Journal of Materials Science Research; Vol. 11, No. 1; 2022
ISSN 1927-0585 E-ISSN 1927-0593
Published by Canadian Center of Science and Education

Dynamic Fracture Toughness Behaviour of CFRP-Foam-CFRP Sandwich Composite and Particles Filled Hybrid Glass Fiber Cloth, Graphene Nanoplates Coated Glass Fiber Strand Composite Materials under Low Impact Velocity

V. K. Srivastava[1]

[1] Department of Mechanical Engineering, Indian Institute of Technology (BHU), Varanasi-221005, India

Correspondence: V. K. Srivastava, Department of Mechanical Engineering, Indian Institute of Technology (BHU), Varanasi-221005, India. Tel: +91-542-236-9029. E-mail: vijayks210@gmail.com

Received: February 23, 2022 Accepted: May 12, 2022 Online Published: May 23, 2022

doi:10.5539/jmsr.v11n1p70 URL: https://doi.org/10.5539/jmsr.v11n1p70

Abstract

The main objective of the present study is to investigate the dynamic fracture toughness behaviors of CFRP-Foam-CFRP sandwich composite of V-notched through -thickness, surface, and un-notched specimens under Izod, and Charpy impact tests. The sandwich composite structures are made of cross-plied carbon fiber reinforced plastic (CFRP) composite faces with polyurethane foam core. CFRP composites are used to combine the upper face and the lower face through the core in stitched sandwich structures. Compressive strength of weight drop impact perforated and un-perforated sandwich composite specimens are measured from a universal testing machine. Also, particles (Al_2O_3, CNTs, and cement) filled glass fiber cloth and graphene nanoplates coated glass fiber strands reinforced polymer hybrid composite are fabricated for V-notched, un-notched Izod impact and Charpy impact tests. The results show that weight drop impact energy is lower than the Izod impact energy but higher than the Charpy impact energy, whereas the dynamic fracture toughness of Izod impact energy is more than the Charpy and weight drop impact energy due to geometry of impactor and sandwich specimen. However energy and dynamic fracture toughness of Al_2O_3, CNTs, and Cement filled un-notched hybrid composites higher than the notched hybrid composites under Izod Impact. The dynamic fracture toughness and energy of CNTs filled hybrid composites is higher than the sandwich composites, Al_2O_3, and Cement filled hybrid composites under Charpy Impact.

Keywords: Carbon Fiber Composites, Dynamic fracture toughness, Polyurethan foam, sandwich composite, Particles filled hybrid composite

1. Introduction

Mostly sandwich structures are made of two stiff and thin faces adhesively bonded to a relatively soft and thick core. The thin faces carry the principal loads while the inner core acts to transmit the shear loads to the faces and absorbs the strain energy. The sandwich structures are widely used in many industrial applications due to their high flexural property to weight ratio, high resistance to corrosion, and good thermal and acoustic insulation. In particular, glass fiber reinforced composites have been employed for the faces and honeycomb structures are preferred as the core in the design and construction of civil and military applications. Recently, polymeric foam was also adopted as the core in certain applications (Srivastava, 2012). The skins are also designed to resist tensile and compressive stresses and are usually made of aluminum or fiber reinforced polymers. Whereas core is resist compression and shear stresses and is usually made of wood, polymer foams, or expanded metal or polymer honeycombs. One of the main drawbacks of these high -performance structures is their relatively poor resistance to impact loading. The impact damage in sandwich structures can be caused by tool drops, runway debris, bird strikes, hailstorms or ballistic loading (Iqbal et al., 2005). It is well known that composite structures in the form of laminates are extremely susceptible to crack initiation and propagation along with laminate interfaces in various failure modes. In fact, delamination is one of the most prevalent life-limiting crack growth modes in laminate composites as delamination may cause severe reductions in in-plane strength and stiffness, leading to catastrophic failure of the whole structure. Delamination may be introduced by external loading as in static bending, compression or tension, in cyclic fatigue or by impacts of low-to-high energies, during manufacturing or in service

(Dogan et al., 2017). Ballistic impacts cause localized damage which is clearly visible on the inspection while low-velocity impacts involve long contact time between impactor and target which results in global structural deformation with internal damage at points far from the contact region. This is also indicates that the performance of marine sandwich composite panels with particularly selected mechanical properties can be enhanced by using glass micro balloon syntactic foams as core materials (Caprino et al., 192). Core materials with a higher volume fraction of glass micro balloon in matrix resin contribute to weight-saving properties. However, it may lead to lower strength properties unless careful consideration is imposed when designing with GFRP skins. The design concept behind composite sandwich panel construction is that the skin carries the in-plane compressive load while the primary function of the lightweight syntactic foam core is to maintain the GFRP skins at the desired distance. In this study, the skin of the sandwich panel consists of a mixture of GFRP with a vinyl ester resin acting as a binder. Furthermore, sandwich panels can be developed using GFRP as the skin and polyol-isocyanate foam as the core, which has been previously used as entry doors and partitions (Nemes et al., 1992; Dogan et al., 2017). Impact absorption and interfacial stability between skin layer and the core layer are critical issues in the manufacture of sandwich composites (Go et al., 2020). A simple fabric surface brushing and abrading method to improve interfacial adhesion between CFRP and core materials has been developed and demonstrated to significantly enhance the delamination resistance of sandwich composites with only moderate in-plane tensile strength loss (Krzy ̇zak et al., 2016; Petroni et al., 2013). The sandwich structure has not been yet realized within primary aerospace and automobile industries mainly due to the complex structural behavior in aerospace industries. Extensive research has been conducted on CFRP-foam- CFRP sandwich structures with mostly PVC foam for application in marine vessels, which provides a large benefit for understanding damage growth under cyclic loading and consequently maximum damage sizes (Mitrevski et al., 2006).The tapered composite sandwich plate configuration is also used to secure the interfacial structure of a sandwich composite (Abrate et al., 1997). Attempts had been made to enhance the properties of sandwich composites using nanoparticles to improve foam mechanical properties and to enhance impact absorption by varying specimen thickness (Evci et al., 2012; Papanicolaou et al., 1996).The present investigation is carried out on the Izod Impact and Charpy impact tests of V-notch and un-notch sandwich composites and particles filled hybrid composites specimen to understand the toughness behavior at low-velocity impact damage. Since, Izod impact and Charpy Impact test are defined as the absorbed energy needed to initiate fracture and continue the fracture until the specimen is broken, whereas notch specimens are used to prevent deformation of the specimen upon impact. These two tests are well-known methods for the measurement of fracture toughness of materials (Kirugulige et al., 2005).

2. Materials and Specimens

2.1 Preparation of CFRP-Polyurethane Foam -CFRP Sandwich Structure

Cross-plied carbon fiber-reinforced epoxy resin composites were moulded by the hand lay-up technique using commercially available carbon fibre woven mats and a matrix comprising Araldite CY-205 epoxy resin and HY951 hardener. Fiber volume fraction of laminates was about 46% with an average thickness of 0.7 mm. These composite sheets were used to prepare sandwich structures. Composite sheets were bonded onto the top and bottom faces of polyurethane foam (thickness 10.5 mm) with the help of epoxy resin adhesive. Figure 1 shows the configuration of stitched sandwich composite specimens used for this study. The fabricated sandwich composite specimen was 250 mm in length, 200 mm in width, and 11.6 mm in thickness. V-notched and un-notched Izod and Charpy impact test specimens were cut from the fabricated sandwich composite.

