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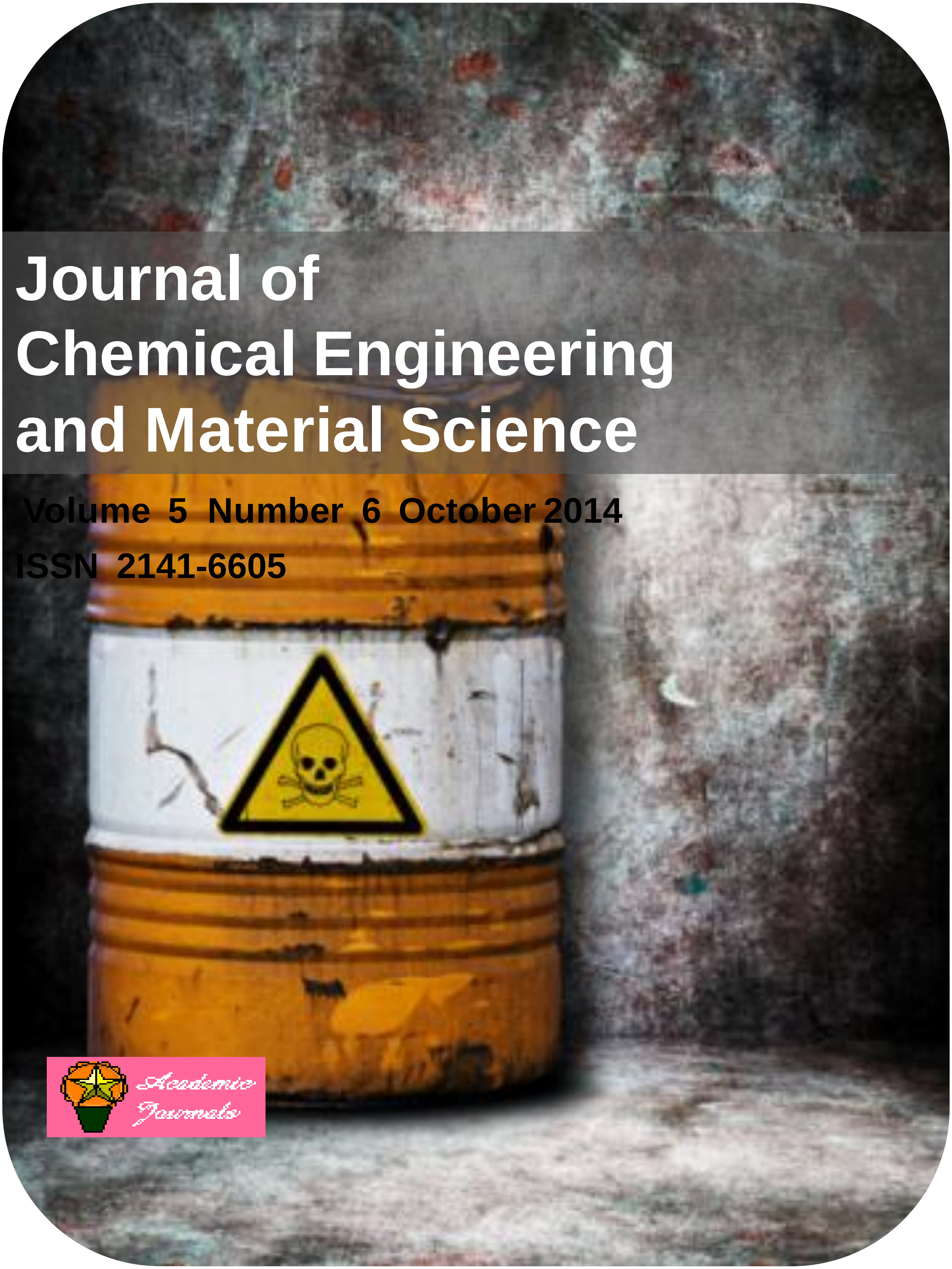

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Journal of Chemical Engineering and Materials Science

Full Length Research Paper

Effect of dioctyl phthalate (DOP) modified matrix on the thermal stability of glass fiber reinforced composite

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Unsaturated polyester was modified with dioctyl phthalate (DOP) and used as matrix in glass fiber reinforced composite. The effect on the thermal stability of the composite was studied in this work. The results of the modification showed that modified matrix had the best thermal stability at 5 wt% DOP with temperature of 373°C at 20% weight loss as compared with unmodified of temperature of 346°C at the same weight loss. The analysis of the resultant composites also indicated that the composite with modified matrix had better thermal stability having 65% of its weight left at 897°C as compared with unmodified matrix with 53% of its weight at the same temperature. The drop weight impact test conducted did not show any significant difference in the properties of the modified composite and unmodified.

