INFLUENCE OF ANGLE PLY ORIENTATION ON IMPACT STRENGTH PROPERTY OF ARAMID FIBER EPOXY REINFORCED COMPOSITE

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Abstract

The present paper concerns experimental and finite element analysis (ANSYS) of Kevlar fiber epoxy composites with and without using filler material when subjected to impact loading. Mechanical properties such as elastic modulus (E), Poisson's ratios (µ), and thickness (t) are kept constant and the fiber orientations are varied to study the effect of angle ply orientation on the impact strength of the composite laminate both experimental and ANSYS. The impact loading is the most commonly observed phenomena in aircrafts, marine, naval, automobiles and defense. In the present paper fabrication of bi-directional Kevlar fiber epoxy composite laminates with $\pm 0^0/\pm 90^0$, $\pm 15^0/\pm 75^0$, $\pm 30^0/\pm 60^0$, $\pm 45^0/\pm 45^0$ *ply orientation and using Talc is the filler material and without using any fillers for the same ply orientation, specimens were prepared using hand layup technique as per the ASTM standards and to experimentally analyze the progressive failure process of laminated composites subjected to impact loads, impact load causing stresses in the composites. From analysis, the impact strength across the cross section of the specimen for different laminated composites is evaluated.*

Keywords: *Ccomposites, Kevlar fiber epoxy, Hand layup technique, ply orientation, Impact loads, Talc powder.*

I. INTRODUCTION

Composites are made by combining two or more natural or artificial materials to exploit their useful properties and minimize their defects. Kevlar-fibers reinforced plastic combines Kevlar fibers with plastic matrix resin to make a composite material that is tough but not brittle, is one of the best-known composites.

Composites are typically used in place of metals because of their unique strength and light weight. Most of the composites contain fibers of one material which is tightly bound into another material called a matrix. The matrix binds the fibers together a bit like an adhesive and makes them more resistant to external damage, whereas the fibers make the matrix stiffer and stronger and help it to resist defects like cracks and fractures. Matrix and Fibers are usually made from different types of materials, the fibers are typically carbon, glass, aramid kevlar, silicon carbide, or asbestos, while the matrix is usually metal, plastic, or a ceramic material.

II. LITERATURE REVIEW

Characterization of fiber-reinforced composites for geometric configurations and various loading has become an important concern to the design engineers. These composites may encounter the impact loading either accidentally or in an anticipated hostile service environment (Zhou 1998)[1].The damage caused by impact is a serious problem as it may severely reduce the integrity of the structure (Leif et al 2001) [2] which may lead to a significant strength reduction in post-damage performance. Cantwell et al (1990) [3] examined the residual tensile properties of a number of carbon fiber-epoxy laminates subjected to both low and high velocity impact loading.

By treating the zone of damage fibers as a sharp crack of equivalent transverse length, a fracture mechanics type analysis was applied to predict the post-impact tensile strength of the coupons. Zhou (1995, 1996). [4] Performed experimental investigation on two types of thick glass fiber reinforced laminates they are E-glass-polyester and S-glass-epoxy resin laminates. The planar delamination and fiber breakage were found to be the dominant damage mechanisms. They concluded that, using impact response to predict the threshold values for damage initiation does not require the examination of impacted specimens, and is significantly faster and cheaper. Khondker et al (2004). [5] proposed two methods to predict the compression after-impact (CAI) strength of glass knitted textile composites. In the first method, linear regression analysis was used to establish a linear relationship between damage width and CAI strength. The second method involved idealizing the damage zone as a circular hole, and using point stress failure criterion, the CAI was predicted.

III. EXPERIMENTAL WORK

A. *Fabrication method (Hand Layup Technique)*

Hand lay-up technique is the simplest and most commonly used method of composite processing. The infrastructural and cost requirement for doing this method is also minimal. Firstly, a release gel is sprayed on the surface of the mould to avoid the sticking of polymeric to the surface. Thin plastic sheets of specified dimensions are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of chopped strand mats or woven mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in the form of liquid is mixed thoroughly with suitable proportion of prescribed hardener (curing agent) and poured onto the surface of chopped mat which is already placed in the mold. After curing either at room temperature or at some specified temperature as our requirement, mold is opened and the developed composite component is taken out and further processed. The schematic layout of hand lay-up technique is shown in Fig.1.

