5	438.00	1445.0	0.198
Plain UPR	332.91	3246.93	519.18		0.195

3.2 Thermal Properties

3.2.1 Thermogravemetric Analysis (TGA)

Figure 1 and Table 2 shows the Distortion start & end Temperature of composites & variation in % weight loss of wool noil reinforced UPR composite with temperature.

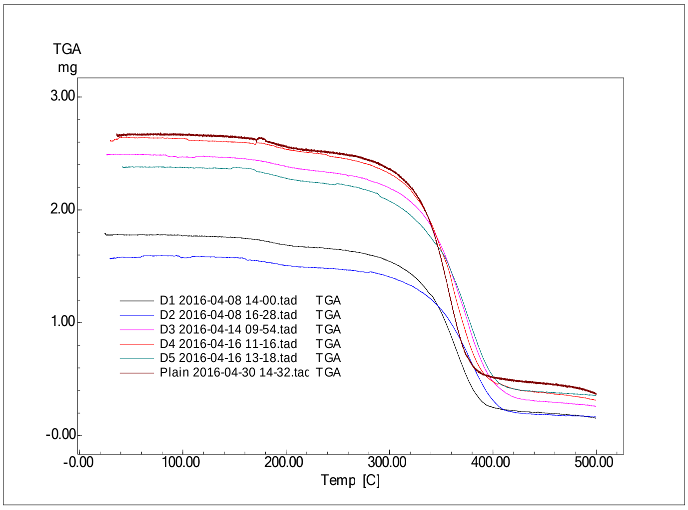

Fig. 1 TGA Analysis

Table 2. Results of Distortion start and last temperature with weight loss %

Sample	Distortion starts Temp. (^{o}C)	Distortion Last Temp. (^{o}C)	Weight loss in %
D1	197.36	411.60	81.93
D2	214.00	412.45	81.818
D3	217.44	411.26	78.973
D4	202.75	412.30	78.924
D5	226.36	411.63	76.633
Plain UPR	270.69	406.77	73.526

As per the results, increase in percentage loading of fibres the distortion last temperature increases up to D4 i.e up to 12% reinforced material, then temperature decreases in case of D5 and even in plain UPR**.** The maximum distortion last temperature is 412.30 ^{0}C in case of sample D4 that means the maximum thermal resistance was showing similar trend with mechanical properties. The % weight loss was higher in case of less loading of fibres and above result shows the consistency in weight loss % D3& D4 i.e from 9 & 12% loading of fibres and found reducing trends from D4 onwards till plain UPR that means composites with wool noil fibers are more thermally stable than plain UPR.

3.2.2 Differential Scanning Calorimetry

Fig.2 and table 3 shows the glass transition temperature (Tg) was highest in D5 and melting temperature (Tm) was highest in D2 whereas energy absorbed was higher in D1. To conclude the results in above tables except plain UPR, the marginal differences in the values of Tm are found in fibre reinforced material. Although the results for D3 showing consistency in all three parameters and reasonably closer results as compared to D1, D2, D4 and D5. Nevertheless the much better thermally stable fibre reinforced composite than pure UPR.

Fig. 2 Differential Scanning Calorimetry

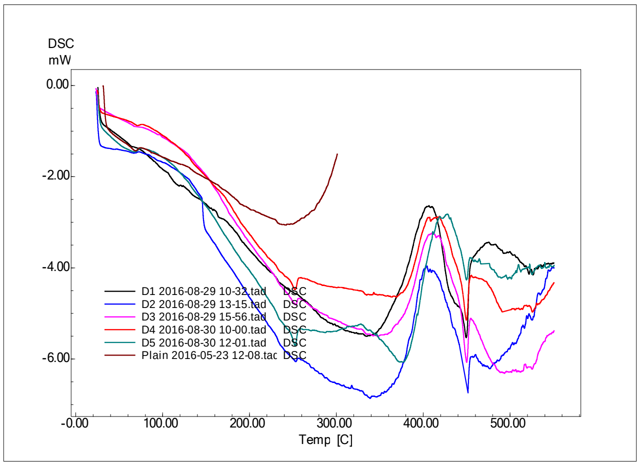

Table 3. Results of Glass transition, Melting temp & heat absorbed.

Sample	**Tg (ºC)**	**Tm (ºC)**	**Heat Absorbed (mJ)**
D1	164.2	450.37	42.44
D2	147.2	452.52	06.73
D3	244.4	451.00	38.69
D4	230.7	450.67	23.23
D5	256.1	450.79	17.56
Plain UPR	087.1	240.00	--

3.2.3 Scanning Electron Microscopy

Following figure depicts the SEM micrographs of wool noil fiber reinforced unsaturated polyester composite. Fig 3 (a, b, c) clearly reflects the presence of reinforced wool noil fiber embedded in the resin matrix. Fig. 3c clearly shows the scales on fiber & makes it easy to identify wool fiber. The physical characteristic of wool noil fibre about its diameter ranges from 16 to 19 um. In fig. d the smooth morphology is marked. The wool noil fibers are uniformly spread in matrix and in Fig. 3e seems in cross section cut view the grooves of fibers reflect the deep bonding with UPR.

