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# Characterization of Tensile and Impact Properties of Polymer Hybrid Composites

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***Abstract* - This paper reports the characterization of tensile and impact properities of polymer based composites filled with polyester fabrics. Polymers are well suited as matrix materials due to their low density and their low processing temperatures. The polymer matrix composites are light weight, high strength to weight ratio and stiffness properties have come a long way in replacing the conventional materials such as metals and wood.The hybridization of specimens is done by maintaining the volume fractions for the different tests as per the ASTM . The composite material is made with glass fabrics, polyester and epoxy resin.**

***Key words:-Glass fabric, polyester fabric, Hybridization, Digital UTM, curing, mechanical properties.***

## INTRODUCTION

Polymer matrix composites find various applications in our daily life. The most matured and widely used composite systems are polymer matrix composites (PMCs), also known as Fiber Reinforced Polymers (Plastics) which provides the major focus for this work. Polymers are well suited as matrix materials due to their low density and their low processing temperatures. The polymer matrix composites are light weight, high strength to weight ratio and stiffness properties have come a long way in replacing the conventional materials such as metals and wood. The applications of polymer matrix composites are decking Boat, Civil, Aerospace, Sports, Domestic, Transport, Marine Applications. The hybridization of specimens is done by maintaining the volume fractions for the different tests as per the ASTM standards. The growing interest in natural fibers is mainly due to their economical production with few requirements for equipment and low specific weight, which results in a higher specific strength and stiffness when compared to synthetic fibers composites. Also, they offer safer handling and working conditions compared to synthetic fibers. Natural fibers from renewable natural resources offer the potential to acts biodegradable reinforcing materials alternative for the use of synthetic fibers or stiffness to weight ratio.

The experimental work is by the E- glass reinforcement with the natural fabrics .the applications of this are, tent poles, sound absorption, heat and corrosion-resistant fabrics, high-strength fabrics, pole vault poles, arrows, bows and crossbows, translucent roofing panels, automobile bodies, hockey sticks, surfboards, boat hulls, and paper honeycomb. The experimental work is gone through the glass/polyester fabrics.

## MATERIAL DETAILS AND SPECIMEN PREPARATION

Material used to prepare the specimen are glass fiber and polyester fiber as reinforced material and L-12 lepoxy ,K-6 hardener as matrix material.

Glass fabric provides excellent strength and moisture resistance. Glass fibers are most common reinforcing fiber. The principal advantages of glass fibers are the low cost and high strength. Glass fiber has high mechanical strength, impact resistance, stiffness and dimensional stability of a resin. Polyester is a strong and durable synthetic fabric. Polyester dries quickly and can be washable or dry clean only, so check your tags.Epoxy is a copolymer. It is formed from two different chemicals. These are referred to as the resin and the hardener. In this experiment we are using L-12 lepoxy as the matrix material. In the experimental work the hardener K-6 is added for the easily drying agent to the epoxy.

## EXPERIMENTAL PROCEDURE

The Characterization of this hybrid composite can be done on these tests .The tests are conducted according to ASTM standards. The following are the tests can be done on the hybrid composites areTensile test, Inplane shear test, Open hole tensile test, Inplane open hole tensile test, Impact test.

The hybrid composites are susceptible to mechanical damages when they are subjected to effects of tension and impact, which can lead to interlayer delamination. In any cases, the increase of the external load favors the propagation of delamination through the interlayer leading to the

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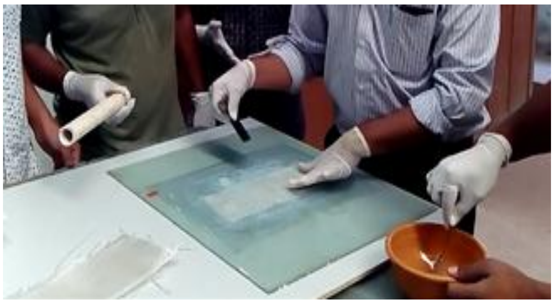
catastrophic failure of the component. The tension and impact tests require only simple specimens, are easy to perform and give accurate and reliable measurements. For these reasons, they are attractive tests to determine as much of the mechanical properties of composite materials as possible. The experimentations have been carried out to characterize the composite material under different loading conditions and with various specimen configurations, the analysis of the results and the influence of various parameters on the physical & mechanical properties.