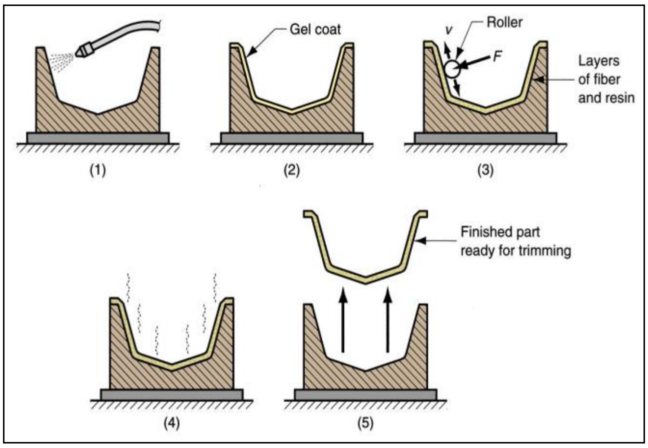

Fig 1: (1) mold is treated with mold release agent; (2) thin gel coat (resin) is applied, to the outside surface of molding; (3) when gel coat has partially set, layers of resin and fiber are applied, the fiber is in the form of mat or cloth; each layer is rolled to impregnate the fiber with resin and remove air; (4) part is cured; (5) fully hardened part is removed from mold.

B. ***Specimen preparation***

First, poly vinyl alcohol (PVA) is applied on the Mould surface to avoid the sticking of resin to the surface. Thin plastic sheets are used at the top and bottom of the mould plate to get good surface finish of the laminate. Reinforcement in the form of unidirectional Kevlar fiber mats are cut as per the mould size (75mm X 10 mm) and required orientations are placed at the surface of mould after Perspex sheet. The thermosetting resin [epoxy] (10 ml) in liquid form is mixed thoroughly in suitable proportion with a hardener [K6] (curing agent.ie, 2ml) and poured onto the surface of mat which is already placed in the mould.

The resin mixture is uniformly spread with the help of brush/roller. Second layer of mat with different orientation (cross ply laminates) is then placed on the resin mixture surface and a roller is moved with a mild pressure on the mat-resin mixture layer to remove any air trapped as well as the excess aramid present. The process is repeated for sixteen layers of polymer and mat and fourteen layers of polymer and mat in case of filler, till the required layers are stacked as shown in fig 2. After curing at room temperature for about 4 hours, mould is opened and the developed composite laminate is taken out and further processed as shown in fig 3 and fig 4.

The time of curing depends on type of resin used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 23-38 hours. Capital and infrastructural requirement for doing this technique is less as compared to other methods. Production rate is less and high-volume fraction of reinforcement is difficult to achieve in the processed composites.

Fig 2 : various steps involved in the fabrication of composite Laminate (a) mould preparation (b) applying wax and PVA (c) filling the mould with resin and fiber (d) clamping

Fig 3: Impact test specimens with filler material before testing

Fig 4: Impact test specimens without filler material before testing

C. ***Mechanical Testing of Composites(Izod test)***

Izod impact test measure the toughness of the materials as shown in fig 5. The Izod impact powerfully depends on size of the specimen being tested because number of imperfection acts as stress raisers and deduce the fracture toughness of the laminate.The Izod impact test was conducted by selecting different specimens and these specimens were designed as per ASTM D-256 standard as shown in fig 6. The dimension of the specimens were 70x10x5 mm and radius of the notch was 0.25R having notch length of 2mm

The performance of polymer matrix composites under impact loading is affected by many factors such as the fiber properties, fiber orientations, fiber contents, matrix properties, fiber-matrix interfaces etc. Increase in volume content of reinforcements can increase the stiffness and strength of a composite to a point. If the volume content of reinforcements is too high then there will not be enough matrix to keep them separate, and they can become tangled.