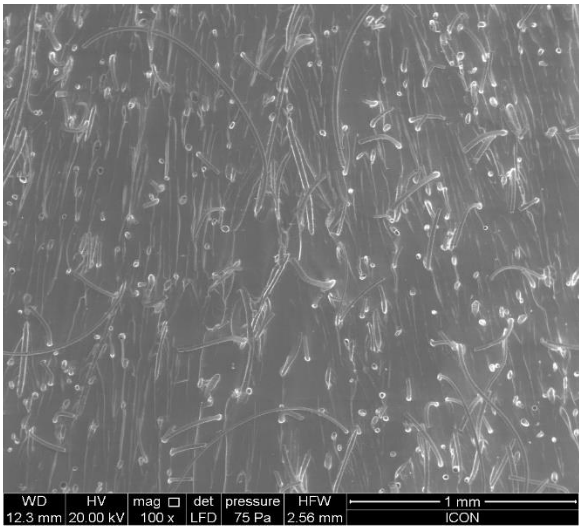

Fig 3(a)

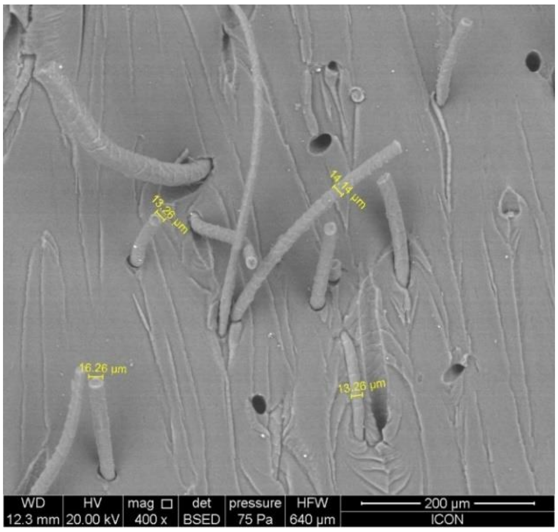

Fig 3(b)

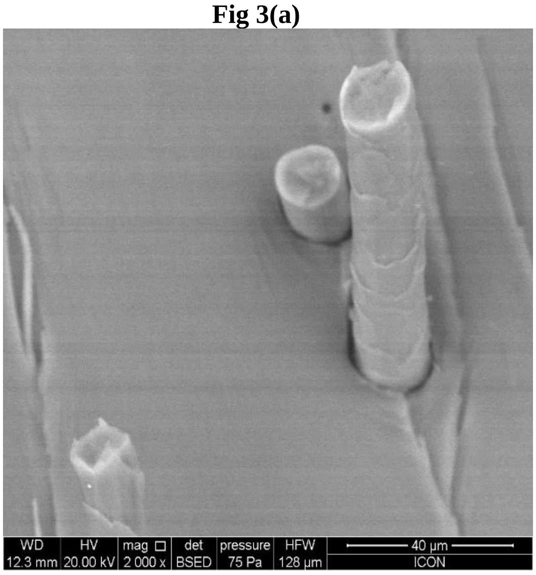

Fig.3(c)

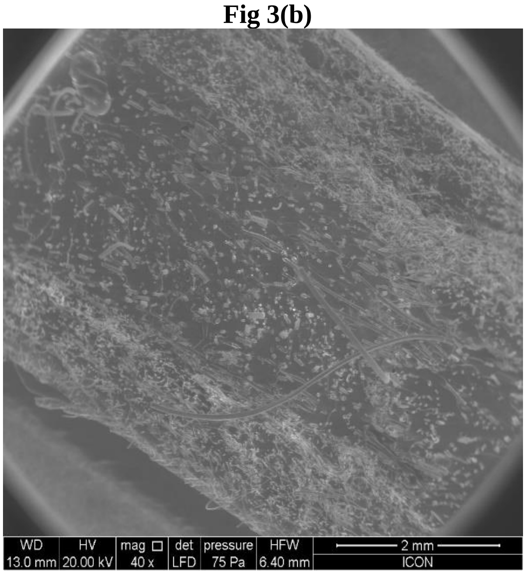

Fig.3(d)

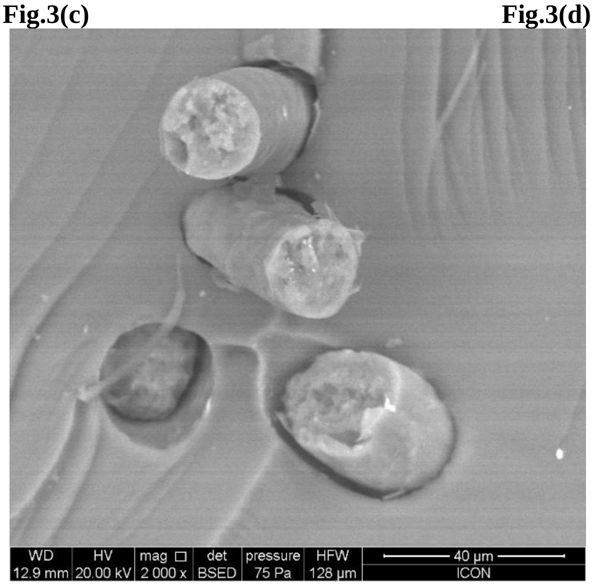

Fig 3(e)

IV. Conclusion

The addition of wool noil fibre improves mechanical properties of pure UPR in terms of their modulus. The wool noil fibre can found to be a value added product in the upcoming days if above results shows consistency in commercial manufacturing.

The thermal properties showing the fibre reinforced composite material thermally stable as compared to pure UPR. It was a successful attempt to develop cost effective composite which can counter conventional reinforcements. The composite properties are found to be optimized near about 12 % loading of wool noil fibre from its thermo-mechanical analysis. The results of SEM direct us the behavior of fibre in matrix and bonding with UPR. Thus the present composite material can be utilized with extensive trail for various applications.

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