Figure 1. CFRP-Foam-CFRP Sandwich (250x200 mm) Composite

2.1.1 Fabrication of Particles Filled Hybrid Glass Fiber Strand Coated with the Mixture of 1% Graphene Nanoplates (GnPs) / Epoxy Resin and 0/90^O Glass Fiber Cloth Reinforced Epoxy Resin Polymer Composites

Glass fiber strand containing 40 glass fibers (diameter of single glass fiber was 10 µm) was coated with the mixture of 1% graphene nanoplates (GnPs) /epoxy resin. Particles (Al_2O_3, CNTs. and Cement) filled hybrid 0/90^O glass fibre cloth reinforced epoxy resin and 1% graphene nanoplates/epoxy resin coated glass fibre strand composites (diameter 2mm) were fabricated with hand lay-up technique. First of all, thin layer of 1% particle of Al_2O_3 and epoxy resin mixture was spread on the top surface of transparent sheet. Then a single layer of glass fibre cloth with the size of (180x180 mm) was laid down on the plastic sheet surface containing mixture (1% particle of Al_2O_3, and epoxy resin). The 1% graphene nanoplates (GnPs) and epoxy resin coated glass fiber strands were arranged along axial and vertical directions on the top surface of the glass fiber cloth. Again, a second layer of glass fiber cloth was put to cover the area of GnPs-epoxy resin coated strand reinforced in the mixture of 1% Al_2O_3, and epoxy resin. Similarly, second and third layers of glass fiber cloths and GnPs-epoxy resin coated glass fiber stands were arranged as shown in Figure 2.

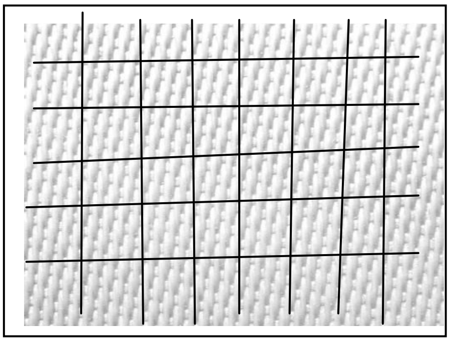

Figure 2. Particles filled hybrid cross-plied glass fibre cloth and graphene nanoplates coated glass fibre strands (Dark black thick line) reinforced epoxy resin composites

Finally, hybrid 0/90^O graphene nanoplate coated glass fiber strand and 0/90^O glass fiber cloth reinforced epoxy resin polymer composites were fabricated with the combination of 4 layers of glass fiber cloths and 3 layer of GnPs-epoxy resin coated glass fiber strand composite specimen as per required thickness of hybrid composites (length=150. Width=140 mm and thickness = 4 mm.) Similarly, 1% CNTs filled hybrid composite and 1% Cement particles filled hybrid composite specimens were fabricated for the V-notched and Un-notched Izod and Charpy Impact tests. The V-notched and Un-notoched specimens dimension of Izod impact and Charpy Impact tests were prepared as per ASTM standard, (Izod Impact specimen dimension: length = 64 mm, width = 15 mm, depth of V-notch- 4 mm, and Charpy impact specimen dimension; length 144 mm, width 15 mm and depth of V-notch 4 mm).

2.2 Izod impact, Charpy Impact and Weight Drop Tests

2.2.1 Impact Test of Sandwich Composites

The dimensions of the Izod impact tests is length 64 mm, width 12.7 mm, thickness 11.6 mm. The Izod impact test was performed on un-notch and V-notch introduces through-thickness and width of sandwich specimen. Charpy impact test dimensions are length 127 mm, width 12.7 mm and thickness 11.6 mm respectively. The difference between Izod impact and Charpy impact tests is shown in Figure 3. Charpy impact test was also carried out on un-notch and V-notch introduce through-thickness and width of sandwich specimen. The un-notch and depth of V-notch introduced 4 mm through-thichness and width in the sandwich composite specimens for the Izod and Charpy impact tests. The Izod and Charpy impact tests were performed with the equipment (Model; Resil Impactor-50, CEAST, S. p. A., Italy) as shown in Figure 4. The impact hammer and vice lever with specimen adapter were used different in Izod and Charpy impact tests. The impact length and impact velocity were 0.327 m and 3.46 m/s. Izod and Charpy impact tests were performed on V-notched and un-notched sandwich specimens.

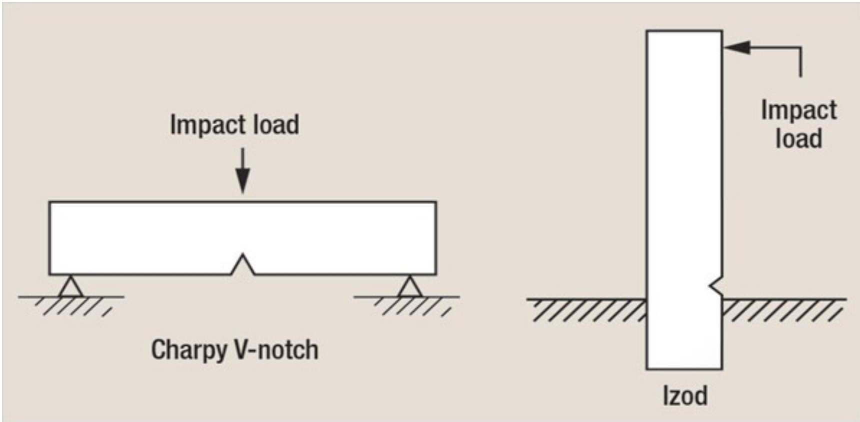

Figure 3. Difference Between Izod and Charpy Impact Test

Figure 4. Photograph of Izod and Charpy Impact Tests on Resil Impactor Instrument

2.2.2 Izod and Charpy Impact tests of Hybrid Composites

The Izod and Charpy impact tests of hybrid composites were performed with the same equipment (Model; Resil Impactor-50, CEAST, S. p. A., Italy) as shown in Figure 4. The impact hammer and vice lever with specimen adapter were used differently in Izod and Charpy impact tests. The impact length and impact velocity were 0.327 m and 3.46 m/s. Izod and Charpy impact tests were performed on notched and un-notched sandwich specimens. Finally, Dynamic fracture toughness (Kdt) was calculated based on the experimentally obtained impact and Charpy impact energy using the following equation (Kirugulige et al. 2005),

$$Kdt = \Delta E /(w-a) h \tag{1}$$

where ΔE is the absorbing energy of material during impact processing, a, w and h are the initial crack length, width, and thickness of specimen, respectively.

2.2.3 Weight Drop Test of Sandwich Composites

The weight drop test was performed on a sandwich composite square specimen (length 30 mm, width 30 mm, and thickness 11.6 mm) as shown in Figure 5. The spherical (diameter = 31.5 mm, mass = 0.932 kg) impactor weight drop was used on the sandwich composite specimen through a specified heights (H). The mild steel impactor (striker) was designed with a spherically shaped end of 31 mm diameter to simulate nondeforming projectiles. The sandwich specimen was placed on the flat surface of a thick plate to avoid bending, and the striker was dropped at height of 176 cm. The surface of the specimen developed scattered cracked due to the impact from the striker, as shown in Figure 5. The impact energy was obtained from the height dropped. The results of each type of test were measured with the average values of five specimens. The following governing equation is as follows (Abrate 1997):

$$Et = mgh = Eb + Es + Ec \quad (2)$$

where Et is total energy, m is the mass of the drop weight in kg, h is the drop height in m and Eb, Es and Ec are the energies absorbed through bending, shear, and contact, respectively. Equation 2 assumes no loss of energy during the drop.

