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Processing and Characterization of Waste Denim Fiber Reinforced Polymer Composites

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Abstract— In recent years, textile waste fiber-reinforced thermoplastic polymer matrix composites have gained commercial success in different applications. In this study, polypropylene matrix based composite structures were produced by using waste denim fiber at different ratios (5 and 10 %) and conditions (with and without moisture). The mechanical, thermal, chemical and morphological properties of the composites were characterized. The results indicated that after removing moisture, the flexural strength and the flexure modulus of the composites improved with increasing fiber percentage, whereas better tensile properties were obtained at lower fiber content. The highest tensile strength was obtained for 5wt% dry denim fiber-pp composites. The surface morphology of the fracture surfaces of the tensile specimens, examined by a field emission scanning electron microscope, revealed the presence of microvoids. The infrared spectra of pp-denim fiber composites were taken and the characteristic peaks were studied. The lower thermal stability of the produced composites were confirmed by Thermo Gravimetric Analysis (TGA).

Index Terms— Waste denim fiber, polypropylene (pp) resin, composite, moisture.

I. INTRODUCTION

A significant amount of fibrous waste from the textile industry and post-consumer product is disposed worldwide. This is not only a cause for environmental concern, but also represents a waste of useful resources[1].For economic and environmental reasons, in recent years, increased emphasis has been placed on reusing techniques for various fibrous waste products from textile industries [2,3] and industries and research organizations are now looking for applications where waste materials may represent an added-value material [3,4] .Though a variety of technologies have been developed in response to customer demands for recycled products and as alternatives to land filling [3,5,6,7], one of the most viable application of these waste materials is in the combination of polymeric matrices, producing composite materials with interesting properties for specific applications, from structural to thermal and acoustic insulations[4]. For fiber reinforcement, normally scientists prefer thermoplastic polymeric matrices than thermosets due to the low production cycle, lower cost of processing and high reparability of thermoplastics[8].

Several studies have been carried out in order to investigate the mechanical behaviour of textile waste fiber based composites. The mechanical properties of low-density polyethylene composite consisted of waste carpet as the reinforcement element were measured [9,10]. The usefulness of cotton waste as a source of reinforcing fibers for the preparation of cost-effective and biodegradable composites has also been studied [9,11]. The most common textile waste is denim. Denim is very strong, stiff and hard wearing woven fabric [12,13]. The fabrics used for today's denim jeans vary. The widely used denim jeans are 100% cotton, 60%cotton/40% polyester, 50% cotton/50% polyester and 60% polyester/40% cotton. Some denim used for jeans is a blend of cotton, nylon and polyester. Denim is twill weave fabric that uses colored warp and white weft yarn. [12,14]. From a previous investigation, it was observed that denim fabrics have high rigidities, better tear characteristics, moderately sufficient tensile and elevated performance [15]. It is estimated that about 2.5 billion yards of denim is produced every year all around the world. Approximately 1600 pieces of denim will divert 1 ton of waste from the landfill, when recycled. The weight of 1.2 metres of denim is approximately 1.0 kg, therefore the wastage factor for the garment manufacturers is 253 kg for 4000 kg of material processed, or 6.3%. So, the recovery and reusing of denim wastes help to maximise the economies and opportunities by applying this to the supply chain from denim manufacture through to the finished garment [16]. In this current research, waste denim fibers have been used as the reinforcement element to develop a new set of polypropylene matrix composite. The novel and environment friendly composites were developed to study the mechanical and thermal properties of the new composites.

II. EXPERIMENTAL

Locally collected commercial PP resin was used as the polymer matrix .Waste denim fibers were collected from a local textile industry and they were chopped in the size of 3-4 mm. Composites materials were produced using hot compression molding technique at 190°C with 30 kN load. Composites were manufactured in two different conditions (with and without moisture) and by varying fiber weight percentages (5% and 10%). In order to remove moisture and other volatile impurities, fibers were dried in the oven at 120ºC for 2 hours. After producing the composites, tensile and flexural tests were performed using a Universal Testing Machine. The loss in mass of the composites as a function of temperature were determined by thermo gravimetric analysis (TGA). By FTIR spectroscopy, the chemical bonding nature of the composites were investigated. Field emission scanning electron microscopy (FESEM) were carried out in order to investigate the morphological characteristics of the composites.