## HAND LAY-UP TECHNIQUE FOR FABRICATION OF SPECIMENS



## HYBRIDIZATION OF COMPOSITES

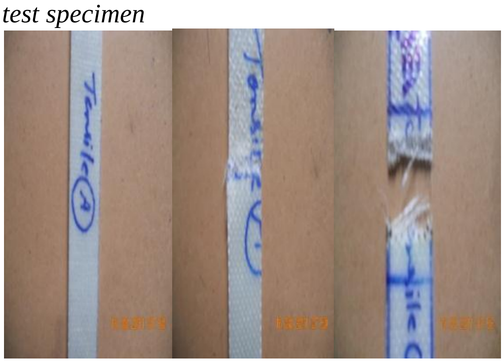
The specimens were prepared according to ASTM standards. Hybrid laminates of glass/polyester fabrics were fabricated by hand lay-up technique in a mold at laboratory temperature. The matrix material used was a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6). This matrix was chosen, since it provides good resistance to alkalis and good adhesive properties. In the present work, three different material compositions of glass/polyester fabrics hybrid composites were made, namely TYPE A, TYPE B and TYPE C. The volume of epoxy was maintained constant (40%) for all the three types. The percentage volume of glass/polyester fabrics is varied from 15% to 45%. The hardener is added in the ratio of 1:10 of epoxy. Then this mixture is stirred thoroughly till it becomes a bit warm. Bit extra amount of hardener can spoil the composite specimens.

## EXPERIMENTATION

### *Tensile Test*

The tensile strength was determined by a static tension test in accordance with ASTM D3039.

*Tensile test specimen*



(a) (b) (c)

The experimental work of the specimen tested (a) specimen before testing (b) yield starts in the specimen (c) specimen breaks after reaching breaking point

### *In-plane Shear Testing*

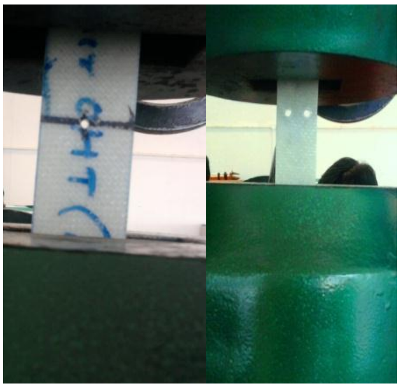
In-plane shear properties such as, Delamination, strength were determined by a ±45$^0$ shear test as per ASTM D3518.

(a) (b) ( c)

The experimental work of the specimen tested(a) specimen before testing (b) yield starts in the specimen (c) specimen breaks after reaching breaking point

### *Open Hole Tensile (OHT) Strength Testing*

The open hole tensile test experiments were performed according to ASTM D5766.



(a) (b)

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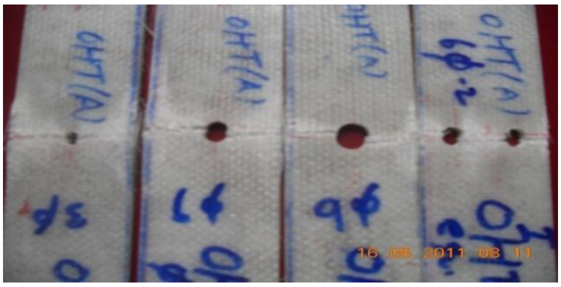
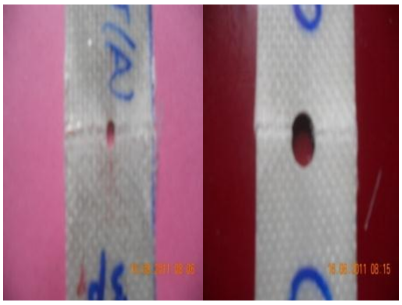


(c)

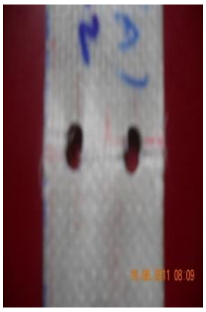
The experimental work of the specimen testing
(a) specimen before testing forSingle notch
(b) specimen before testing for double notch (c)specimensBreaks after reaching breaking point for different notch sizes

*In-plane Open Hole Tensile Test*

The In-plane open hole tensile test experiments were performed according to ASTM D5766.



(a) (b)

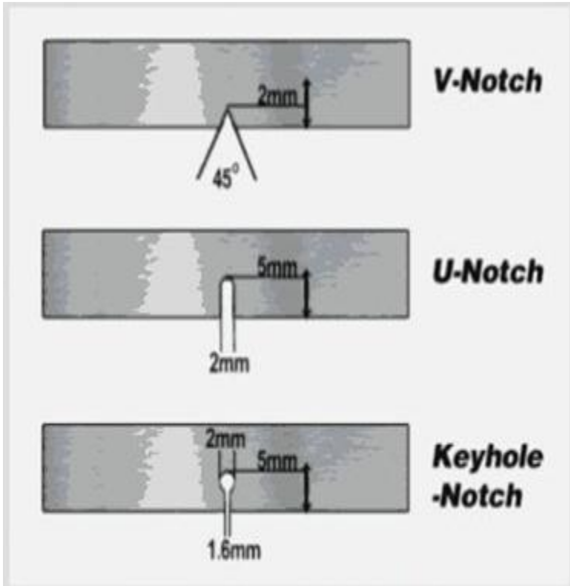


(c) (d)

The experimental work of the in plane OHT test specimen testing (a) specimenof 3 mm notch (b) specimen of 6 mm notch (c) specimens of 9 mm notch (d) specimen of Equispaced 6 mm notch

*Impact Test*

For the impact test, the specimens are prepared to find out the impact energy absorption. The specimens are prepared as per ASTM E23 Standards.




