ABSTRACT

Fiber reinforced plastic composites replace wood and metals due to their light weight, high strength to weight ratio, non-corrosive nature and stiffness. Natural fibers are used in place of synthetic fibers because of environmental concerns. Natural fibers exhibit low specific strength and low density. Also they are easy to process and recycle. However Poor interfacial adhesion between fiber and matrix, low melting point, and lack of resistance to moisture has limited the use of natural fibers. Chemical pre-treatments are used to overcome the above limitations which improves the scope for the usage of the natural fibers.

This research work aims at studying the possibility of using Palmyra Palm Leaf Stalk Fiber (PPLSF) a natural fiber exacted form Palmyra palm tree (Borassus fablifier). This fiber is rich in cellulose, inexpensive and is abundantly available. At present this fiber is used for manufacturing of painting brushes and brooms. PPLSF is subjected to various chemical pre-treatments using sodium hydroxide (Mercerization), benzoylchloride and potassium permanganate. The effect of these treatments on various properties of the fibers was studied. Composites were prepared by hand layup method followed by compression molding with the following types of reinforcements i) 50 mm length untreated fiber composite with random orientation, ii) 50 mm length chemically pretreated fiber composite with random orientation, iii) unidirectional continuous untreated fiber composite, iv) unidirectional continuous chemically pretreated fiber composite, v) 50 mm length alkali treated PPLSF/jute hybrid composite with different layering patterns such as bi-layer (PPLSF/Jute) and tri-layer (PPLSF/Jute/PPLSF, Jute/PPLSF/Jute) vi)
bi-layer unidirectional continuous PPLSF/jute hybrid composite and vii) bi-
layer unidirectional continuous PPLSF/non-woven glass fiber mat hybrid
composite. The mechanical properties such as tensile, flexural and impact
strength and also tensile, flexural modulus were experimentally determined.
Fourier Transform Infra Red Spectroscopy (FTIR), Thermo Gravimetric
Analysis (TGA), Differential Scanning Calorimetry (DSC), Scanning
Electron Microscopy (SEM), Dynamic Mechanical Analysis (DMA) were
used to characterize the fibers and composites. Wear characteristics of PPLSF
composites were studied using Design of Experiments (DOE).

Properties of pre-treated 50 mm length fiber composites were compared with untreated 50 mm length fiber composites. Results showed
60% increase in tensile strength and 37% and 60% increase in tensile modulus
upon mercerization and benzoyl treatment respectively. Flexural strength
increased by 70% and flexural modulus increased by 110% upon
permanganate treatment. The impact strength for the mercerized and
permanganate treated fiber composite improved by 55% and 42%
respectively. Chemical pretreatment of fibers reduced water absorption of the
composites, of which, the least was observed in the case of benzoyl treatment.
Thermo gravimetric analysis showed enhanced thermal stability of the
chemically treated fiber composites. Enhanced properties are attributed to the
improved adhesion between the fiber and matrix.

Properties of pretreated unidirectional continuous fiber composites
were compared with untreated unidirectional continuous fiber composites.
There was an increase of 33% in tensile, 55% in flexural and 50% in impact
strength for benzoyl, permanganate and alkali treated composites respectively.
More than 100% improvement in tensile, flexural and impact properties were
observed for untreated unidirectional continuous PPLSF composites in
comparison with pre-treated 50 mm length fiber composites. The dynamic mechanical analysis showed that the use of untreated/treated fibers in polyester matrix has enhanced the storage and loss modulus of the composites. The reduction in the height of the Tan δ peak and shifting of the peak to higher temperatures was also observed which is an indication of good fiber/matrix adhesion.

Properties of layered composites were compared with untreated 50 mm length fiber composites. The bi-layer composites exhibited the highest possible tensile properties while the tri-layer (Jute/PPLSF/Jute) composites exhibited the highest possible flexural properties. 17% improvement in tensile strength, 51% improvement in tensile modulus for bi-layer composites and 45% improvement in flexural strength, 60% improvement in flexural modulus for jute/PPLSF/jute composites were observed.

Properties of the bi-layer unidirectional continuous PPLSF/jute hybrid composite was compared with unidirectional continuous alkali treated fiber composite. Increasing jute fiber content resulted in 46% and 56% improvement in tensile and flexural strength respectively. The impact strength was observed to decrease by 31%. Addition of jute fibers to PPLSF and alkali treatment of the fibers enhanced the storage and loss modulus of the hybrid composites. A positive shift of Tan δ peaks to higher temperature and reduction in the peak height of the composites was also observed. Jute hybrids exhibited increased tensile, flexural and dynamic properties.

Properties of bi-layer unidirectional continuous PPLSF/non-woven glass fiber mat hybrid composite were compared with unidirectional continuous alkali treated fiber composite. Hybridization of non-woven glass fiber mat resulted in 54%, 36%, 58% improvement in tensile, flexural and
impact properties respectively. Reinforcement of alkali treated fibers and hybridization with glass fibers, enhanced the loss and storage modulus of the composites, increased glass transition temperature ($T_g$) and also reduced the Tan $\delta$ peak. A positive shift in Tan $\delta$ was also evident for all the glass hybrid composites.

The wear behavior of PPLSF composites at different sliding speed, normal loads with constant sliding distance was studied using pin on disc wear tester. The wear results showed that reinforcing of fibers in the matrix lead to improved wear performance of the composites. This was further enhanced by using alkali treated fiber. Design of Experiments (DOE) was used to identify the number of wear tests to be conducted with fiber length, speed and load as experimental parameters (factors) and the optimal set of parameters that would result in minimum wear loss and coefficient of friction was also determined.

Chemical pretreatments of PPLSF improved the mechanical properties and moisture resistance of composites. Bi-layer arrangement resulted in improved tensile and flexural properties compared to tri-layer composites. Use of continuous fibers with unidirectional arrangement increased the tensile, flexural and impact properties of composites by more than 100% compared to composites reinforced with 50mm length fibers. Hybridization of jute and glass resulted in enhanced mechanical properties compared to unidirectional alkali treated PPLSF composites. Reinforcing with alkali treated PPLSF improved the wear performance by reducing the wear loss and coefficient of friction.