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III. RESULTS AND DISCUSSION

Figs. 1 and 2 show the tensile properties of the PP/denim fiber composites. With increasing wt% of fibers, the tensile strength of the composites decreases. This behavior can be explained by the presence of voids in the composites. Mwaikambo and Bisanda reported that for polyester/cotton fabric composites, the tensile strength of the composites decreased with increasing content of the cotton fabric, possibly because the void content increases with increasing fabric volume fraction [17].

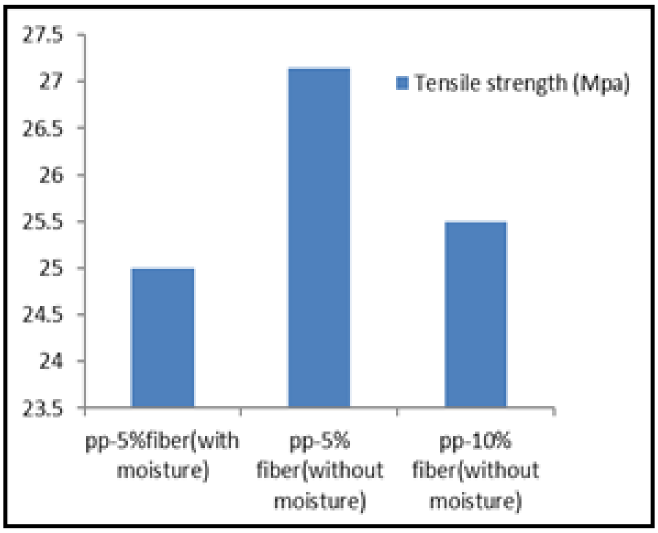

Fig 1: The tensile strength of the composites

On the other hand, the tensile strength is highest for the composite containing 5% dry denim fiber. From the previous studies, it was reported that the interactions between fiber/matrix have an important role in transferring the stress from the matrix to the fiber under the load [9,18]. Generally the tensile strength depends on the weakest part of the

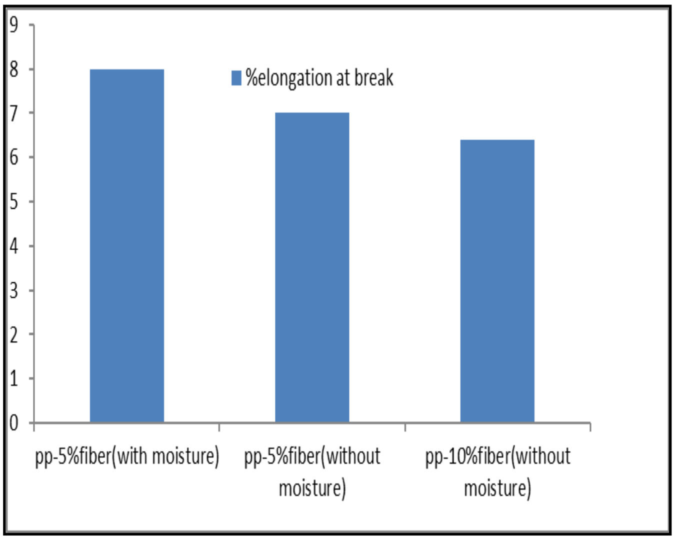

Fig 2: The % elongation at break of the composites

composites and the interfacial interaction between PP and fiber is weak when moisture is present in the fiber surfaces.

The elongation at break during tensile test of the composites are shown in Fig 2. There was a decrease in the elongation at break for the composite containing 10% fiber. This reduction in elongation is due to the fact that higher amounts of fibers present in the matrix restrict the plastic flow of the polymer [19,20]. It was also observed that the presence of moisture ensure the smooth flow of the polymer matrix which results in increased %elongation at break. The young's modulus was increased with increasing fiber percentage because of the increased stiffness at higher fiber contents.

Figs. 3 and 4 show the flexural strength and flexure modulus of the PP/denim fiber composites respectively.