Fig 5 : Izod Test machine

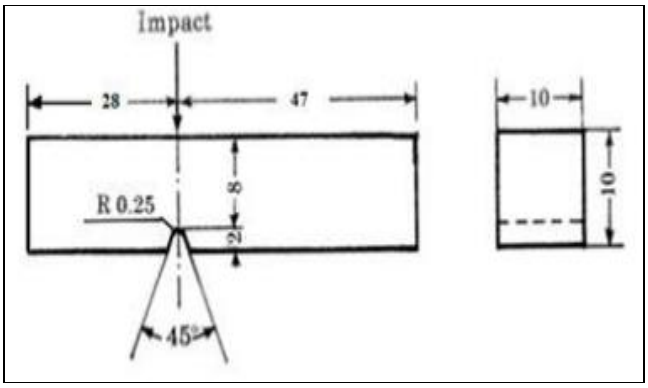

Fig 6 : Test Specimen (ASTM D256 standard)

The Izod impact test measures the energy required to break a vertical cantilever beam specimen. The principle involves striking the specimen with a hammer mounted on the end of a pendulum. The position of the pendulum at the beginning of the swing, together with the weight of the hammer is a measure of the kinetic energy at the point of impact on the specimen. After striking the specimen, the hammer makes contact with an indicator which measures the amount of energy required to break the specimens. The swing of the hammer after impact decreases as the amount of energy required to break the specimen increases. The test procedure of impact testing is mounting the specimen in the holding device and allowing the pendulum to fall, after striking the specimen the pendulum records a reading on the digital indicator which is the impact energy required to break the specimen.

IV. RESULTS AND DISCUSSIONS

The results of experimental and finite element analysis behavior of polymer composites and the effect of fiber parameter such as angle ply orientation on the performance of composites is also analyzed.

A: Effect of angle Ply Orientation on Impact Strength of Composites:

The influence of angle ply orientation on the toughness of composites is shown in the Fig 7 to fig 8 and the results which are plotted in fig 9 to fig 14. It is evident that the impact strength gradually increases with increase in fiber orientation up to $[\pm45°]_{16}$ and $[\pm45^0]_{14}$. It is observed that impact strength is maximum for angle ply oriented at $[\pm45°]_{16}$ and $[\pm45^0]_{14}$ in a composite specimen and is minimum for $[\pm0°]_{16}$ and $[\pm0^0]_{14}$ oriented fiber in a composite specimen.

Fig 7: Impact test specimens with filler material after testing

Fig 8: Impact test specimens without filler material after testing

B: Modal Analysis

For this analysis the materials used are Kevlar fibers and epoxy resin as matrix material and the Analysis of the specimens is carried out by using ANSYS 15 finite element method. In preferences we use structural type for the analysis. In the pre-processing the material properties specimen, stacking sequence, modeling and meshing are created and then solve the current problem in the solution stage and the final general post processor is used to read and analyze the different parameters obtained by the solutions.
In pre-processing 3D 4 nodes 181 shell element is used to model the laminates. Specification of the specimen is taken according to the ASTM D256, 70 mm x 10mm laminates with 5mm thickness. From simple rule of mixtures material properties are calculated with Kevlar FRP composite is made of 60% fiber and 40% epoxy matrix by volume and the results are plotted in fig 15 to fig 20.

C :Impact Test Results

The specimens of various angle ply orientations are subjected to impact loading and the failure of specimens as shown in table 1 using filler and table 2 is using without filler, The calculations of impact strength and resilience are

Table 1: Impact properties for different angle ply orientations without using filler

S.NO	Orientation	Impact Energy(J)	Impact Strength(mpa)		Resilience (J/m)
			Experimental	Ansys	
1	$[\pm 0^o]_{16}$	1.975	3.95	4.78	395.2
2	$[\pm 15^o]_{16}$	2.635	5.27	5.53	527.4
3	$[\pm 30^o]_{16}$	3.260	6.52	6.81	652.8
4	$[\pm 45^o]_{16}$	3.561	7.12	7.32	712.6

Table 2: Impact properties for different angle ply orientations with using filler

S.NO	Orientation	Impact Energy(J)	Impact Strength(Mpa)		Resilience (J/m)
			Experimental	Ansys	
1	$[\pm 0^o]_{14}$	2.160	4.32	5.45	432.6
2	$[\pm 15^o]_{14}$	2.880	5.76	6.06	576.2
3	$[\pm 30^o]_{14}$	3.335	6.67	7.21	667.5
4	$[\pm 45^o]_{14}$	3.672	7.34	7.62	734.9

D: Izod impact test results:

The results are plotted and analyzed to know the influence of ply orientation on the impact properties.