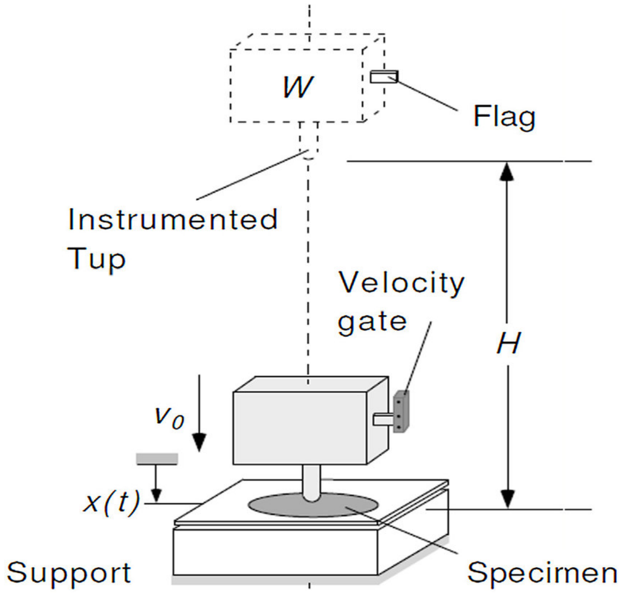

Figure 5. Weight drop Impact test of Sandwich Composite Specimen

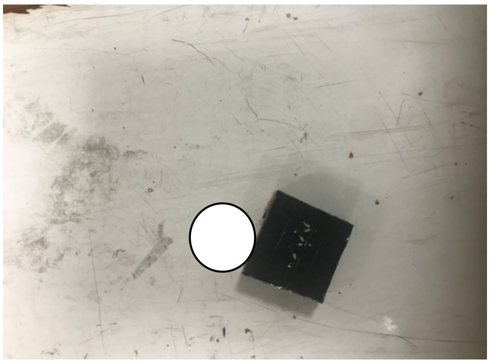

Figure 6. Perforated Sandwich composite sample with weight drop impact test

2.2.3 Compressive Test

Finally, the compressive strength of weight drop impacts perforated (Figure 6) and un-perforated weight drop impact sandwich composite specimens were measured on the basis of fracture load (Ft) from the universal testing machine to the given equation.

$$\text{Compressive strength} = Ft / W \times L \quad (3)$$

where Ft is the fracture load. W and L are the width and length of the specimen.

3. Results and Discussion

3.1 Impact Behavior of CFRP-Polyurethane Foam-CFRP Sandwich Composites

The low-velocity Izod, Charpy impact, and weight drop impact tests were conducted on the fabricated sandwich structure to investigate the impact behaviours of sandwich composites. Five specimens were tested in each category for the Izod, Charpy, and weight drop test to investigate the impact behavior of sandwich composites. The average values of impact test values of the impact test results are presented in Figure 7. It has been demonstrated that the impact energy generated by the unnotched specimens increases under Izod and Charpy impact tests. When sandwich structures are struck with an Izod impactor, the impact energy is localized through the thickness of the specimen, and the sandwich structures fracture.

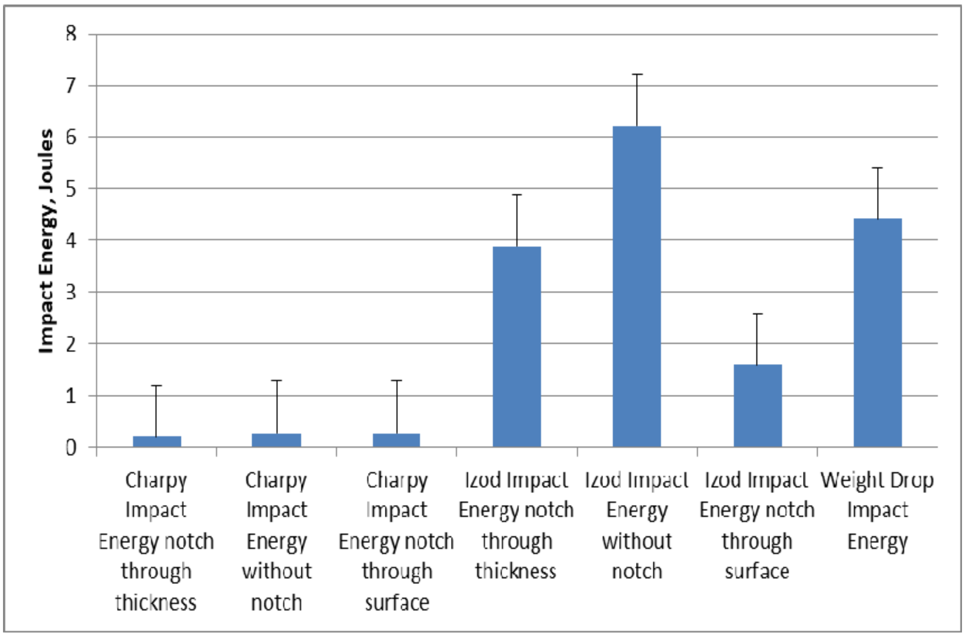

Figure 7. Variation of Impact Energy of V-notch and Un-notch sandwich composites under low velocity Izod Impact, Charpy Impact and Weight Drop Impact tests

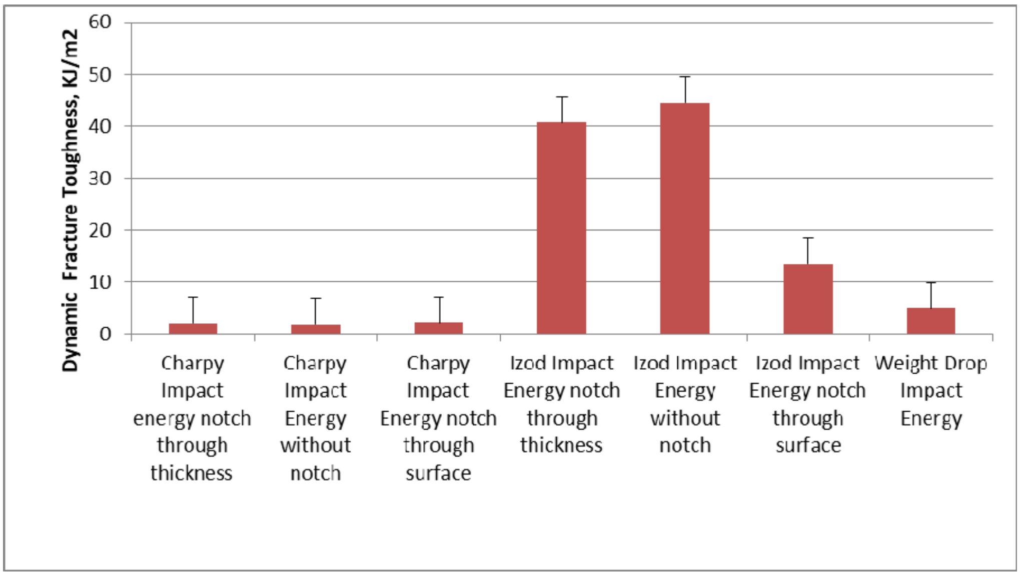

Figure 8. Variation of Dynamic Fracture toughness of V-notch and un-notch sandwich composites under Izod, Charpy and Weight drop Impact energy