Key words: Thermal stability, glass fiber, impact test, unsaturated polyester.

INTRODUCTION

Fiber reinforced polymers have wide range of applications in aerospace, defence, transportation etc because of their high specific strength and modulus (Rout et al., 2001; Thanomsilp and Hogg, 2003; Wan et al., 2005; Huda et al., 2007; Muhi et al., 2009). In recent time, the applications of fiber reinforced polymer matrices have found tremendous growth in primary load bearing structures such as airframe in aircrafts, satellites and space vehicles where service temperature requirement is about 120°C, however, attention is now turning to high temperature application of such composites in such areas as aero-engines and airframes of supersonic or hypersonic aircraft where temperature requirement is about 200 to 400°C (Mangalgiri, 2005). Typical applications such as electrical components and under hood automotive are those areas where high temperature polymer composites are also required (Kalavenness and Reichold, 2009).

Properties of composites have been reported to be affected by nature of fiber and their combinations, type of matrix, construction and configuration of the material. Wong et al. (2001) reported that composite produced from E-glass fiber and Epoxy mix 57 matrix had a better mechanical property than that produced from pure phenolic or epoxy resin as matrix using the same type of fiber. Dutral et al. (2000) showed in the epoxy matrix (EP)

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based composite studied that plain EP/PP (poly propylene) fiber composite had higher impact energy than plain EP/CF where CF is carbon fiber. The modulus of elasticity and tensile strength of Kevlar fiber reinforced polyester composite was reported higher than that of glass fiber reinforced composite by 75 and 25% respectively (Isa et al., 2013). In the same work, the hybrid of the fibers in the same matrix was reported to have better mechanical properties than the monolithic composites. The effect of fiber combination of high impact velocity property was reported, Muhi et al. (2009), showed that hybrid of E-glass fiber/Kevlar 29 fiber composites composite using hand lay-up method performed better than glass fiber reinforced polyester (GFRP) where polyester was used as matrix under high impact velocity. The tensile strength and modulus of aramid fiber in 50:50 matrix of phenol formaldehyde and polyvinyl butyral were also reported to be higher than those of nylon 66 in the same matrix (Morye et al., 2000). Pukansky (2005), indicated that fiber-matrix inter phase also played important role in the general properties of composites. Various researchers have studied and reported ways of improving composites properties (Morye et al., 2000; Wong et al., 2001) because of reported effect of matrix type on composite properties.

Unsaturated polyester resin is widely used as matrix in composites materials because it is versatile, cheap and easily processed (Bryson, 1999; Bakar and Dajaider, 2007; Akter et al., 2013; Saravana and Mohan, 2013). However, it has poor mechanical properties, thermal stability which sometimes limits its applications in structural composite materials (Shimaa and Remm, 2012). Studies on the modification of unsaturated polyester to enhance its mechanical, thermal and impact properties have been reported (Shaker et al., 2002; Cherian and Thachil, 2006; Bakar and Djaider, 2007; Isa et al., 2012). Dioctyl phthalate (DOP) has been identified as one of the plasticizers for the modification of the unsaturated polyester's properties successfully (Bakar and Djaider, 2007; Isa et al., 2012).

The reported works on the use of DOP for unsaturated polyester resin modification were not extended to its combination with fibers. More so, attention is now turning to high temperature application of polymer composites in such areas as aero-engines and airframes of supersonic or hypersonic aircraft where temperature requirement is about 200 to 400°C and unsaturated polyester matrix composite can be candidate for such application. Therefore, the effect of DOP on thermal stability of unsaturated polyester resin was studied and the resultant effect on thermal stability of glass fiber composite and its low velocity impact properties as air craft where it can be applied is usually subjected to low velocity impact.