Impact test the specimens specifications

The objective of this experiment is to evaluate the energy absorbing characteristics of composite materials by varying the temperature for the specimens using the Charpy impact method. The tests were carried out in accordance with ASTM D 256. The specimens are then required to keep in different service temperatures.

The different temperature conditions are

- Normal condition
- $0^0$C condition
- $60^0$C condition
- $90^0$C condition
- $120^0$C condition

These specimens are heated by using hot air oven. The specimens are heated for a 30 min and test is carried. The specimens were tested and recorded the results.

(d)

RESULTS AND DISCUSSION

Behaviour of hybrid composite under tensile loads with different fabric orientations

The hybrid composite material is laminated to ± (0°/90°) and is being tested in the UTM.

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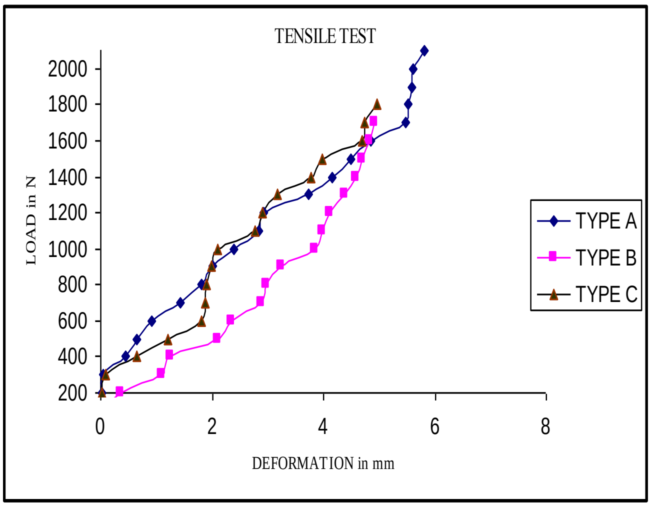


Fig The tensile load/deformation curve of the composites with three different volume fractions

The results shows as the volume of glass fabrics increases the load carrying capacity also increases due to its properties, the TYPE A and TYPE B shows fewer properties of glass fabrics as compared to TYPE C.From the results it was found that the breaking load is nearly same for the three volume fractions but the deflections are variable due to the varying in the volume fraction in the reinforcement's material. From Fig.5.1 the final conclusion is that the equal ratio of volume fractions of glass and polyester fabrics is having more load carrying capacity with less deformation. TYPE B shows a good tensile property compare to TYPE A, C.

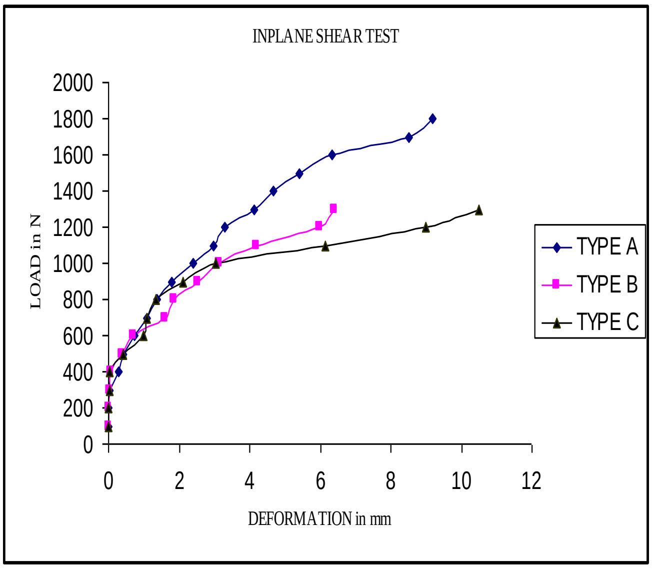


Fig 5.2. The Inplane shear load/deformation curve of the composites with three different volume fractions