Figure 8 shows the dynamic fracture toughness of sandwich composite under Izod, Charpy, and weight drop impact tests. The results show that dynamic fracture toughness under Izod Impact energy is greater than under Charpy and weight drop impact tests.This may due to vibrations of the supports and initiation of damage in the materials (Mitravski et al., 2006). The differences observed in the interfacial region of the specimens affect impact damage size. Both faces of sandwich specimens fractured under Izod and Charpy impact energy, while weight drop impact energy fractured only top face of sandwich structure, as can be identified by Figure 6. This shows the good mechanical resistance which prevent formation and transformation of cracks from top face to back face, because, foam core absorbed the maximum energy. The change of the impactor's momentum as it passes through the specimen relates to the energy consumed by the fracture process. The velocity of the impactor becomes zero when the sandwich structure reaches its maximum deflection (Abrate, 1997). During the Izod and charpy impact tests, top and bottom faces of CFRP composite became fully penetrated. As a result, the foam core was also fractured in a different plane as shown in Figure 9.

(a) **(b)** **(c)**

Figure 9. Sandwich composite specimens fractured under Izod Impact Test

(a) **(b)**

Figure 10. Sandwich composite specimens fractured under Charpy Impact Test

The V-notched through-thickness and surface of sandwich composite specimens under the Izod Impact test produced higher impact energy and dynamic fracture toughness than the Charpy Impact and weight drop tests due to localized effect of kinetic energy at the tip of notched under Izod impact. The local deformation with the Izod /Charpy impactor's damaged only the front face of sandwich composite (Figure 9a) and energy not transferred on the back side of the composite face (Figure 9 b-c) because foam absorbed the impact energy (Caprino et al., 1992; Dogan et al., 2017). When low-energy impacts occur, their damage is difficult to detect visually. At certain energy levels, however, when delaminations form in the composite face, the impact damage area can be observed and estimated quantitatively. As shown in Figure 10a and 10b, the top face of the sandwich composites specimen was damaged after impact. Core cracking followed by debonding of the face sheet and the fiber being broken accordingly. Damage includes delamination of the face sheet as well as additional debonding at the upper face and foam inserter face as shown in Figure 11.

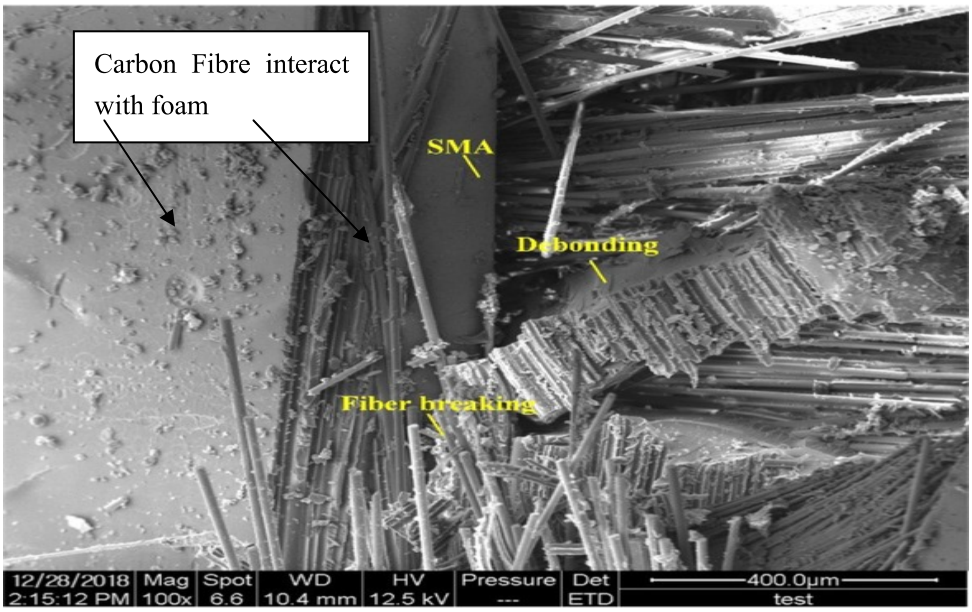

Figure 11. Low impact fracture morphology of CFRP-Plyeurethan foam sandwich composites

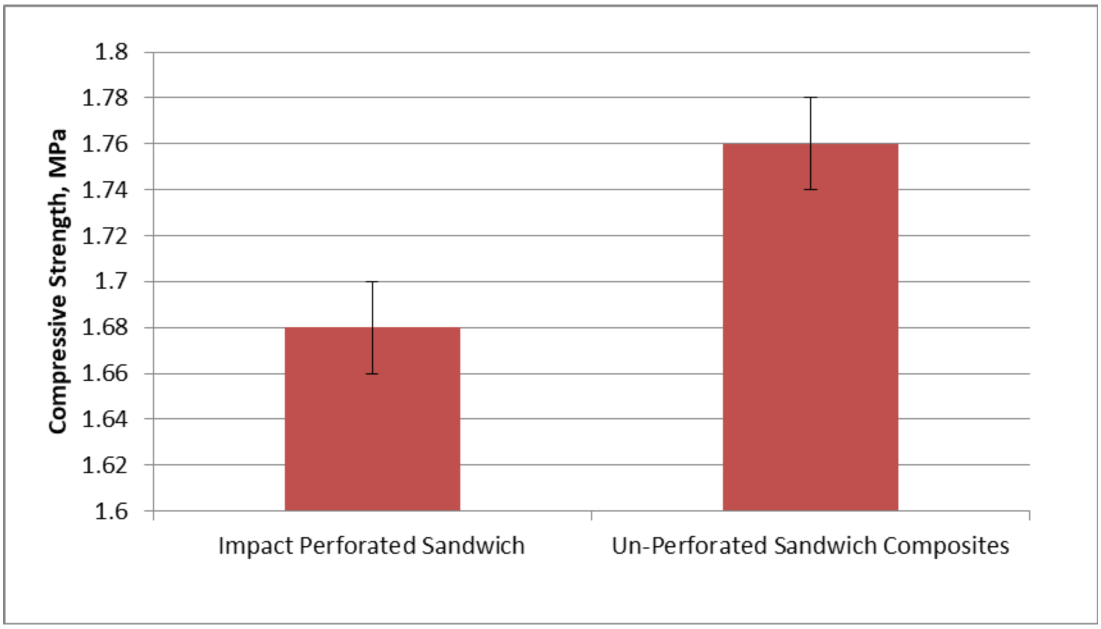

Figure 12. Difference Between Compressive Strength in Perforated Weight Drop Impact Energy of 1.42 Joules and Un-Perforated Sandwich Composites