EXPERIMENTAL

The materials used in this investigation were general purpose polyester resin manufactured by ADD resins and chemicals (pty) LTD, South Africa. DOP was manufactured by Zhenzhou p and b Chemical Co. Ltd, China. The glass fiber was woven roving E-glass fiber of denier 10820, tightness of weave 7.65 cm^2, manufactured by Jiaxing Sunlong Industrial and Trading Co. LTD China.

Modification of polyester

Polyester mix was prepared by measuring 150 ml of general purpose unsaturated polyester resin and weighed into a plastic cup, 2 wt% of initiator (methyl ethyl ketone) was added and stirred for 3 min, then 2 wt% of cobalt accelerator was added and stirred for another 2 min. The mixture was poured into the prepared already prepared mould up to 4 mm mark. The content of the mould was removed 24 h later, after it was allowed to cure in a fume cupboard. It was transferred to an oven to post cure at temperature of 60°C for 3 h. This sample was considered as unmodified. Other sets of samples considered modified were produced by adding DOP (5 wt% - 20 wt% at 5 wt% intervals) to the polyester resin. In this case, the DOP was mixed into the unsaturated polyester resin for 10 min, 2 wt% of initiator was added stirred for 3 min, followed by the addition of 2 wt% of cobalt accelerator and stirred for another 2 min. The same procedure used to cast the unmodified samples was also used to obtain cured modified samples.

Production of composite materials

Based on the results obtained from the matrix modification, composite was prepared with matrix modified with 5 wt% DOP and glass fiber. The composite was characterized for drop weight impact test and thermal gravimetric analysis (TGA). The results were compared with those of sample of unmodified matrix composite. Two sets of samples were produced, one produced with unmodified matrix, GFRP and the other with 5 wt% of DOP modified unsaturated polyester resin, modified glass fiber reinforced polyester (MGFRP). The polyester used in this section was prepared using the same procedure used for the production of polyester mix in polyester modification. After which nine layers of the glass fiber used in each case were weighed and then hand lay up in the mould using 1 inch pure bristles brush to apply the polyester mix one after the other in an already prepared metallic mould. The mould was covered and transferred to a Carver laboratory hydraulic press, (model M, serial number, 23505-208) for compression at a pressure of 1013.40 kN/m^2. The mold was removed from the press after 6 h and was left to cure for another 18 h after which the content was removed and post cured in the oven at 60°C for 3 h. The composites produced correspond to 59.2 wt%.

Thermal analysis

Thermal gravimetric analysis (TGA) was carried out using approximately 25 mg of the sample in a Perker Elmer testing machine for unreinforced unsaturated polyester and reinforced polyester. The test was conducted at heating rate of 10°C/min under nitrogen flow of 20.0 ml/min for a temperature range of 30 to 900°C. The weight loss was obtained with respect to temperature and from the chart; percentage weight loss at various temperatures was recorded.

Drop weight analysis of composite

The samples were cut into approximately size of 80 x 80 mm and one sample at a time was held on a beam with double sided tape, on the sample holder of a drop weight impact tester that was set up