Fig.5.2. shows load versus displacement for three different volume fractions of glass fabrics and polyester fabrics for in plane shear test. From varying the volume fraction and the results obtained. From the results, it can be observed that breaking load is nearly same as for all the volume fractions but deformation is varying. In Fig 5.2, it can be seen that the TYPE B is having low deformation with high load carrying capacity due to the equal volume fractions are casted by the materials, but in TYPE A, C the deformations is more for the same loads. In this Fig 5.2, by the same ratio of glass and polyester fabrics the deflection is less for the same loads as applied for the three volume fractions, this is because of the ratio and also the ± $45^0$ orientation of lamination. By these it is found that the polyester and glass fabrics acts as a media for high load carrying capacity and polyester absorbs the deformation due to the stretchable material

*Comparison on Tensile And In plane Shear Test for the Ultimate Load in Three Volumes Fractions*

The effect of fabrics content in the specimens for ± ($45^0/90^{0)}$ laminated has differentiated by testing the ultimate load in three volume fractions. Here the comparison is made to find out the strength of the specimens for both the orientations separately.

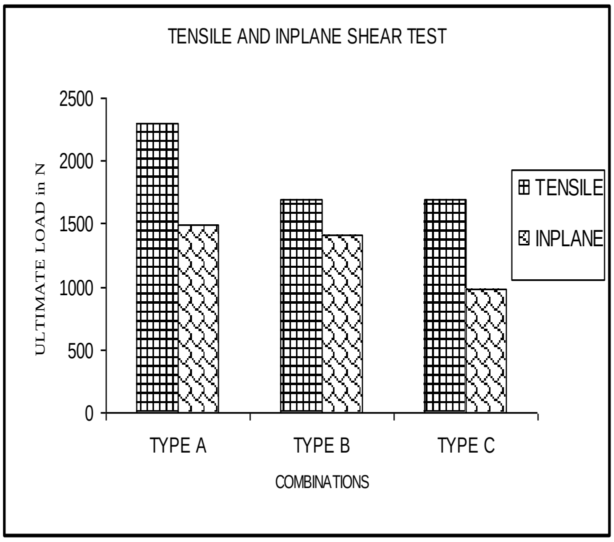


Fig 5.3. Effect of ultimate load in three volume fractions

The Fig 5.3 shows the ultimate load obtained for the three volume fractions in tensile and in plane shear test. The result shows that the tensile strengths are affected by the fiber orientation significantly. The tensile strength is superior in case of ± ($0^0/90^0$) oriented specimens as compared to specimens with ±$45^0$ orientations as shown in Fig 5.3. This is attributed to the reason that, in case of ± ($0^0/90^0$) orientation the external tensile load is equally distributed on all the fibers and transmitted along the axis of the fibers. Whereas in case of other fiber orientations, fiber axes is non-parallel to load axis, resulting in off axis pulling of fibers and increased stress concentration causing the earlier failure of laminates.

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(a) Tensile specimen (b) In plane shear specimen

Fig 5.4. Comparison of tensile and in plane shear tests specimens after testing

From above Fig 5.4 (a) and (b) the results shows that there is a maximum load carrying capacity in tensile as compares to the in plane shear and also the load carrying capacity is more in TYPE A, because in TYPE A both the tensile and in plane shear specimens is having more glass fabrics ratio it will be withstand more load more over it has been under yield. From the testing results come to know that the ultimate load carrying capacity is more in tensile as compared to in plane shear.

*Behaviour of hybrid composite under open hole tensile test with different notch sizes*

From the result as shown in Fig 5.5, The 6 mm hole notch is having the maximum load carrying capacity and Equispaced drilled with 6 mm hole notch is having less load carrying capacity this is because due to the large cross sectional area of the drilled hole on the specimen. The results revile that, when the center axis hole diameter increases the failure rate increases with the increase in the load and it depends upon the strength of the material, because of this is the TYPE A having more ratio of glass content, the hole notch of 9 mm is having less deformation with small load carrying capacity. The increase in hole diameter failurerate is more when the holes are in same axis

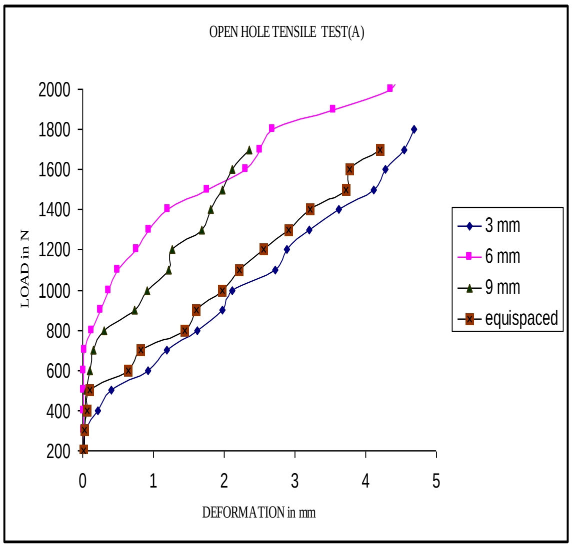


Fig 5.5. The Open hole tensile load/deformation curve of the composites with three different notch sizes

From the Fig 5.6.The 3 mm hole notch dia is having maximum load carrying capacity and Equispaced with 6 mm hole notch dia is having less load carrying capacity this is because the 3 mm hole dia is having more area of cross section around the notch and notch size is also small, the main objective is in TYPE B the volume fraction is equal for both the materials, as the notch size increases the deformation also increases with small load.