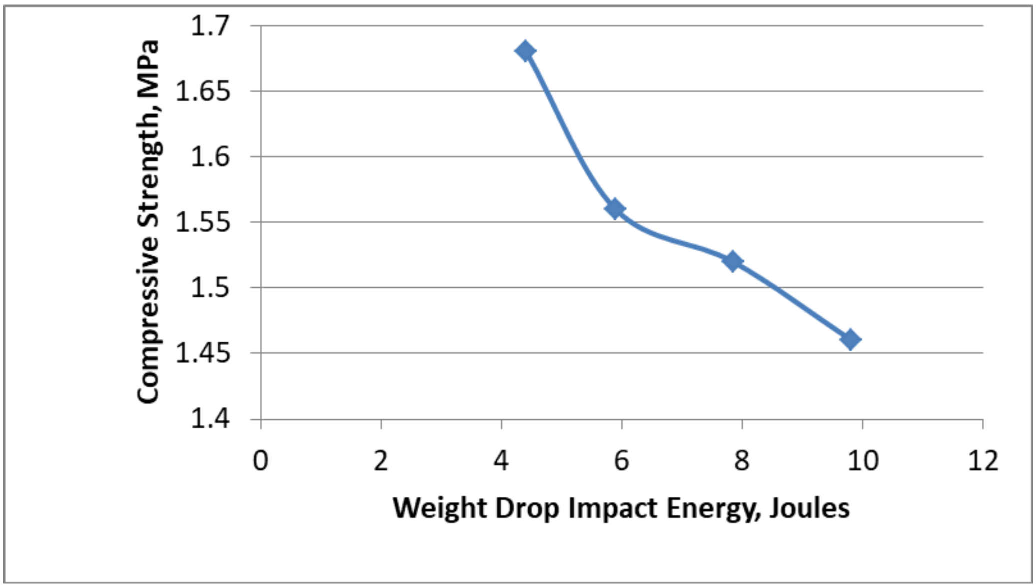

Figure 13. Variation of Compressive Strength with Weight Drop Impact Energy of Sandwich Composites

The weight drop impact test comprised dropping a mass of 0.932 Kg on the specimen through specified heights by a design and develop weight drop test rig. The mild steel impactor (striker) was designed with spherically shaped end of 31 mm diameter to simulate non-deforming projectiles. The square sandwich specimen was placed on the flat surface of a thick plate to avoid bending, and the striker was dropped at different height 45, 60, 80, and 100 cm respectively, to measure the impact energy from Equation-2. The surface of the specimen developed impression of striker and internal mirco cracks appeared due to the impactor from the specified height of mild steel striker, as shown in Figure 6. The results of each type of test were measured with the average values of five specimens. The compressive strength of perforated sandwich composite with weight drop impactor have lower value than the un-perforated sandwich composite as shown in. Figure 12, because perforated sandwich composite introduced with residual stress and microcracks within the perforated area due to sudden drop of compressive force. Figure 13 show the variation of compressive strength decreases with increase of impact energy due to increase of impact height.

3.2 Impact Behavior of Particles Filled Hbrid Composites

Figures 14 and 15 clearly indicate that the Izod and Charpy Impact energy affected with variation of type of fillers such as Al_2O_3, CNTs, and Cement particles and shape of composite specimens. Izod impact energy of un-notched hybrid composite specimen gave higher value than the notched specimen due to dominant of bending stress. From Figure 16 show that dynamic fracture toughness of Al_2O_3, CNTs, and Cement filled hybrid composites of un-notch specimen gave higher value than the notch specimens. Whereas, Figure 17, indicate the dynamic fracture toughness of CNTs filled hybrid notched composites have higher than the Al_2O_3, and Cement filled un-notched and notched hybrid composites, due to more dominents of graphene nanoplates compare to micro particles of Al_2O_3 and cement (Srivastava et al., 2017).

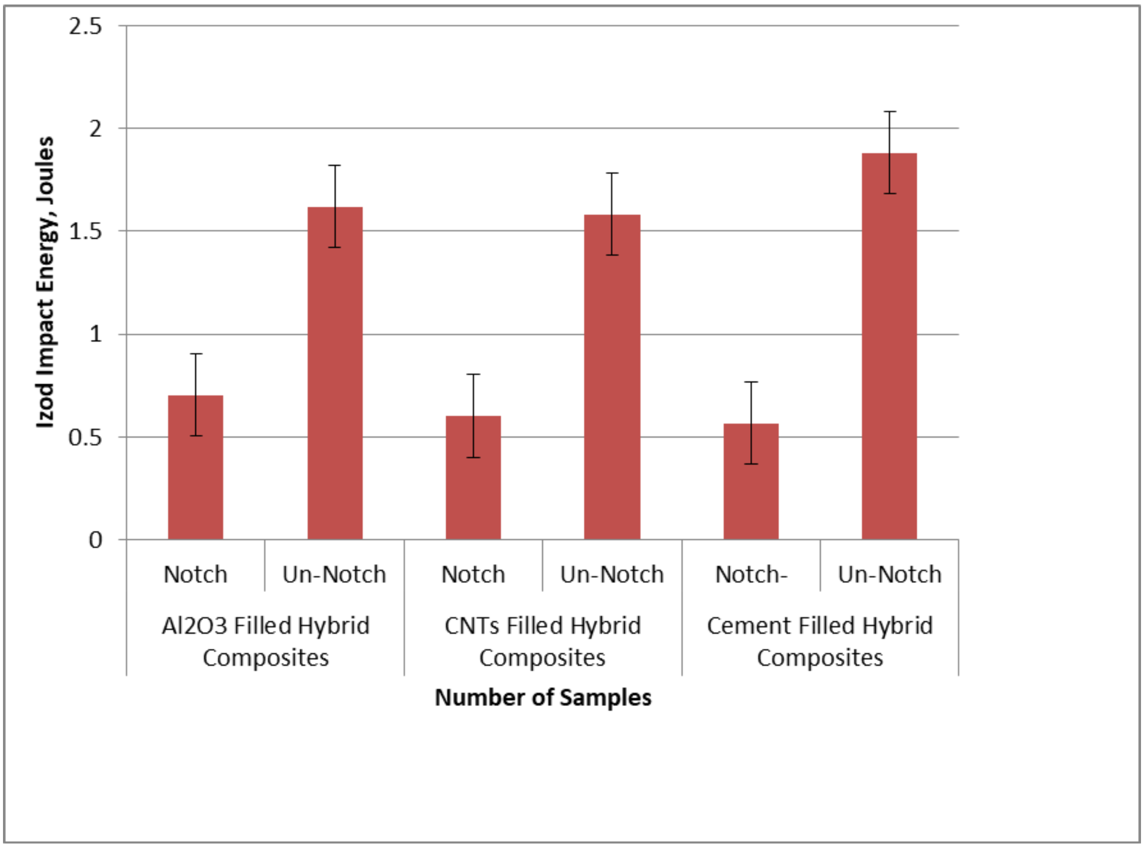

Figure 14. Variation of Impact Energy with type of fillers and V-notch/Un-notch hybrid composites under Izod Impact Test

