

ABSTRACT

Recently, the world is facing a serious problem in developing proper methods of decomposing the solid wastes through different chemical processes with minimal energy, which are actually not cost-effective and may subsequently produce harmful gases during the processes. This environmental issue has urged the scientists and material designers to focus considerable attention in the development of recyclable and biodegradable composite materials. With low cost and high specific mechanical properties, natural fiber represents a good renewable and biodegradable alternative to the most common synthetic reinforcement such as glass/carbon fibers. In the current study, an attempt has been made to develop natural fiber composite materials from date palm leaf (DPL) fiber, an agricultural waste, in two thermoplastic polymers i.e. polyvinyl alcohol (PVA) and polyvinyl pyrrolidone (PVP).

The use of natural fibers in fiber reinforced polymer (FRP) composite has attracted the research communities because of their advantages such as: high-specific strength and stiffness, lightweight, nonabrasive, combustible, nontoxic, low cost and biodegradable properties. However, natural fibers are hydrophilic nature and are not compatible with hydrophobic polymer matrices giving rise to poor interfacial adhesion which restricts their application. The mechanical properties of natural fiber based polymer composites are strongly influenced because of their affinity towards moisture. Over and above this low melting point of natural fiber reinforced composites also restricts their application in some situations. To overcome this issue, surface modifications of the fiber are done which can clean the fiber surface, chemically modify the surface, stop moisture absorption process, increase surface roughness and also improve mechanical properties of composites. In the current work, different surface modifications (i.e. Alkaline, Benzoylation, Permanganate, Peroxide, Maleic Anhydride, and Acrylic Acid) have been given to DPL fibers to improve the compatibility and strong interfacial adhesion with the matrix. Single fiber tensile tests have been done on both treated and untreated fibers to measure the strengths. Out of different treatments, it has been observed that acrylic acid treated DPL fibers is the best one on the basis of maximum tensile strength. In addition to that fiber –

characterization have been done through FTIR, XRD, and SEM to study the properties of DPL fibers. Various weight percentages such as 10 %, 20 %, 30 %, and 40 % of randomly oriented short acrylic acid treated DPL fibers have been reinforced with PVA and PVP matrices separately to fabricate PVA/DPL and PVP/DPL composite specimens by injection moulding processes. Tensile tests have been conducted separately for each composite specimen at various weight percentages in order to know the optimum weight percentages of fibers for maximum strength. By applying regression analysis in the tensile test results of both the composites, it has been observed that PVA/DPL composite gives maximum tensile strength at 28 wt% of fiber loading whereas, that of PVP/DPL composite gives maximum tensile strength at 26 wt% of fiber loading. Then, the weight percentages of DPL fibers have been varied as 10 %, 20 %, 28 %, 30 %, and 40 % for PVA/DPL composite and 10 %, 20 %, 26 %, 30 %, and 40 % for PVP/DPL composite during fabrication process. Characterization of composite has been done through various tests such as FTIR, XRD, and SEM.

The mechanical properties such as tensile strength, Young's modulus, elongation at break, flexural strength and impact strength have been conducted at different fiber loadings. From the observed test results it has been found that like tensile strength, flexural and impact strengths also give maximum values at optimum fiber loadings for both the composites. The thermal properties such as Dynamic Mechanical Thermal Analysis (DMTA), Differential scanning calorimetry (DSC), and Thermal Gravimetric Analysis (TGA) have been conducted on composite specimens at optimum fiber loadings in order to study their thermal behavior. Similarly, the tests on rheological properties at optimum fiber loadings for both the composites have been conducted and analysed to know the variation of complex viscosity as a function of frequency.

Biodegradability properties of the composites have been studied by saline water and sludge water treatment methods at all fiber loadings. From saline water treatment tests, it has been observed that by increasing the amount of date palm leaf fibers the water absorption capacity of both the composites increases but the saturation time decreases. Further, from diffusivity (D) measurement, it has been found that the diffusivity increase with increasing the fiber loading it indicates that the incorporation-

of date palm leaf fibers enhances the water absorption process. From sludge water treatment tests, it has been observed that biodegradation properties (i.e. percentage of weight loss) of both the composites are dominated by the percentage of filler. It is also enhanced by the number of days.

Abrasive wear (dry sliding wear) tests of both PVA/DPL and PVP/DPL composites have been carried under multi-pass two-body abrasion condition on a PIN ON DISC type wear testing machine as per ASTM G99-95 standard. From the test results it has been observed that the tribological performances of both the composites are better at optimum fiber loadings (i.e at 28 wt% for PVA/DPL and 26 wt% PVP/DPL composite). Generally, there is no remarkable correlation between the mechanical and tribological performance of major polymeric composites. But the novelty of the present investigation is that there is a correlation between the mechanical and tribological properties showing better performances at optimum fiber loadings.

The solid particle erosion tests have been conducted for both PVA/DPL and PVP/DPL composites at different fiber loadings as per ASTM G76 standard. From the results it has been observed that solid particle erosion of PVA/DPL and PVP/DPL composites is strongly affected by cumulative mass of impinging particles, impact angle and impact velocity. As far as effect of impact angle on erosion performance of the composites is concerned, both the composites have maximum erosion at 45° impact angle irrespective of fiber loading which shows ductile wear behaviour. The erosion efficiency varies from 4.316 to 16.289% for PVA/DPL composites and 3.128 to 15.289% for PVP/DPL composites at different impact velocities studied. Observing this range it can be concluded that the mechanism of erosion may be due to micro-ploughing and micro-cutting. The impact velocity (v) of the composites has a tremendous effect on the steady state erosion rate (E) and is related as $E = Kv^n$. The velocity exponents are in the range of 2.018 – 2.88 for PVA/DPL composites and 2.095 – 2.742 for PVP/DPL composites for different impingement angles (15-90°) and impact velocities (48-109 m/s) which further confirms the ductile nature of the composites.

From the overall studies of present research work it can be concluded that date palm leaf, a waste material obtained from date palm tree, can be fruitfully used to –

produce low cost composite materials by reinforcing with thermoplastic polymers such as polyvinyl alcohol (PVA) and polyvinyl pyrrolidone (PVP) for the development of value added products due to its economic and environmental advantages. Further, it has been observed that that 28 wt% and 26 wt% are the optimum fiber concentrations in PVA and PVP matrices to manufacture natural fiber composites where there is significant improvement of some of the properties like mechanical, thermal, and abrasive wear. However, there are other properties such as erosive wear, moisture absorption and biodegradability which have to be compromised while using these composite materials in various structural and non-structural applications.