Fig 5.7 shows the open hole tensile test in TYPE B volume fraction, shows the load versus displacement for open hole tensile test. From the results it shows that the hole notch size having small dia is withstanding more loads with less deformation and it all depends on the volume fraction of the materials. Due to this reason the specimen is having more strength in TYPE B

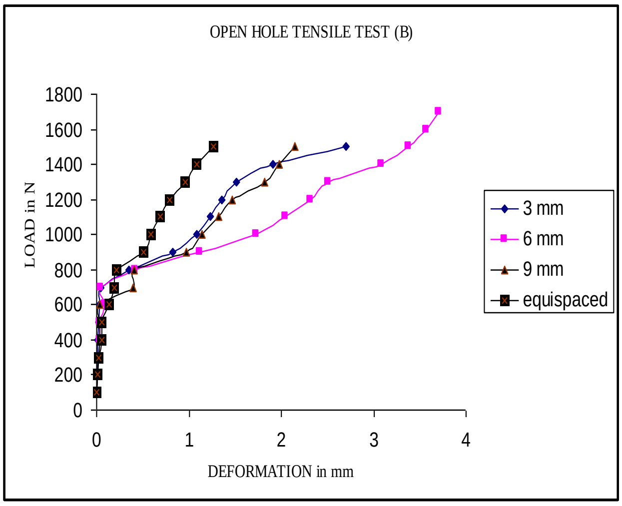


Fig 5.7. The Open Hole tensile load/deformation curve of the composites with three different volume fractions

From the Fig 5.7, the 6 mm hole notch size is having more load carrying capacity but the deformation is also more and in the 3 mm hole notch size the load carrying capacity is less as compared to 6 mm hole notch size but the deformation is less in the 3 mm hole notch size.

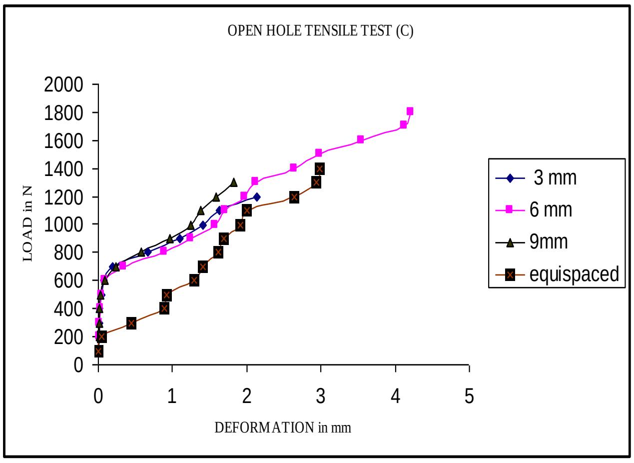


Fig 5.8. The Open Hole tensile load/deformation curve of the composites with differentNotch sizes

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From Fig 5.8 shows the open hole tensile test in TYPE C volume fraction. The result shows that, as the hole notch size increases the deformation also increases and it depends on the volume fraction fabricated, as the reduction in percentage of glass fabrics in the fabrication it will come to know that it will with stand to small loads so that the specimen is having more strength due to the small hole notch size

*Comparison of the Ultimate Load for Three Volume Fractions in Open Hole Tensile Test*

Fig 5.9. Shows the comparison between the three volumes fractions TYPE A, TYPE B, TYPE C, for the different hole notch sizes.

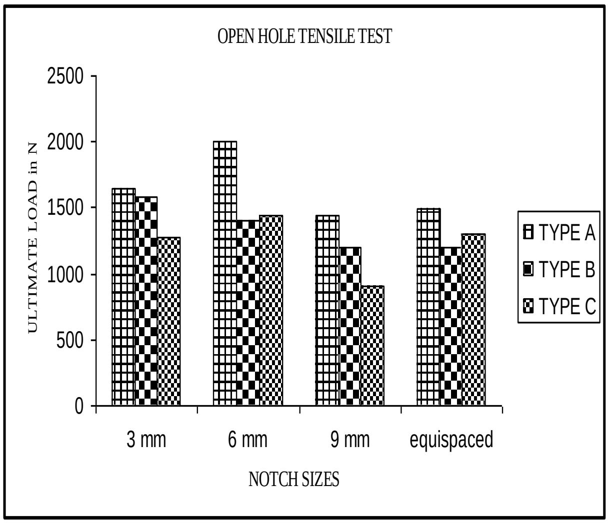


Fig 5.9. Effect of ultimate load in three volume fractions with different notch sizes.