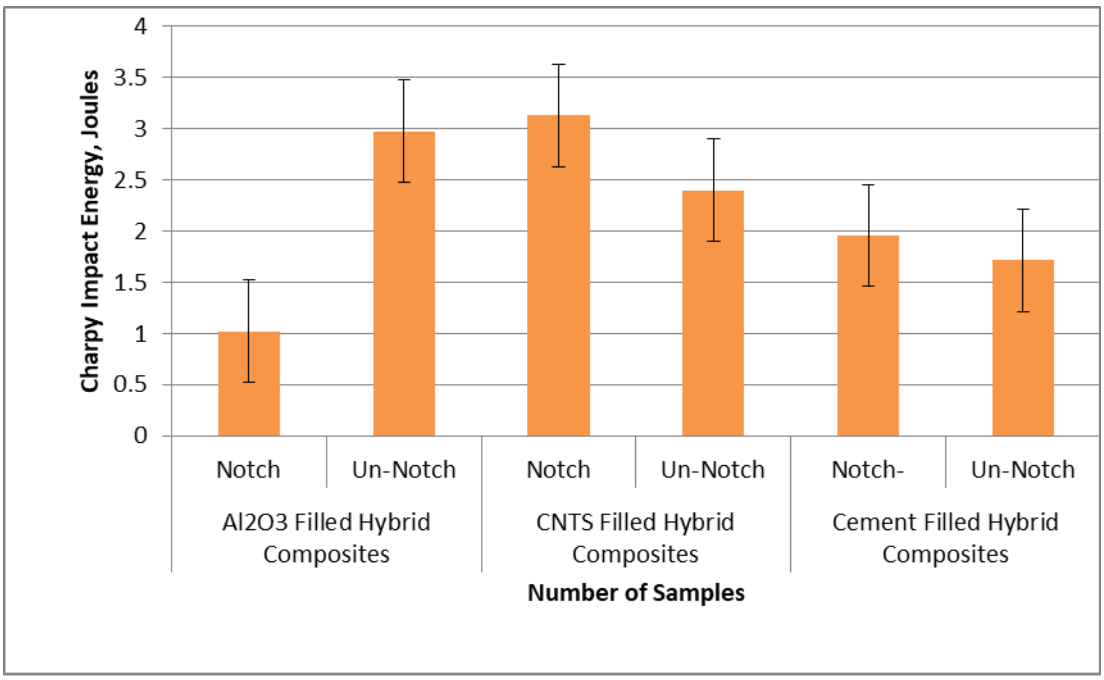

Figure 15. Variation of Impact Energy with type of fillers and V-notch/Un-notch hybrid composites under Charpy Impact Test

Under Charpy impact load, debonding and delamination growth appeared followed by fiber broken due to the strain rate at the crack tip will be very high and the material toughness significantly reduced rather than the un-notched composites. The brittle fracture surface exhibited that large deformation of the matrix. The dynamic fracture surface due to the initiation of less plastic deformation during crack propagation. It was also observed from Figure 18 that the less plastic zone size at the crack tip dominated with increase of strain rate in particles filled hybrid composite materials. Consequently, the decrease in the fracture toughness is attributed to the transition from debonding of fiber to brittle fracture in the resin rich area dominated by large amount of strain rate at crack tip during impact load as shown in Figures 16 and 17.

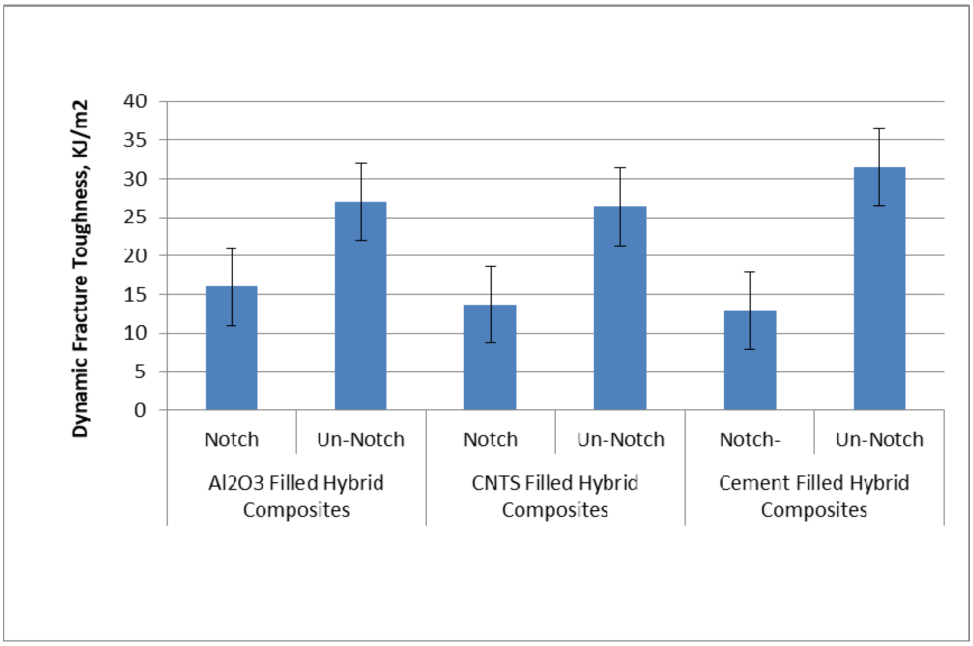

Figure 16. Variation of Dynamic Fracture Toughness with type of fillers and V-notch/Un-notch hybrid composites under Izod Impact Test

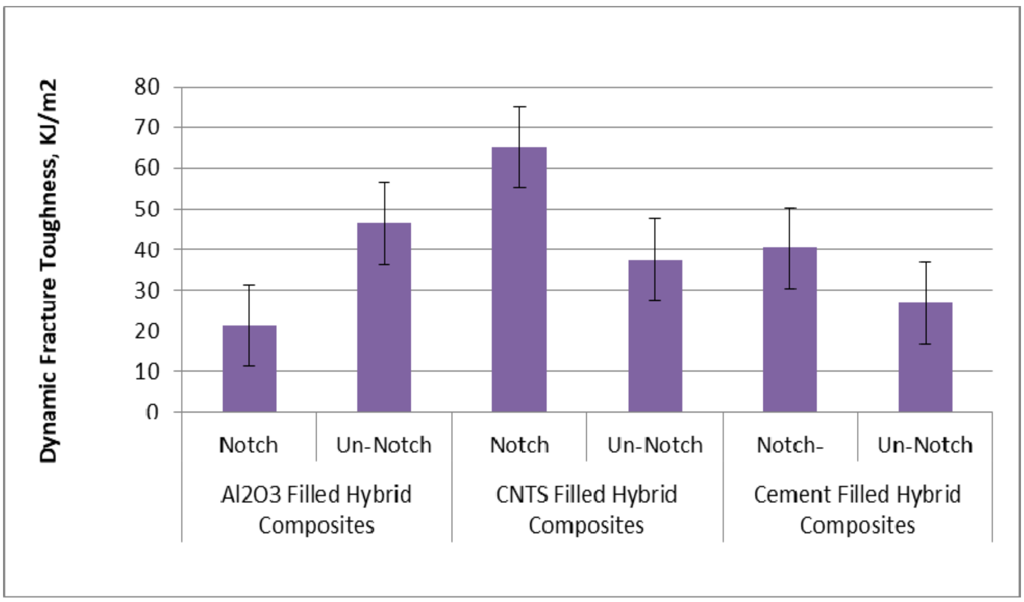

Figure 17. Variation of Dynamic Fracture Toughness with type of fillers and V-notch/Un-notch hybrid composites under Charpy Impact Test

Figure 18 shows how a filler particle acted as an obstacle to crack propagation and deflected it from the interfacial region into the fiber area. The propagation of crack along the fiber direction arrested with the particles size to affect the fracture toughness of hybrid composites. Also, the crack deflected by the filler particle to indicates that the epoxy resin is weaker and the crack did not penetrate from matrix into the filler particle. Epoxy resin reinforced with CNTs, and Al_2O_3, and Cement micro particles are offered high surface energies due to a high surface area to volume ratio, which greatly improves mechanical properties when compared to bulk material. This high surface energy leads to high particle attractive forces resulting in agglomerations and decrease composite strength.