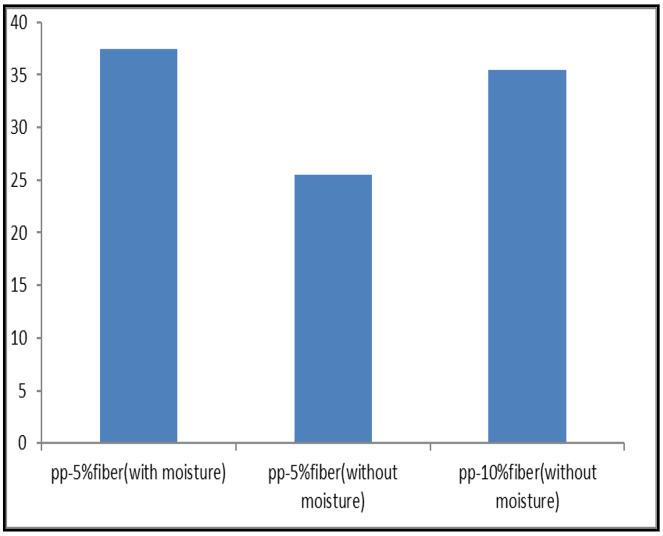

Fig 3: The flexural strength (MPa) of the composites

The flexural properties of the composites display different behavior from the tensile properties. The flexural strength and the flexural modulus increased with increasing wt% of fiber. This behavior can be explained by the entanglement of the denim fiber when its content is higher. This entanglement was confirmed by the FESEM study.

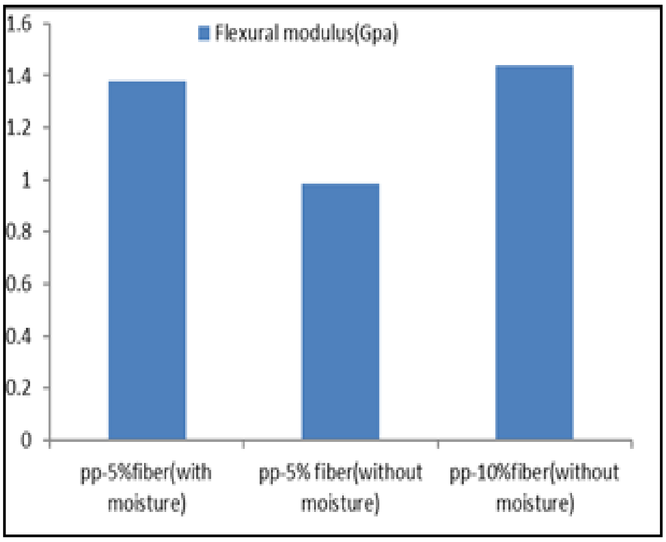

Fig 4: The flexural modulus of the composites

The SEM micrographs of the fractured surfaces are shown in Fig 5. The fibers are broken at many different levels. The fracture surface of the composite revealed some voids are formed on the surface of the resin. The fibers are detached from the resin surface because of poor interfacial bonding.

This results in poor stress transfer from the matrix to fiber. The cracks have easily propagated through the resin matrix as little resistance has been offered.

The FTIR spectra of pp-denim fiber composite is shown in figure 6. From the spectrum we can see that some major peaks are found at 2918.5 cm^{-1},1462.6 cm^{-1} and 1376.9

cm^{-1} which are the characteristic absorption band of pure pp

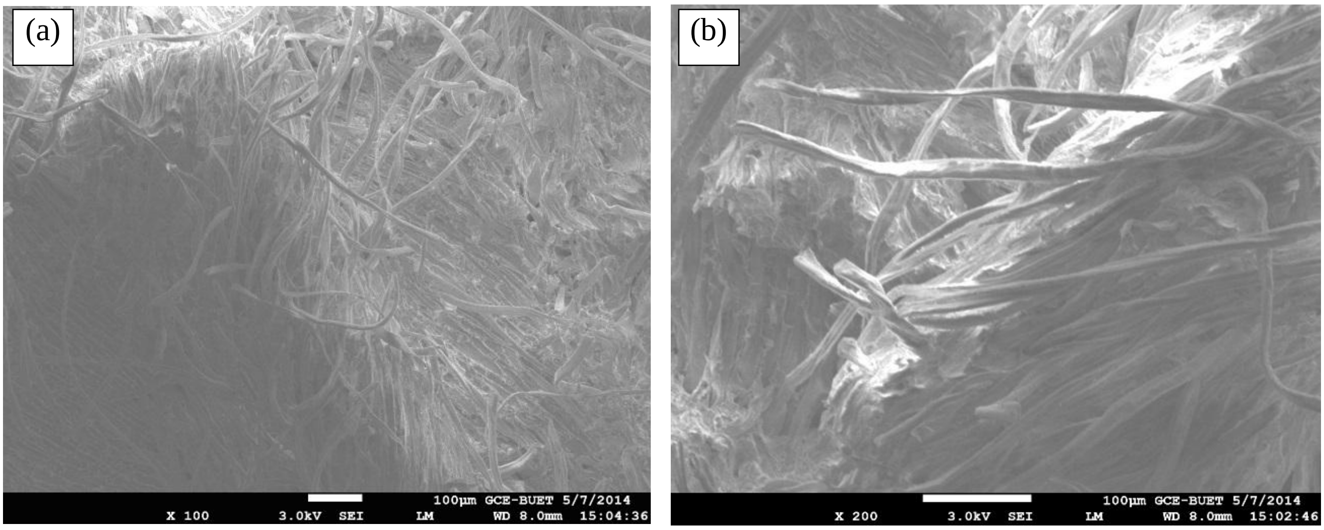

Fig 5: SEM micrographs of fracture surfaces of pp-10wt.% denim fiber composites showing (a) presence of microvoids and (b) fiber/matrix interfaces