From the Fig.5.9, the TYPE A is having more ultimate load carrying capacity in all the notch sizes this is because of the volume fractions. In the TYPE A the glass fabrics ratio is more than other two types and in TYPE B the variation is occurring in small amount in deflection due to the equal amount of fabrics are casted and in the TYPE C the glass fabrics content is very small so the variation is more in all the notches. So the conclusion is that as the notch sizes increases the load carrying capacity will decreases due to the small cross sectional area around the hole notch and also depending on the volume fraction fabricated for testing the open hole tensile test. So finally the strength is more in the TYPE A.

*Behaviour of hybrid composite under in plane open hole tensile test with different notch sizes*

Fig.5.11 shows the in plane open hole tensile test in TYPE A volume fraction. From the Fig 5.11, the TYPE A with 3mm holedia having maximum load carrying capacity this is due to the smaller notch size, and also the fabrication is made for $\pm 45^0$

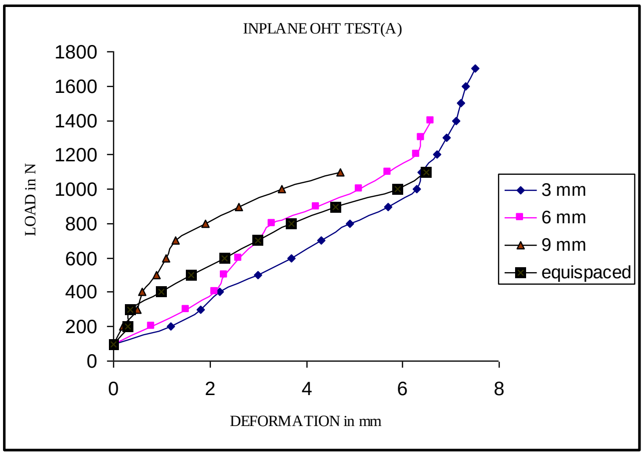


Fig 5.11. The Inplane Open Hole tensile load/deformation curve of the composites with different notch sizes

In this specimen the elasticity is more than the $\pm 90^0$ lamination. But the contribution for getting the maximum load is not based on the notch size but also the volume fractions fabricated, this is the TYPE A volume fraction, so in this the glass content is more and it acts as more elastic nature. From the results it can be inferred that, as the hole notch size increases the load carrying capacity decreases, because of the small cross sectional area around the notch. But in this why the 9 mm hole notch size is having less loading capacity with small deformation and why the 3 mm hole notch size is having more load carrying capacity is because of the hole size. If it is more it will withstand small loads, if it is small hole notch it can withstand high loads. So from this result the 3mm is having more strength and also the content of glass is also more in TYPE A.

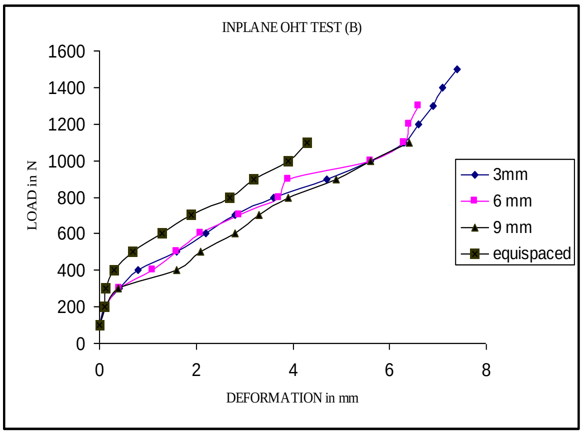


Fig 5.12. The Inplane Open Hole tensile load/deformation curve of the composites with different notch sizes

Fig 5.12 shows the load versus displacement for inplane open hole tensile test. From the Fig.5.12, The results shows that in the TYPE B with 3 mm hole notch size are having more load carrying capacity this is due to the orientation of lamination to make the specimens and also hole notch size. From the results the 3 mm drilled hole notch size is withstanding more load because of the hole notch size is small, because of the equal distribution of layers are casted the deformation is also takes place with constant ratio between load and displacement.