3.3 Comparision of Dynamic Fracture Toughness of Sandwich Composite over Particles Filled Hybrid Composite

Both Izod impact and Charpy Impact tests were performed utilizing 3.46 m/s impactor velocity. In the Izod impact test, the test piece is clamped at one end and struck towards the top with an impactor. The Charpy test involves resting a beam on two anvils and hitting it in the center with an impactor. If the beam is notched, the notch is at the top of the clamped section and usually faces a direct impact. The impactor velocity is 3.46 m/s in both tests. Results from the Izod and Charpy impact tests of sandwich and particle-filled hybrid composites indicate that the impact energy and dynamic fracture toughness of CNTs filled hybrid 1.3 Joules and 64 KJ/m2 under Charpy impact and 0.629 Joules under Izod impact test.

The dynamic fracture toughness of Al_2O_3 filled hybrid notched composite is 20 KJ/m^2 and Cement filled hybrid notched composite is 40 KJ/m^2 under harpy impact, which is lower than the CNTs filled hybrid notched composite due to micro size Al_2O_3 (60 μm) and cement (40μm) particles as shown in Figure 16). This clearly indicates that the CNTs, particles resist the propagation of cracks and increase the toughness of composites (Srivastava et al., 2017). This can be explained by considering the fact that particles filled hybrid composite induce changes in the interface region. The dynamic fracture toughness increased with particles filled hybrid fiber composites are more pronounced when the glass fiber strands are coated in graphene nanoplates.

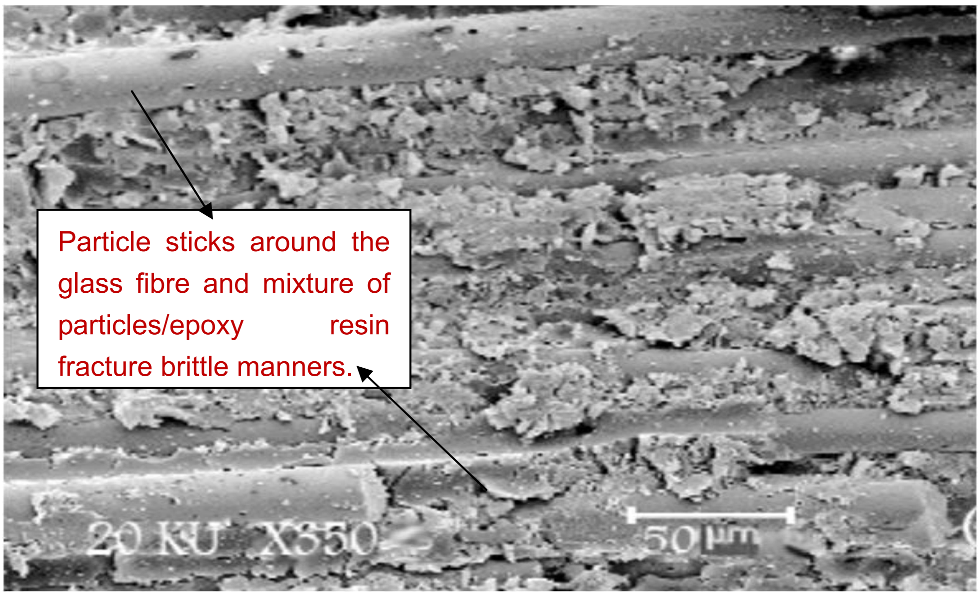

Figure 18. SEM Micrograph showing the brittle fracture pattern of particles filled hybrid CNTs coated glass fibre Strand and Glass fibre cloths reiornfced epoxy resin composites

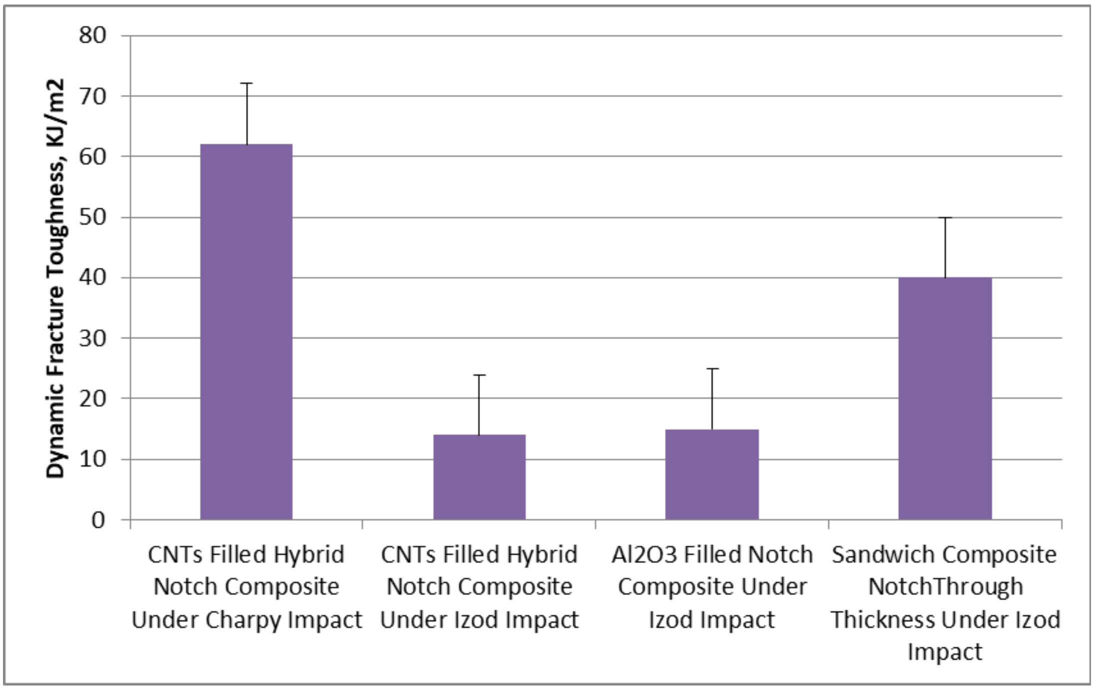

Figure 19. Comparision of Dynamic Fracture Toughness of sandwich composite and particles filled hybrid composite under Izod/ Charpy Impact Tests

Whereas impact energy and dynamic fracture toughness of sandwich notched (through -thickness) composite measured are 4 Joules and 40 KJ/m^2 under Izod impact test. However, sandwich composites have lower value (less than 0.58) of impact energy and However, sandwich composites have lower value (less than 0.58) of impact energy and dynamic fracture toughness under Charpy impact test (Kirgulige et al., 2005).