They are

1) Impact energy Vs Angle ply orientations for comparing impact energy of specimens with using filler and without using filler at different ply orientation.
2) Impact strength Vs Angle ply orientations for comparing impact strength of specimens with using filler and without using filler at different ply orientation.
3) Resilience Vs Angle ply orientations for comparing resilience of specimens with using filler and without using filler at different ply orientation.
4) Impact strength Vs Angle ply orientations for comparing experimental impact strength and Ansys impact strength of specimens without using filler at different ply orientation.
5) Impact strength Vs Angle ply orientations for comparing experimental impact strength and Ansys impact strength of specimens with using filler at different ply orientation.
6) Finite element analysis by Ansys15 is carried out for all the specimens and both experimental and analytical results are compared.

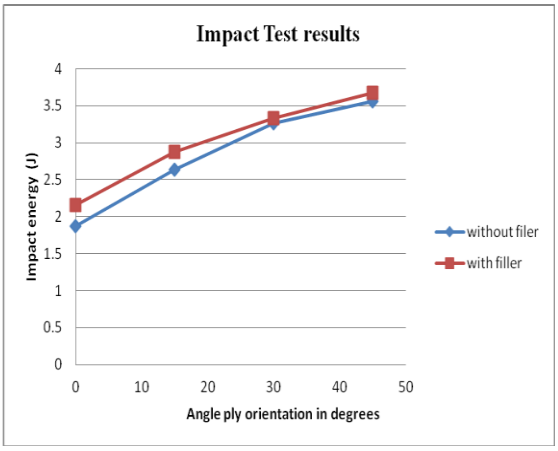

Fig 9: Impact energy Vs Angle ply orientations

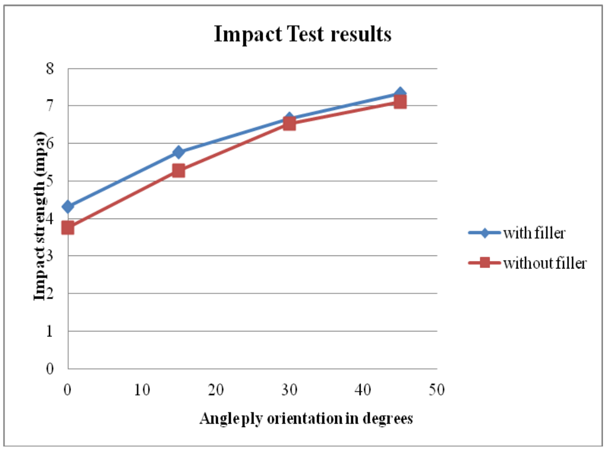

Fig 10: Impact strength Vs Angle ply orientation

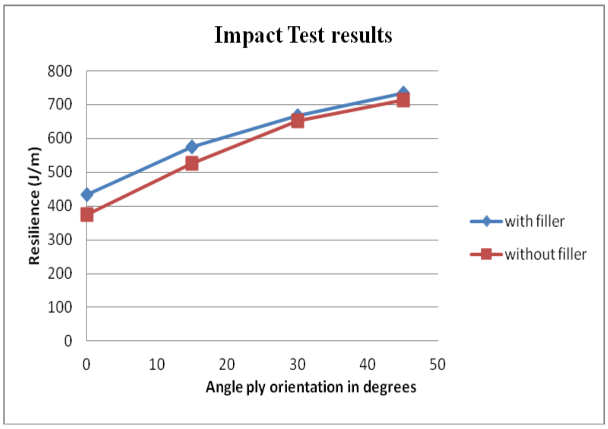

Fig 11: Resilience Vs Angle ply orientations

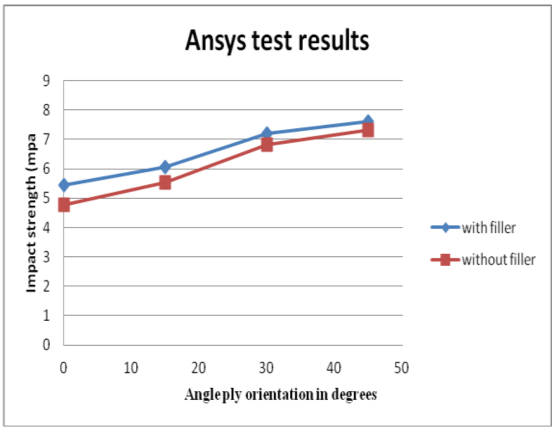

Fig 12 : Ansys results plotting in Impact strength Vs Angle ply orientations

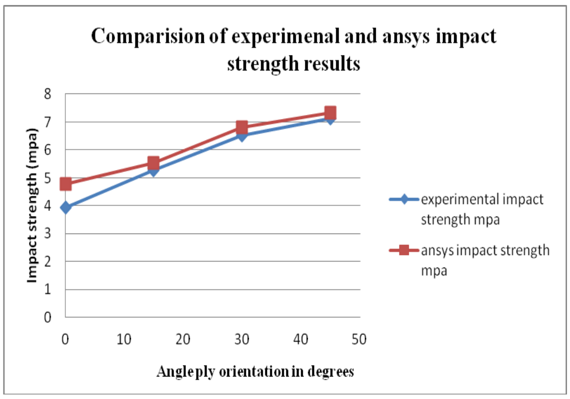

Fig 13: Both experimental results and Ansys results without using filler specimens plotted in Impact strength Vs Angle ply orientations

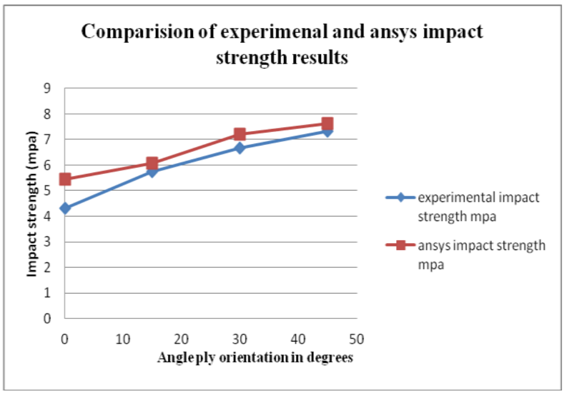

Fig 14: Both experimental results and Ansys results with using filler specimens plotted in Impact strength Vs Angle ply orientations

E: Impact test results in Ansys.

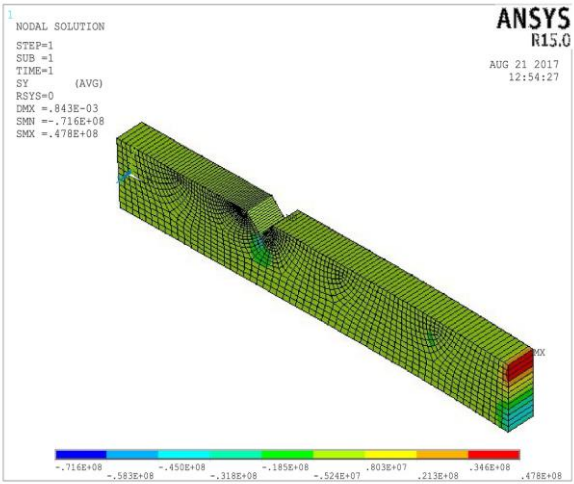

Fig 15: Analysis of [±0° /±90^0] Orientation by Ansys(without filler)

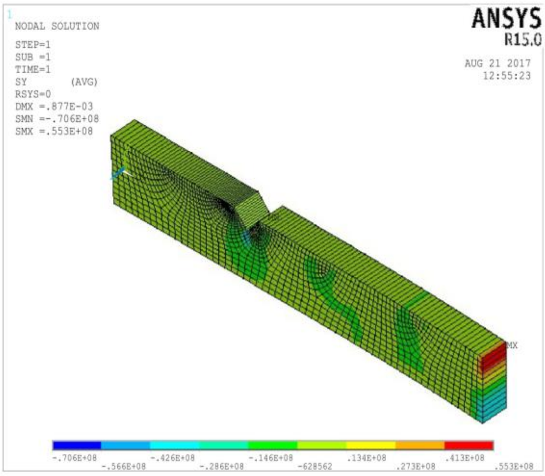

Fig 16: Analysis of [±15° /±75^0]Orientation by Ansys(without filler)