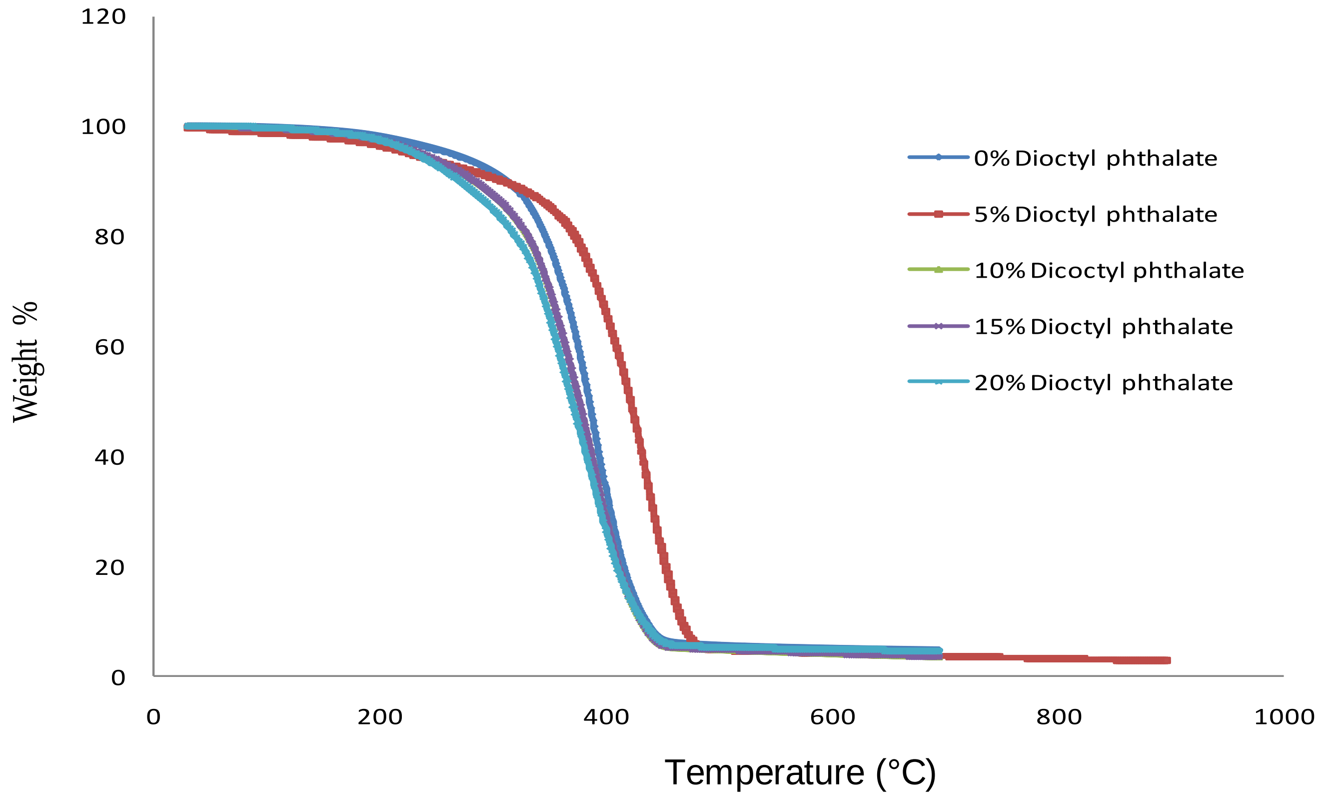

Figure 1. Weight percent as a function of temperature for DOP modified and unmodified unsaturated polyester.

with sensitivity of –4.019, fast on trigger mode, pre-time and post-time of 1000 s respectively. A weight of 2 kg was added to a load cell which already weighed 2.5 kg with hemi-spherical impactor of length 60 mm and diameter of 12.24 mm. The load cell was then released from a distance of 0.1 m which is equivalent to 4.5 J to impact on the sample. The load–time response was captured through Dewsoft, software for capturing load-time response data. The same procedure was followed to test other samples at impact distance of 0.4 and 0.6 m corresponding to impact energy of 18 and 27 J respectively.

RESULTS AND DISCUSSION

Thermal analysis

Figure 1 showed that the resin with 5 wt% was more thermally stable than the neat resin. Meanwhile, the neat resin had higher thermal stability than other plasticized resin beyond 5 wt%. At plasticizer content beyond 5 wt%, matrix weakening obviously resulted to accelerated resin degradation. There were only marginal differences when the thermal stability at higher plasticizers content was compared to one other. Figure 2 also showed that the composite with modified matrix MGFRP had better thermal stability than the composite with unmodified matrix GFRP. The modified had up to about 62% of its weight left at 897°C, the unmodified had only about 53% left. The result therefore indicated that the modification of the matrix had effect on the composite, as the same fiber was used in the composite production yet, displayed different thermal stability. It is reported that matrix type has effect on the properties of resulting polymer.

