ABSTRACT

Environmental aspects and fast depletion of fossil fuels initiate concentration on the utilization of agricultural wastes as raw materials for the development of polymeric materials. Economically favourable composites from the plant derived fibres and crop derived plastics are the most keenly required materials of the twenty first century. Therefore, most suitable polymer composites materials are expected to be made from sustainable plastics in combination with inexpensive reinforcement materials and natural fibre for sustainable applications.

The present study mainly deals with the development of polymer composites using matrix and reinforcements from the agro waste natural resources. Matrix was formulated by using agro based industrial waste byproduct, cardanol, obtained from cashew nut shell liquid. It is a naturally occurring phenolic source serves as partial replacement for conventional epoxy resin. Bisphenol-A, the monomer of commercial epoxy resin, has negative biological effect over human health. This motivated to choose cardanol, a natural monomer, for matrix synthesis. Cardanol is a meta substituted alkyl phenol from Cashew Nut Shell Liquid (CNSL) that gives feasible reaction mechanism to form a novolac resin. Phenolic–OH of cardanol was epoxidised and blended with commercial epoxy resin in various ratios which introduces flexibility to epoxy resins and reduces the toxicity. Inorganic fillers, SiO_2 (SD) and $Mg(OH)_2$ (MO) are incorporated with synthesized cardanol based resins to improve the inherent physical, mechanical and flammable properties.

The main objective of the present study is to assess the effective impact of using unidirectional waste banana fiber as reinforcement for the composite

development. Chemical treatments of the banana fibre are done to improve the compatibility between fibre and matrix. Hybrid composites are also developed using woven glass fabric and unidirectional banana fibre. Thermal, mechanical, flammability properties, water absorption behaviour and morphological studies are carried out for both filler and fibre reinforced composites. EPC and ECN are developed in good yield using epichlorohydrin and a base catalyst. Synthesized resins are blended with the commercial epoxy resin, DGEBA, in various ratios (15, 25, 35 and 50 wt %) and cured with amine hardener. Characterization of synthesized and blended resin systems (DC and DCN) are carried out by ATR FT-IR and UV spectroscopy. Biodegradation study of the DC system is done by soil burial test. Blending of bio resin improved the thermal and mechanical properties as analyzed by DSC, TGA and tensile testing instruments. The blended resins DC1 (15% EPC : 85% DGEBA), DCN1 and DCN2 (15% ECN:85% DGEBA and 25% ECN:75% DGEBA) which possess high mechanical and thermal stability after curing with hardener are selected for further improvement of mechanical and thermal properties with inorganic fillers SD and MO and also for hybrid composite development. These optimized resin systems are subjected to physico chemical studies such as EEW, iodine value, viscosity, flash and fire points. 1, 3 and 5% of inorganic fillers, SD and MO, are incorporated in to the selected resin systems. Curing behaviour of the resin system with and without fillers is investigated by DSC. 1% SiO_2 and 5% $Mg(OH)_2$ incorporated resin systems which exhibited superior mechanical and thermal stability and also imparted flame retardency. Flame retardency was determined using UL - 94 and LOI test. Dispersion of fillers in the resin is studied by XRD. Morphology of the cured resin and filler incorporated composite is observed by Hot stage optical microscope and fracture surface analysis is done by FE-SEM. It is noticed that the agglomeration of $Mg(OH)_2$ lowered the mechanical properties. Water absorption behaviour increased with increase in bio resin content

whereas filler reinforced composites showed reduction in the water uptake percentage.

Fibre content, weight of resin, and post curing temperature of unidirectional banana fibre/DGEBA composite are optimised using Box-Behnken Design optimisation technique. Based on BBD, proposed 17 set of composite samples are developed and tested for their tensile and flexural strengths. Composites are developed from various proportions of DC and DCN resin systems using the optimized parameters. DC1 based composites show enhanced mechanical properties while DCN1 and DCN2 show lowered mechanical properties due to the de-wettability of the fibre. All the developed composites show the thermal stability up to 250ºC. Hence, DC1, DCN1 and DCN2 resins are selected to develop hybrid type I & II composites.

Sodium hydroxide, laundry chemical and heat treated DGEBA composites are developed and tested for mechanical properties. It was found that the sodium hydroxide and thermal treated fibre reinforced composites exhibit lower mechanical properties due to the de-wettability of the fibre, whereas the laundry treated composite exhibited higher mechanical properties due to better interaction between the fibre and matrix. Hence, laundry treated fibres incorporated composites of DC1, DCN1 and DCN2 are fabricated and their mechanical properties are evaluated. Hybrid type I composites are fabricated using laundry treated fibre as reinforcement and dispersion of optimized fillers, 1% SiO_2 and 5% $Mg(OH)_2$, into the matrix. DC1 and DCN2 based filler incorporated composites are observed to be with higher mechanical properties comparable to that of the untreated fibre composite. Significant difference in mechanical properties is not observed with filler inclusions in type I hybrid composite. Hybrid type II composites are fabricated by placing woven glass fabric as top and bottom layers and using untreated banana fibre as a core layer with varying filler ratio. Nine sets of such composites are developed using DC1, DCN1 and DCN2 resin matrixes and

subjected to mechanical properties analysis. Uniform dispersion of filler in the matrix exhibited better mechanical and thermal properties. Mechanical properties are found to decrease with increase in filler content in the composite. But increasing the filler content increased the flame retardency property. Char residue formation of these composites imparted higher flame retardency compared to other developed composites.

Water absorption and its kinetic studies of unidirectional and hybrid composite revealed that filler inclusion in the composite decreased the water absorption behaviour. Thermal degradation kinetics of thermoset and filler reinforced composites is studied using the Broido, Horowitz and Coats-Redfern model with single heating rate. It is also observed that the 5% SD incorporated DC1 and 3% MO incorporated DCN2 system showed higher activation energies compared to other systems, indicating improved thermal stability with flame retardency property. Flame retardency of the composite is studied by UL-94 test and LOI analysis. It is found that flame retardency is improved by inclusion of fillers. The developed composite exhibited LOI value of 26% and V-1 rating in the UL-94 test. The glass fabric based hybrid composite exhibited excellent flame retardency property with LOI value of 31%.

The evaluation of this investigation suggested that the 15% of epoxidised cardanol blended resin and 25% of epoxidised novolac blended resin exhibit better mechanical and thermal properties with the incorporation of SD and MO which also enhances thermal, mechanical and flame retardency properties.