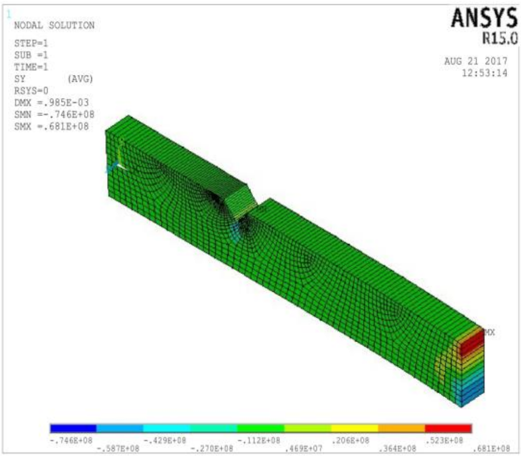

Fig 17: Analysis of [±30° /±60^0]Orientation by Ansys(without filler)

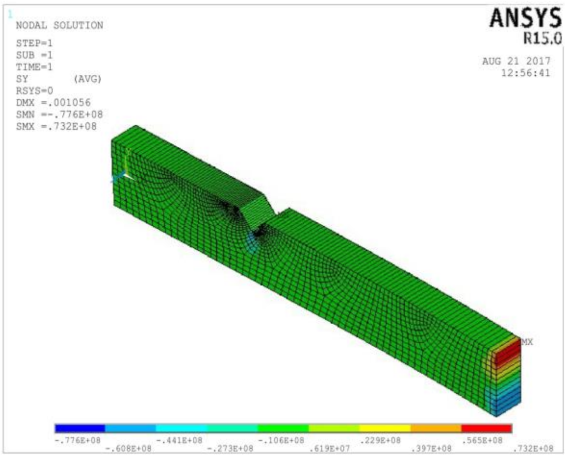

Fig 18: Analysis of [±45° /±45^0]Orientation
by Ansys(without filler)

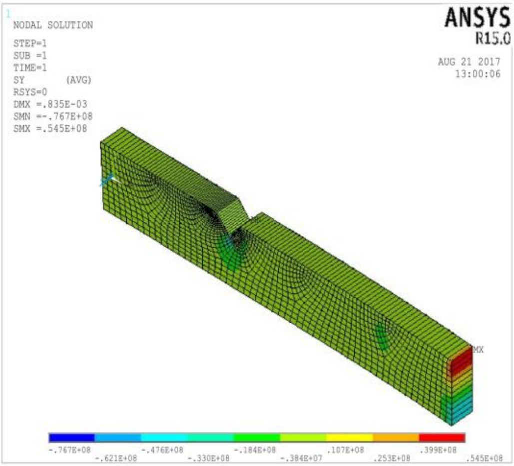

Fig 19 : Analysis of [±0° /±90^0]Orientation by Ansys(with filler)

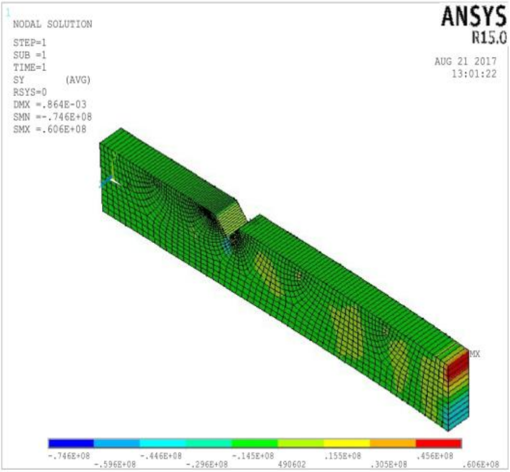

Fig 20 : Analysis of [±15° /±75^0]Orientation by Ansys(with filler)

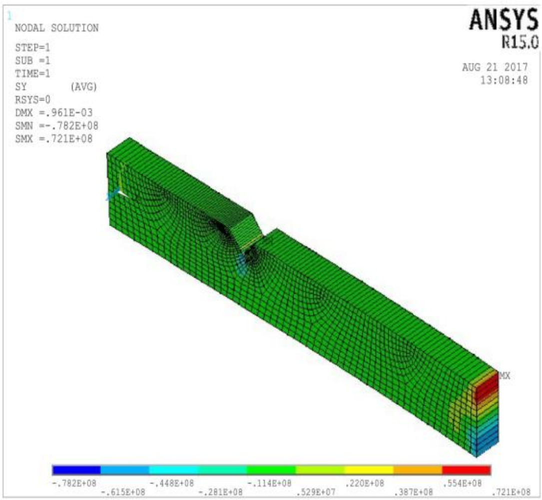

Fig 21: Analysis of [±30° /±60^0] Orientation by Ansys(with filler)