The experimental comparative results show that (Figure 19) the Izod impact test of Al_2O_3, CNTs, and Cement filled hybrid glass fiber strand graphene nanoplates coated and glass fiber cloth reinforced epoxy resin un-notched composite is more than 25 KJ/m^2 dynamic fracture toughness. Whereas, CNTs filled hybrid notched composite have 60 KJ/m^2 under Charpy impact test. This is clearly indicates that the hybrid composites have higher absorbing resistance than the sandwich composites under three-point flexural (Charpy) impact load. But, sandwich un-notched and notched composite have high impact resistance, dynamic fracture toughness values more than 40 KJ/m^2 compare to Al_2O_3 filled hybrid composites (16 KJ/m^2, notched un-notched, 26 KJ/m^2, CNTs filled hybrid composite (13 KJ/m^2 notched, 15.5 KJ/m^2, un-notched) and cement filled hybrid composite (13 KJ/m^2 notched, 32 KJ/m^2 un-notched) under Izod impact load as shown in Figures 16 and 17. The main difference in dynamic fracture toughness of sandwich composite notched through-thickness is higher than the Al2O3 filled hybrid notched composite and CNTs filled hybrid notched composite under Izod Impact test because foam absorbed more impact resistance than hybrid composite and crack propagate to fracture sandwich composite (11.6 mm) takes longer time the hybrid composite (4 mm).

However, dynamic fracture toughness of CNTs filled hybrid composite have very high value (62 KJ/m^2) than the Cement filled hybrid composite and sandwich composite under Charpy impact testas shown in Figure 19. In this way, CNTs are most useful for improving the fracture toughness and strength of structural materials (Srivastava et al., 2017).

5. Conclusions

An experimental investigation has been conducted to study the dynamic fracture toughness behaviour of CFRP-polyurethane foam-CFRP sandwich composite and Al_2O_3, CNTs, cement particles filled hybrid composites V-notched and un-notched specimens under low impact velocity. The specimens of V-notched through-thickness, through-surface and un-notched sandwich composites show high dynamic fracture toughness and impact energy under Izod impact than the Charpy impact. Whereas impact energy and dynamic fracture toughness of Al_2O_3, CNTs, cement filled hybrid 1% graphene nanoplate coated glass fiber strand and glass fiber cloth reinforced epoxy resin composite of un-notched specimens have higher values than the notched composite specimen under Izod and Charpy impacts. CNTs filled hybrid glass fiber cloth and a mixture of epoxy resin, 1% graphene nanoplate coated glass fiber strand reinforced epoxy resin composite notched specimens have higher values of dynamic fracture toughness (62 KJ/m^2) and impact energy (3.1 Joules) than the Al2O3, filled hybrid composite (42 KJ/m^2), cement filled hybrid composite (40 KJ/m^2) and sandwich composite (0.2 KJ/m^2) under Charpy impact. Whereas; dynamic fracture toughness of sandwich notched through-thickness composite (40 KJ/m^2), un-notched composite (43 KJ/m^2) are more than the particles filled hybrid un-notched composites (26–31 KJ/m^2) under Izod impact. However, particles filled hybrid composite is more pronounced to resist the propagation of cracks at low-velocity impact damage, and sandwich composite absorbed impact energy to resist the sudden fracture of composite.

Acknowledgements

The author is grateful to Professor-Inchage, Experimental Mechanics and NDT Laboratory, Department of Mechanical Engineering, Indian Institute of Technology, BHU, Varanasi, India for the supports.

References

Abrate, S. (1997). Localized impact on sandwich structures with laminated facing. *ASME Appl Mech Rev, 50*, 69-82. https://doi.org/10.1115/1.3101689

Atas, C., & Sevim, C. (2010). On the impact response of sandwich composites with cores of balsa wood and PVC foam. *Compos Struct, 93*(1), 40-48. https://doi.org/ 10.1016/j.compstruct.2010.06.018

Caprino, G., & Teti, R. (1994). Impact and post impact behavior of foam core sandwich structures. *Compos Struct, 29*, 47-55. https://doi.org/10.1016/0263-8223(94)90035-3

Dogan, A., & Arikan, V. (2017). Low-velocity impact response of E-glass reinforced thermoset and thermoplastic based sandwich composites. *Compos B Eng, 127*, 63-9. https://doi.org/10.1016/j.compositesb.2017.06.027

Evci, C., & Gougec, M. (2012). An experimental investigation on the impact response of composite materials. *Int J Impact Engine, 43*(40), 51. https://doi.org/10.1016/j.ijimpeng.2011.11.009

Go, S. H., Lee, M. S., Hong, C. G., Kwac, L. K., & Kim, H. G. (2020). Correlation between drop impact energy and residual compressive strength according to the lamination of CFRP with EVA sheets. *Polymers, 12*(1), 224. https://doi.org/10.3390/polym12010224

Iqbal, P. K., Khan, S. U., Munir, A., & Kim, J. K. (2009), Impact damage resistance of CFRP and nanoclay-filled epoxy matrix, *Composites Science and Technology, 69*, 1949-1957. https://doi.org/10.1016/j.compscitech.2009.04.016

Kirgulige, M. S., Kitey, R., & Tippur, H. V. (2005), Tippur, Dynamic fracture behavior of model sandwich structures with functionally graded core: a feasibility study. *Composites Science and Technology, 65*, 7-8.1052-1068. https://doi.org/10.1016/j.compscitech.2004.10.029

Krzyzak, A., Mazur, M., Gajewski, M., Drozd, K., Komorek, A., & Przybyłek, P. (2016). Sandwich structured composites for aeronautics: methods of manufacturing affecting some mechanical properties. *Int J Aerosp Eng*, 1-10. https://doi.org/10.1155/2016/7816912

Mitrevski, T., Marshall, I. H., & Thomson, R. (2006). The influence of impactor shape on the damage to composites laminates. *Compos Struct, 76*, 116-22. https://doi.org/10.1016/j.compstruct.2006.06.017

Nemes, J. A., & Simmonds, K. E. (1992), Low velocity impact response of foam core sandwich composites. *J Compos Mater, 26*(4), 500-519. https://doi.org/10.1177/002199839202600403

Papanicolaou, G. C., & Bakos, D. (1996). Interlaminar fracture behaviour of sandwich structures. *Compos Part A-Appl S, 27A*(3), 165-173. https://doi.org/10.1016/1359-835X(95)00026-X

Petrone, G., Rao, S., De Rosa, S., Mace, B. R., Franco, F., & Bhattacharyya, D. (2013). Behaviour of fibre-reinforced honeycomb core under low velocity impact loading. *Compos Struct, 100*, 356-62. https://doi.org/10.1016/j.compstruct.2013.01.004

Srivastava, V. K. (2012) Srivastava, Impact Behaviour of sandwich GFRP-Foam-GFRP Composites. *International Journal of Composite Materials 2012, 2*(4), 63-66. https://doi.org/10.5923/j.cmaterials.20120204.04

Srivastava, V. K., Gries, T., Dieter, V., & Quadflieg, T. (2017). Benjamin Mohr and Martin Kolloch, Effect of Nanomaterial on Mode I and Mode II Interlaminar Fracture Toughness of Woven Carbon Fabric Reinforced Polymer Composites. *Eng Fract Mech, 180*, 73-86. https://doi.org/10.1016/j.engfracmech.2017.05.030

Copyrights