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Thermoplastic impact property improvement in hybrid natural fibre epoxy composite bumper beam

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Abstract. Utilization of thermoset resin as a bumper beam composite matrix is currently more dominated in car manufacturer suppliers, because of availability, easy processing, low material cost and production equipment investment. Moreover, low viscosity, shrinkage and excellent flow facilitate better fibre impregnation and proper surface resin wetting. Three-dimensional cross linking curing increase impact, creep and environmental stress cracking resistance properties. Low impact properties of natural fibre epoxy composite, are main issues in its employment for automotive structural components. Impact properties in epoxy composite bumper beam could be increased by modifying the resin, reinforcement and manufacturing process as well as geometry parameters such as cross section, thickness, added ribs and fixing method optimizations could strengthen impact resistance. There are two main methods, flexibilisation and toughening, as modifying the resin in order to improve the impact properties of epoxy composite, which form single phase or two-phase morphology to make modifier as epoxy or from separate phase to keep the thermo-mechanical properties. Liquid rubber, thermoplastic, core shell particle and rigid particle are different methods of toughening improvements. In this research, thermoplastic toughening has used to improve impact properties in hybrid natural fibre epoxy composite for automotive bumper beam and has achieved reasonable impact improvements.

1. Introduction

The growth of the automotive system is strongly related to the economic growth in early part of this century [1]. So, manufacturing the car being strategic products and the developing the new material resources for staying in the competitive edge is a must cause by environmental, economical and technological reasons [2]. Natural fibres have concerned by scientists and technologists nowadays because of low density, cost, less tool wearing rate, low production energy requirement, good formability, renewability, suitable acoustic and thermal insulating as well as no splintering properties. Therefore bio-composites application is rapidly growing in past two decades [3],but some deficiency cause poor mechanical properties and decreased their utilization in automotive structural components such as hydrophilic, heterogeneous, low impact, non-uniformity and low processing temperature.

Polymer matrix composite (PMC) is more common in natural fibre composite. Thermoplastics against thermoset become viscous at higher temperatures, and they are reversible [4]. Thermosets can flow only once and cross-link with curing agents. They have excellent flow to impregnate the fibre bundles during the manufacturing process, so present better adhesions, tough, corrosion resistance, high creep resistant because of 3D cross linking reaction network, stiffness, dimensional stability, strength and higher performance and low shrinkage. It could present better properties as a matrix [5], but the brittle behavior of the thermoset material decrease the amount of energy absorption. Therefore, it is essential to improve their plasticity for better impact damping.

Kenaf is not strong enough to use in automotive structural components. So, hybrid of glass and kenaf as reinforcement, epoxy as matrix and SMC as manufacturing method are considered in this research. In application of bio-composite as a bumper beam, the main issue is low impact properties, which could be improved by incorporation of discrete layers of tough resin (interleaving), introduction of z-directional fibre (stitching) and addition of whiskers or short fibres to the interlaminar zone (supplementary reinforcement). Moreover, increasing the flaxibilzation and toghtening properties of epoxy can help to overcome to the desired deficiency. Also, the demand for improved recycling concepts of thermoset material can substitute it by thermoplastic [6].

2. Epoxy Bio-Composite Impact Property's Improvements

Improvement of the mechanical properties of the composite material totally is based on reinforcement improvement, matrix improvement and manufacturing method improvement. Since, epoxy is considered as a matrix, so in this paper is focused on epoxy matrix composite improvement. During the damage, process caused by impact load, at first the laminate response as a linear-elastic with incident energy, which causes the matrix cracking and fibre kinking to make significant strength reduction. By more penetration the damage continued by delamination or debonding of the individual laminas or layers until the force pass through the delamination theroshold load (DTL) to fibre fracture and complete failure. The laminate failure depends to the type of loading tension, compression and bending. Among the different methods for impact improvement reducing delaminations has a more effect. Since delamination commencement and propagation are thought to be mainly dependent upon the fracture toughness of the matrix material one way that researchers have attempted to improve delamination resistance is through the use of toughened resins and interleaves [7].

There are different methods for improving the impact properties of epoxy composite material. Flaxibilization is blending a plasticizer in order to make tougher thermoplastic material, but in thermoset it exudes out from the matrix and undergoes macro-phase separation or the accumulation of free liquid plasticizer molecules at the fibre surface can act as a weak boundary layer and cause a substantial decrease in inter laminar shear strength ILSS [8].

oughening is blending in two-phase morphology, which could maintain the thermo-mechanical properties. According to the second pphase,the toughening categorize in four types: liquid rubber toughening, core-shell particle toughening, thermoplastic toughening and rigid particle toughening. Moreover, ttheirnano-reinforcement offers a great potential for novel properties and toughening strategy can be coupled with a suitable nano-reinforcement by using nanofiller like nanoclay and CNT, to produce strong and tough composites, which are still expensive and uuneconomical.

Bumper beam belong to exterior parts, which has to pass the external parts special test. Different modifiers present different properties that should be compatible with the desired conditions and have to maintain its properties in different temperature, humidity and pressure. The previous research demonstrated, epoxy toughening is the most successful method for impact strength improvement for a structure and thermoplastic toughening could be more suitable for bumper beam as external structure automotive components because of their high modulus and high Tg of engineering thermoplastics, the modified epoxy resin will reach or even exceed the corresponding values and could maintain the thermo-mechanical properties compare with other toughening techniques, however thermoplastic toughening has poor processability [9-10].