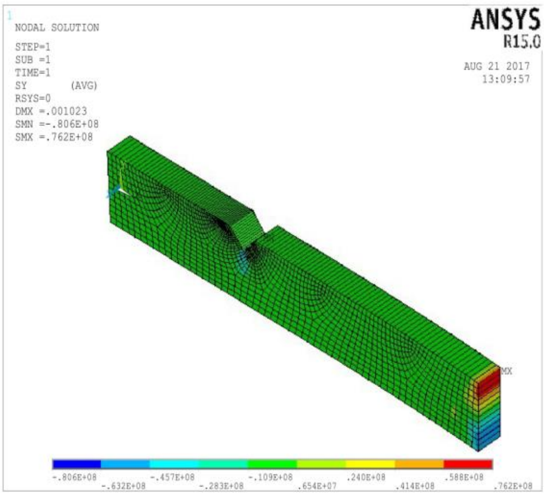

Fig 22 : Analysis of [±45° /±45^0] Orientation by Ansys(with filler)

F: Failure analysis.

- Kevlar epoxy composite fabricated of [±0°/±90^0] angle ply Orientation without filler, impact strength, from experiment 3.95MPa was obtained; while from finite element technique 4.78MPa was obtained.
- Kevlar epoxy composite fabricated of [±15°/±75^0] angle ply Orientation without filler, impact strength, from experiment 5.27MPa was obtained; while from finite element technique 5.53MPa was obtained.
- Kevlar epoxy composite fabricated of [±30°/±60^0] angle ply Orientation without filler, impact strength, from experiment 6.52MPa was obtained; while from finite element technique 6.81MPa was obtained.
- Kevlar epoxy composite fabricated of [±45°/±45^0] angle ply Orientation without filler, impact strength, from experiment 7.12MPa was obtained; while from finite element technique 7.32MPa was obtained.
- Kevlar epoxy composite fabricated of [±0°/±90^0] angle ply Orientation with filler, impact strength, from experiment 4.32MPa was obtained; while from finite element technique 5.45MPa was obtained.
- Kevlar epoxy composite fabricated of [±15°/±75^0] angle ply Orientation with filler, impact strength, from experiment 5.76MPa was obtained; while from finite element technique 6.06MPa was obtained.
- Kevlar epoxy composite fabricated of [±30°/±60^0] angle ply Orientation with filler, impact strength, from experiment 6.67MPa was obtained; while from finite element technique 7.21MPa was obtained.
- Kevlar epoxy composite fabricated of [±45°/±45^0] angle ply Orientation with filler, impact strength, from experiment 7.34MPa was obtained; while from finite element technique 7.62MPa was obtained.

CONCLUSIONS

Experiments were conducted on aramid fiber and Epoxy resin angle ply laminates with different fiber orientation to characterize the impact properties. The following conclusions were drawn and recorded.

1) The appearance of the specimen after fracture showed expected behavior and all the samples are subjected to fracture at the notch only.

2) Mechanical properties such as elastic constants and thickness are kept constant and angle ply orientation is varied to estimate impact strength and resilience in Kevlar fiber epoxy composite.

3) The angle ply orientation of composite laminated specimens has significant effect on the impact strength where it increases with increase in angle ply orientation till $[\pm45°]_{16}$, $[\pm45°]_{14}$ and later decreases with increase in orientation.

4) Maximum value of impact strength is observed at $[\pm 45°]_{16}$ and $[\pm 45°]_{14}$ angle ply orientation of Kevlar fiber epoxy composite.

5) From above we concluded that the mechanical properties for other orientations, the maximum impact properties can be obtained only in $[\pm 45°]_{16}$ and $[\pm 45°]_{14}$ angle ply orientation. Further research work needs to be carried out in the development of hybrid fiber-reinforced composites by the inclusion of filler material and fiber treatment for getting improved mechanical properties.

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