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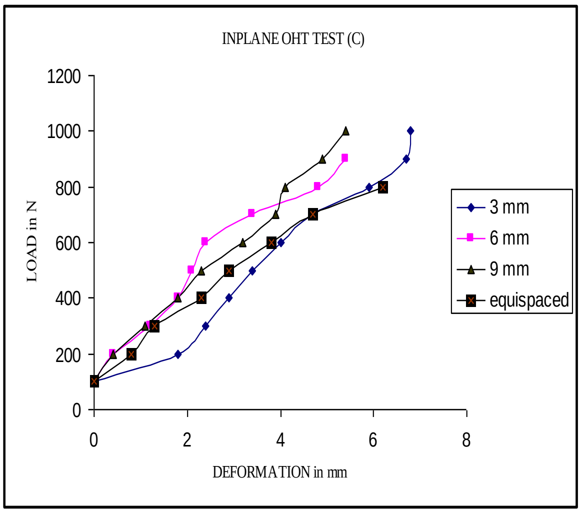


Fig 5.13. The Inplane Open Hole tensile load/deformation curve of the composites with different notch sizes

Fig.5.13. Shows the inplane open hole tensile test in TYPE C volume fraction. It shows the load versus deformation for inplane open hole tensile test. From the results the TYPE C with 3 mm hole notch size is having maximum load carrying capacity and Equispaced notch with 6 mm hole notch size is having less load carrying capacity, this is due to variation in the volume fraction while fabricating the specimens and also the area around the notch is also so small as compared to other notches, so it has less load carrying capacity and also the glass fabrics content ratio is also very small in this type, so it will withstand small loads with more deformation.

*Comparison of the Ultimate Load for Three Volume Fractions in Inplane Open Hole Tensile test*

Fig 5.15. Shows the comparison between the three volumes fractions TYPE A, TYPE B, TYPE C, for the different notch sizes

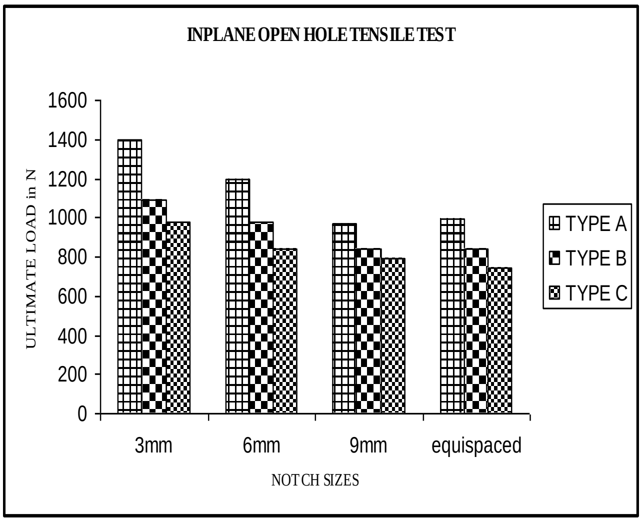


Fig 5.15. Effect of ultimate load for three volume fractions

From the Fig 5.14 and Fig 5.15, the TYPE A in all the notches is having more ultimate load carrying capacity, because in this the volume fraction of glass fabrics is more and the properties of glass fabrics is having good properties to influence the load to with stand, but from the Fig 5.15 the TYPE B the load carrying capacity is maintaining constant because of the equal distribution of layers are casted and also the notch sizes are also dependent in this testing. In the TYPE C in all the different hole notch sizes the load carrying capacity is less because of the less content of the glass fabrics in the TYPE C, From the results seen that the load carrying capacity is not only depends on the hole notch sizes but also the volume fractions of the fabrics added to the make the specimens.

*Effect of fabrics content on the impact energy absorption*

To determine the effects of fabric content on the impact energy absorption. The test specimens were prepared with three different types of volume fractions is fabricated and also to identify the effect of service temperature on the impact test the specimen were impact tested at five different temperatures. The impact tests were done for different notch geometries, namely U, V, and Keyhole (KH) for the different conditions. The obtained results are plotted in the Fig.5.23 and Fig.5.24 as shown below.

*Effect of Impact load for three volume fractions by varying the temperatures*

Fig 5.24, In the TYPE A, TYPE B and TYPE C, shows the results of the impact test carried out on thespecimens with the notch across the laminate, the testing is carried out under varied temperature.

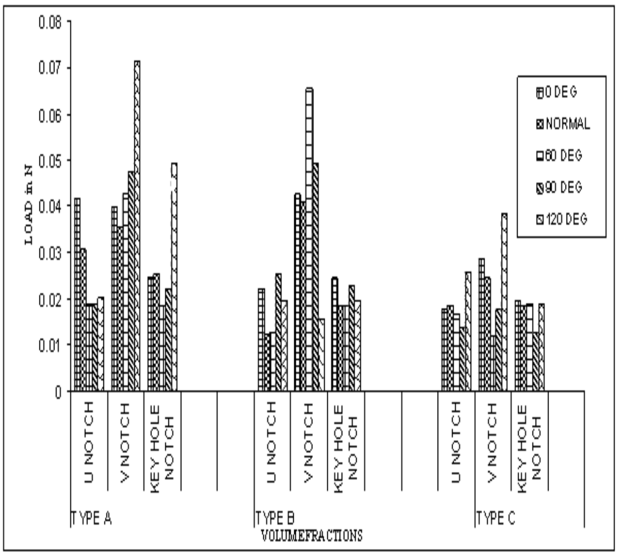


Fig 5.24. Effect of Impact load for three volume fractions by varying the temperatures