Effect of DOP on low velocity impact properties of composite

Figure 3 presents the load–time curves obtained from the drop, weight test. From the curves important parameters such as peak load and ductility index were obtained. The shapes of the curves showed that the samples tested at impact energy of 4.5 J exhibited load–time response that is symmetrical with equal loading and unloading for both modified and unmodified glass fiber reinforced composites. This is an indication that samples tested at this impact energy were essentially undamaged (Hosur et al., 2005). Both composites also, exhibited unsymmetrical curve shape at higher impact test energy of 18 and 27 J respectively, indicating unequal loading and unloading at those test impact energies. Table 1 presents the summary of the properties obtained from the curve. The drop weight impact test showed that the unmodified GFRP composite had higher peak load indicating that it absorbed more load and therefore stiffer than modified.

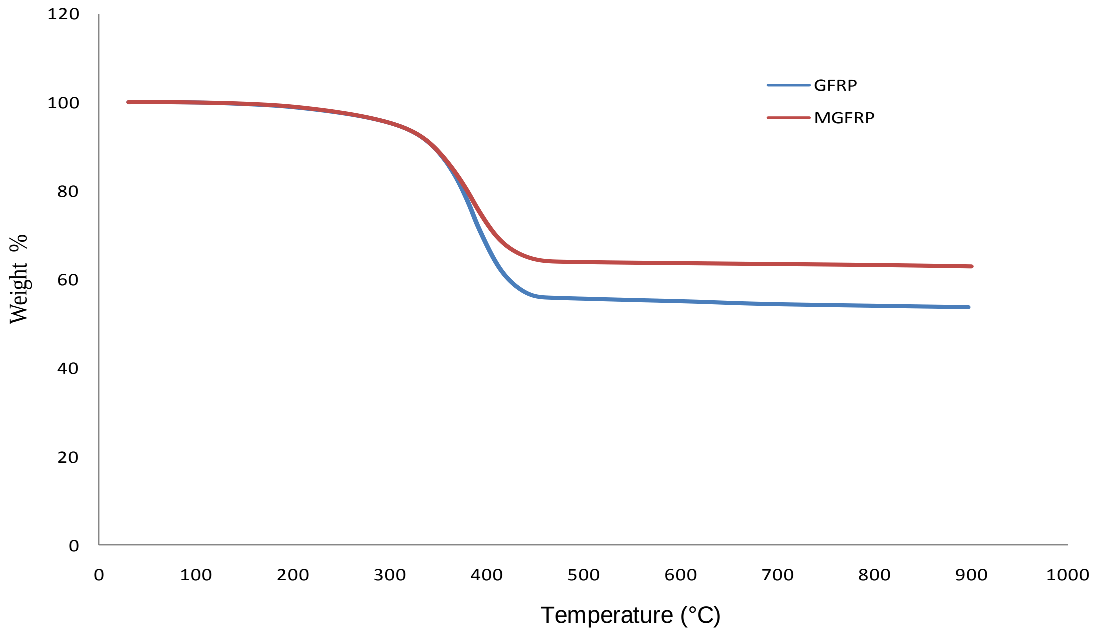

Figure 2. Percent weight as a function of Temperature for unmodified (GFRP) and modified (MGFRP) matrix of glass fiber reinforced polyester.