3. Materials and Method

In this research, epoxy is considered as a matrix. Five plies have been used to fulfil the common desired bumper beam thickness. The modified sheet-molding compound (SMC) selected as a fabricating method to enhance the required mechanical properties. Since the long fibres present, more strength and kenaf fibres are twisted naturally, so a fixture is made to stretch the fibres. A thin frame was located on the top of the fixture to keep the fibres in the stretched condition. Sample is made from two kenaf fibre and three glass fibre layers. In SMC method the fibres disperse over the slurry resin then pass through sequential roller to make it denser and more stable, but in this method resin spray onto the different directions stretched fibres (Figure 1). Next, the stacked layers put into the preheated mould and mount into the controlled temperature and pressure hot press for forming the desired shape, which in this research was flat plate (Figure 2).

Figure 1. Stretched kenaf fibre

Figure 2. Hot press machine

Thermoplastic toughening is considered as a method for improving the impact properties. The selected thermoplastic toughening material was CBT 160 from Cyclics cooperation in USA. CBT 160 resin is a low melt viscosity thermoplastic that can be processed in typical composite processes including pultrusion and compression molding. Through a reaction with the catalyst contained in CBT 160 resin, it is converted into the engineering thermoplastic polyester polybutylene terephthalate (PBT). It has lightweight, high service temperatures, excellent chemical resistance, high impact resistance, and improved fatigue. There are studied three different morphologies in blending of PBT into the epoxy, which exhibit different mechanical properties named: spherulitic dispersion, gel with spherulites and structure less gel. Since the strucureless gel with spherulites showed higher impact properties compare with other methods [11], so it is selected as a fabricating process.

4. Results and Discussion

The aim of thermoplastic CBT toughening in second batch specimens was an impact property's improvement. By reviewing stress strain (S_S) curve of hybrid materials, it is evident that the behaviour of the material has been changed by increasing the thermoplastic CBT material. It presents the nonlinear elastic region and ductile plastic behaviour, which is more suitable for energy absorbing. After sustaining the maximum load, material still tolerate the load during the plastic deformation, which can absorb more energy during the failure process. The Izod impact was conducted according to the ASTM D256-04 with calibrated monitor impact Izod test machine model TMI. Six samples with specified dimensions and defined notched were prepared. The suitable pendulum hammer was mounted and machine was calibrated and considered all excess energies to show the exact amount of impact energy in J/m. The average impact energy value was 40.2 (J/m) which shows a significant improvement compares with previous batch. Seven tensile specimens with a specified dimensions are tested according to the ASTM 3039-89 by universal hydraulic Instron machine model 3382 The. tensile strength of the first batch was higher than the second batch and the GMT. The impact property considerably improved in second batch but still is lower than common bumper beam material (See Figure 3).

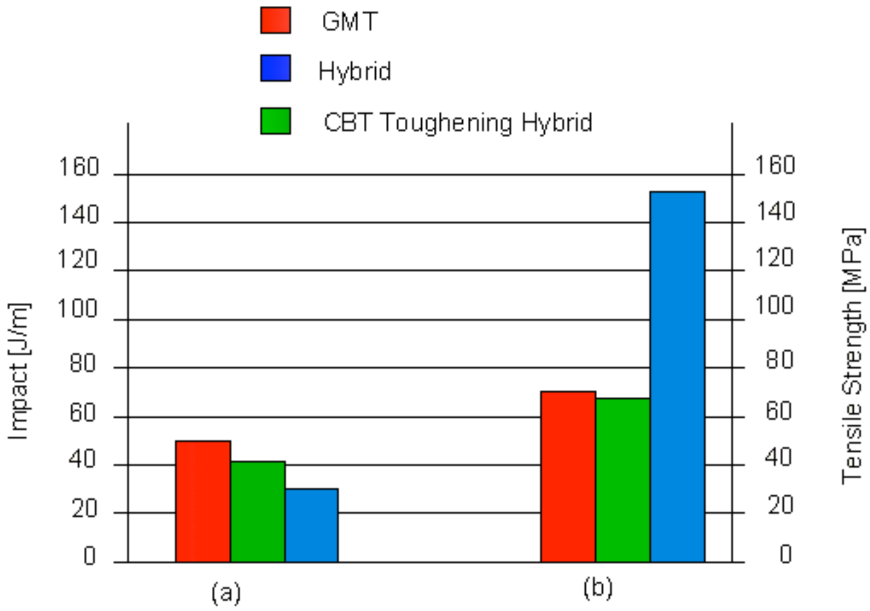

Figure 3. Comparison chart (a) Impact (b) Tensile strength

5. Conclusions

According to the result, however CBT significantly increased the toughness and impact properties of the hybrid material; it still could not completely fulfil the GMT impact properties and need more improvement. Moreover, design parameters such as, thickness, bumper beam curvature, and strengthening ribs could improve the bumper beam to be more productive to comply with the desired product design specification (PDS).

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