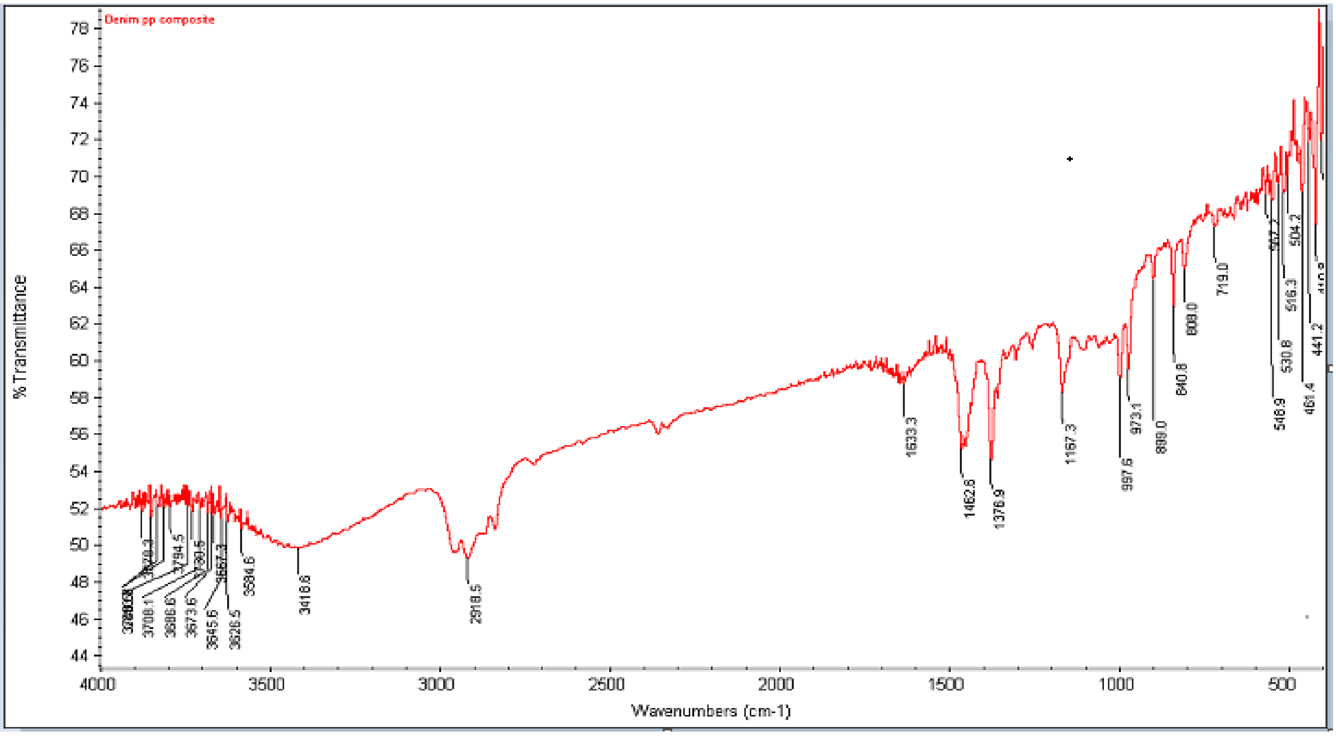

Fig 6: FTIR spectrum of pp-10 wt. % denim fiber composite

that correspond respectively to the sp^3 C-H stretch , CH_2 (methylene) bend and CH_3(methyl) bend. The peak at 3418.8 cm^{-1} and at 1633.3 cm^{-1} corresponds to N-H (amide) stretching vibration and C=O (carbonyl group) stretching vibrations respectively. The absorption bands at 1167.3 cm^{-1} corresponds to C-O (ester) bond vibrations and the peaks in the region of 719-997.6 cm^{-1} corresponds to C-N (amine) bond vibration. From these results it can be concluded that the PP bonds remain dominant in the composites and the denim fibers and PP coexist in the composite maintaining their individual characteristic

The TGA curve obtained is a one-stage decomposition curve and therefore can be used to define the stability limit of the composite. From Fig 7 it can be seen pp-denim fiber composite start to decompose at

209.27 ºC. From this

observation it can be concluded that the composite have lower thermal stability. However, almost 3.358% residual products are obtained after decomposition. This is due to some non-decomposable elements and impurities present in the composite.