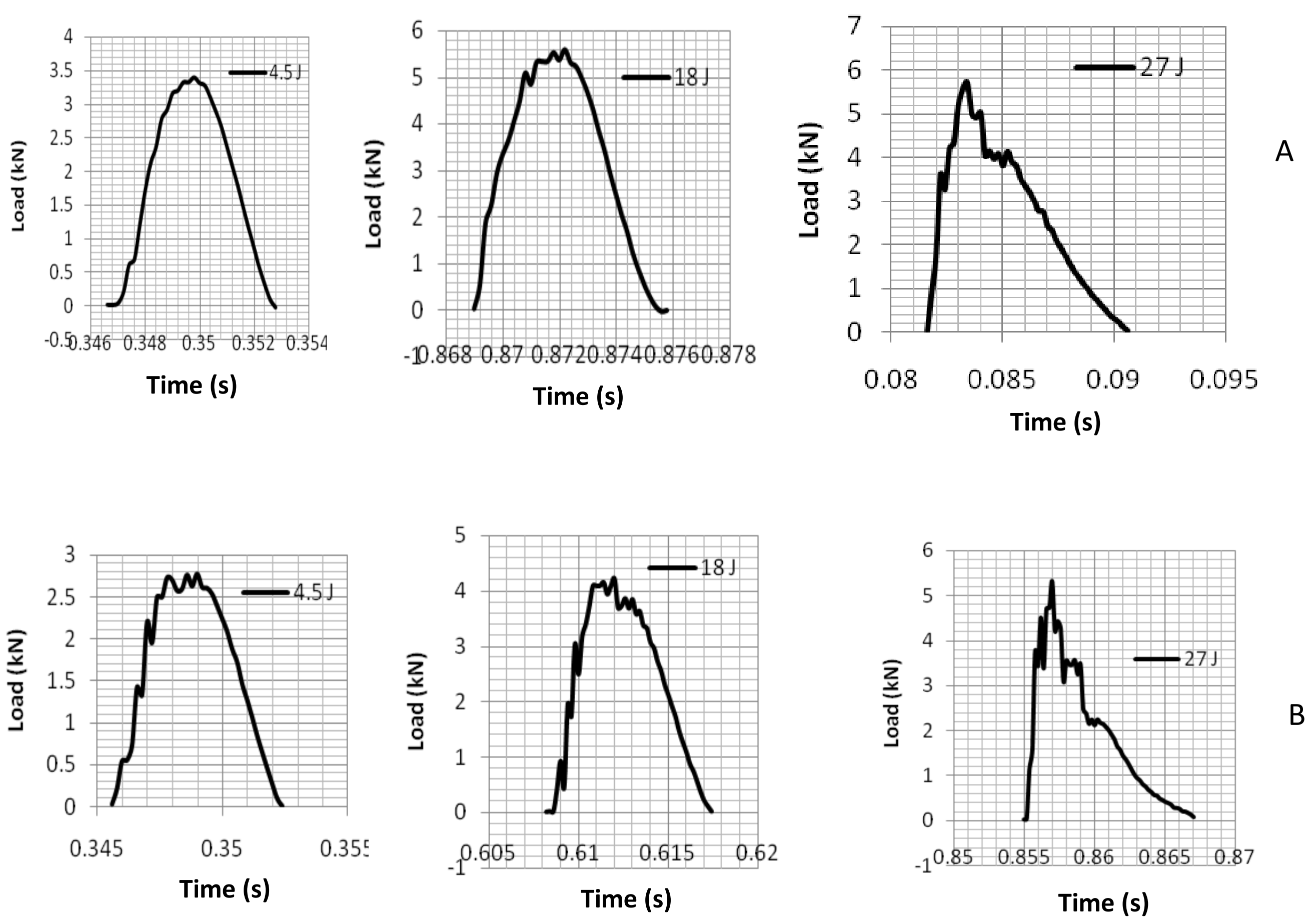

Figure 3. Impact load-time response of composites used in this study: (A) GFRP and (B) MGFRP.

Table 1. Drop weight impact properties of unmodified matrix and DOP modified matrix of glass fiber reinforced composite.

Impact energy	4.5 J	18 J	27 J	Material
Peak Load (kN)	3.399	5.599	5.694	GFRP
	2.770	4.200	5.321	MGFRP
Difference (%)	18.5	25.0	6.6	
Ductility index	0.943	0.744	2.781	GFRP
	0.814	1.2	2.777	MGFRP

However, at high impact energy of 27 J the difference was just 6.55%. The difference in peak load of the unmodified GFRP at impact energy of 18 and 27 J was only 9.5% while that of modified MGFRP was 21.1%. This indicated that the unmodified could reach the threshold impact load before the modified. The ductility index (DI) exhibited by the two composites showed that, the modified MGFRP has DI higher than that of unmodified composite GFRP at impact energy of 18 J, but there was no much difference in DI at impact energy of 4.5 and 27 J. It was expected that the modified composite should have the ability to absorb more load after post peak at higher energy, but that was only observed at impact energy of 18 J while at 27 J no significant difference was recorded between the two.

Conclusions

Modification of the matrix increased the thermal stability of matrix and consequently that of composite over the unmodified and the drop weight impact properties of the composites were not so much compromised by the modification.

Conflict of Interest

The authors have not declared any conflict of interest.

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