Fig 5.24, the TYPE A of $0^0$C in V notch specimen posses high impact toughness. It is observed that, at the higher service temperatures the strength has reduced to a considerable extent. This is mainly because of the fusing of the matrix material, and also the volume fractions used for preparation of specimens, so the TYPE A material is best suited for the applications in $0^0$ C. In the TYPE A the V notch is having maximum impact energy absorption as compared to other two notches, In all the volume fractions the

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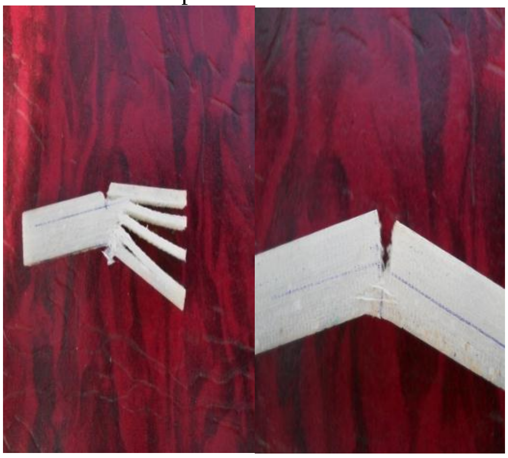
V notch is having high impact energy absorption this is due to small cross section area of the notch, and in the other two notches the only TYPE A is having high impact energy absorption because of more glass fabrics content is more in that as compare to other volume fractions, and about the normal condition the TYPE A is having the more impact energy absorption. So in the TYPE A the same V notch is absorbing more strength because of the two reasons, one is the volume fraction of glass content is more and the V notch area of cross section area is small so it is absorbing more strength, as increasing the temperature up to $60^0$C the strength of the specimen goes on decreases but as compared to along the notch the strength will be more than that because, In the across laminate the bonding of the laminate will get yield late as compared to along the notch in this condition only the V notch is having the good energy absorption as compared to all the volume fractions, again if increased the temperature to the $90^0$ C the equal volume fraction will only with stand the temperature and gets more energy absorption in this as the service temperature increase the stiffness of the specimen goes on decreases by burning the matrix material, so from results the V notch in TYPE A is more applicable. Finally if again increased the temperature to $120^0$ C the specimen get loose all its stiffness if the glass proportion is less. But from results the conclusion is TYPE A and TYPE B is having maximum ratio of glass content in this two volume fractions the impact energy absorption is more in this two volume fractions as compared to TYPE C.



(a) V-Notch (b) U- Notch

(c) Key hole Notch after delamination

Fig 5.25. Impact test specimens after testing

By the above Fig 5.25, The results come to know that the deformations of specimens with different notches is varying, by this the conclusion is as there is an increase in the impact strength with increased volume of the glass fabric. It is also very clear that the impact strength of the test with the notch grooved across the laminates is higher than the notch along the laminates, irrespective of the volume fraction. From the results it is been found that the glass fabrics is have better impact strength than that of the polyester fabrics. It is noticed that the specimens with notch grooved across the laminates have yielded maximum impact strength for both notch configurations. The maximum impact strength is obtained at lower service temperatures. It is observed that at the higher service temperatures the strength has reduced to a considerable extent. This is mainly because of the fusing of the matrix material. It was found that the notch along the laminate is highly prone to the catastrophic failure and the notch across the laminates will sustain the impact loads to a considerable extent. The durability of TYPE A laminates with 45% of glass and 15% of polyester fabric, under much application was found to be very high, compared to other two types.

## CONCLUSIONS

From the experimental study the following conclusions were derived,

- As the percentage of glass fabrics increases in the volume fraction, the load carrying capacity increases in the specimen.
- In open hole tensile specimen the increase in diameter decreases the load resisting capacity when the holes are in axis but hole is in off axis the load resisting capacity increases. And it not only depends on the holes but also the volume fraction used for the preparation of specimens.
- In the impact test as observed from the results the impact energy absorption depends upon the type of notch grooved on the specimen, if the specimens are tested at different service temperatures, as the temperature increases the strength of the specimen goes on decreases due to loosing the stiffness and elastic property of the resin gets reduced.
- The suitable volume fraction used for the application is the TYPE A, because in this the Load carrying capacity is maximum.

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