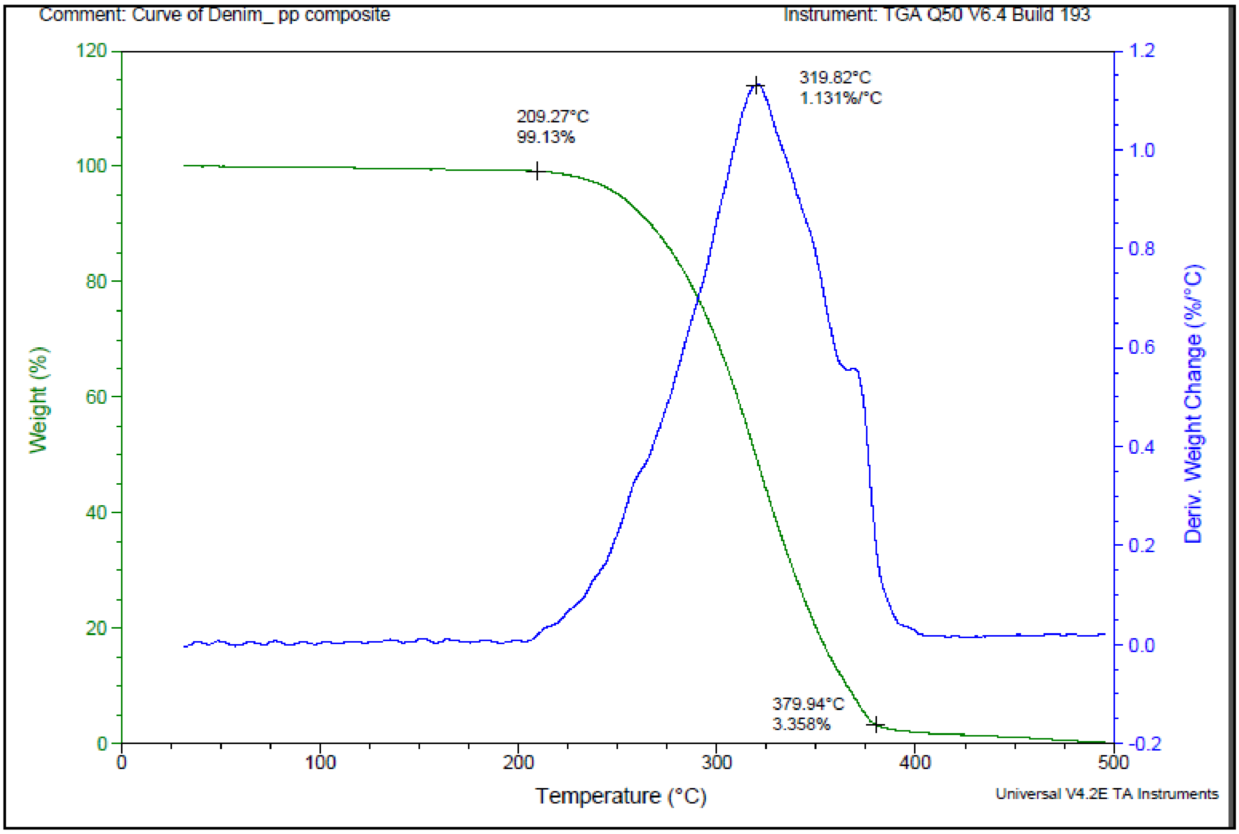

Fig 7: TGA curve of pp-10 wt. % denim fiber composite

IV. CONCLUSION

In summary, this work reports about the different properties of pp-denim fiber composites containing upto 10 wt. % of fiber at two different conditions. The tensile strength decreases with increasing fiber content because of increased amount of voids. However, improved flexural properties are obtained for composites with higher fiber percentage. It is clearly seen that the presence of moisture influence the mechanical properties of composites. The entanglement of the denim fibers and the matrix-fiber adhesion characteristics are confirmed by the SEM micrographs. Thermal behaviour of the composite are obtained by TGA. From FTIR, presence of different functional molecular groups in the composite are observed.

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