

Effect of Corrugated Cores on Impact Behavior of Fiber Reinforced Polymer Sandwich Structure

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ABSTRACT: Aircraft wing structures are strongly required to be stiff in order to withstand aerodynamic forces, while structural flexibility is preferable in morphing wings. Many researchers found solution for this problem by adopting fiber-reinforced plastics (FRP) which acts flexible in the chord direction and stiff in the span direction. The significant feature of corrugated core sandwich structure is its high strength-to-weight ratio. The corrugated core keeps the face sheets apart, stabilizes them by resisting vertical deformations, and enables the whole structure to act as a single thick plate by virtue of its shearing strength. This second feature imparts outstanding strength to the sandwich structures. Impact test is carried out according to the ASTM D 5628 standards for determining the energy required to crack or break the specimen under various specified condition of a free falling dart. A free-falling dart is allowed to strike a supported specimen directly from various heights. The piezoelectric dart has a hemispherical tip. The impactor hits the skin of the test specimen, which gives a qualitative indication of severe damage in the sample. The collected data were analysed and the results obtained were discussed.

Keywords -Aircraft Structure, Corrugated Core, Impact

I. INTRODUCTION

Composite materials are formed by combining two or more materials that have quite different properties. Fiber Reinforced Plastic is a composite material made of a polymer matrix reinforced with fibers. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic fibers, while the reinforcements are usually fiberglass, carbon, or aramid. The advantages of composite material are high strength, modulus bending stiffness and chemical resistance. This work has been carried out by L. Olovsson et al [1]. The structure of the composite may be laminated or sandwich structure. In this paper sandwich structure is investigated for impact strength. R.S. Thomson et al [2] has reviewed that in a sandwich, the faces act as the flanges and the core takes the place of the web, in other words, the faces carry in-plane and bending loads, while the core resists transverse shear forces and keeps the facings in place. Compared to a single laminate structure, by using the sandwich concept, the flexural rigidity and flexural strength can be significantly increased.

R. Vignjevic et al [3] has reviewed that the Sandwich structures are special class of materials that is fabricated by attaching two thin and stiff skins to

light weight core. A corrugated-core sandwich structure is comprised of a corrugation sheet between two thin face sheets. The corrugated core keeps the face sheets apart and stabilizes them by resisting vertical deformations, and also enables the whole structure to act as a single thick plate as a virtue of its shearing strength. The geometry of corrugation causes anisotropy to a much higher degree compared to a fiber reinforced material. The separation of the skins by the core increases the moment of inertia of the panel with little increase in weight producing an efficient structure for resisting bending and buckling loads.

The objective of the research focuses on the fabrication and impact behavior study of the corrugated core sandwich structure. The research methodology involved the following steps.

- Preparation of Corrugated cores of Sinusoidal, square, & Triangular profile using epoxy resin and Fiber glass.
- Preparation of face sheet for sandwich structures using Epoxy and Fiber glass.
- Preparation of different sandwich structure using corrugated cores and FRP skin.
- Characterization of sandwich structure for low velocity impact behavior for various heights with free falling constant weight.

The failure mechanisms of sandwich structure are discussed below. Sandwich structures, as many other structural materials are characterized by a mechanical behavior that is strongly dependent on the loading rate. In fact, they can have a ductile behavior in case of static loading, but may behave in a brittle

manner and fail catastrophically when subjected to impact loads. Generally, when a sandwich structure is subjected to an impact, part of the energy associated to the impact is used for the elastic deformation of the material and returned back by the system. The energy in excess is dissipated through several mechanisms, such as fibers breaking, fiber-matrix debonding and delamination in the skins; while the core dissipates energy by crushing and shears deformation. Gupta A et al [4] has explained that the energy absorption capability of glass-epoxy composites is influenced by the factors such as fibers reinforcement type, type of structure, geometry and shape of specimens, orientation of fibers in a layer and stacking sequence of layers. Damage tolerance can be referred to the capability of a structure to carry load after different types of impacts, e.g. things dropped, projectile hits, rough seas and foundering. It can also refer to the capability of the same structure to absorb the energy from, and stop, impacting objects such as projectiles or shrapnel from explosions. Because of its composition a composite sandwich can show a magnitude of failure modes.

Agardh. L et al [5] has reviewed that the modes of failure in sandwich structures depicted can be divided into two main categories, the point load related damages and the structural response related damages. The point load damages occur as a direct result of something hitting the sandwich structure. The researchers performed Impact tests by a drop test machine in order to investigate the structural response of PVC foam sandwiches and AFS panels. Structural response related damages occur because the hitting object forces the structure to deflect too much, resulting in damages.

Less research works are done on the composite corrugate structures using fibers as reinforcement and polymers as matrix. Limited research work is done on the impact behavior of corrugated structure. The effect of change in geometry like thickness and profile of the core made from glass fiber reinforced composite, on the load carrying capacity under different loading conditions is studied to a less extent.

II. CORRUGATED CORE

2.1 Various Shapes of Corrugation

The various shapes of corrugated core used to prepare the sandwich structures are sinusoidal, square, and triangular. Corrugated cores are fabricated using epoxy and glass fiber by hand layup technique.

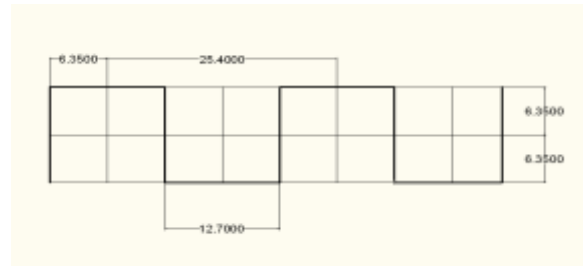


Fig.1 Dimensions of Square Profile

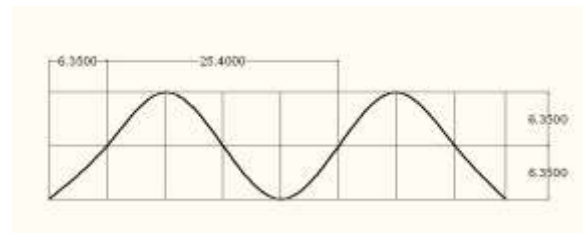


Fig.2 Dimensions of Sinusoidal Profile

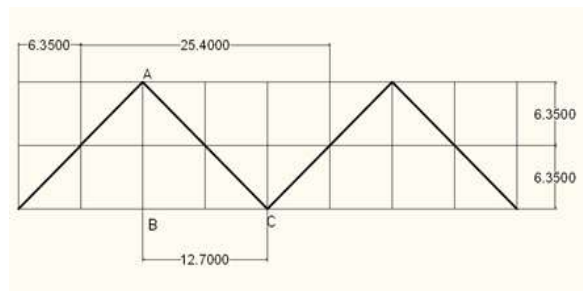


Fig.3 Dimensions of Triangular Profile

Table 1 Configuration of Impact Test

Shape of the Core	Thickness of Core	Mass of the Dart	Height of Falling
Square	0.5, 0.75 & 1.0 mm	11.5 kg	760, 630 & 500 mm
Sinusoidal			
Triangular			

2.2 Preparation of Sandwich structure

- Wooden moulds of three profiles namely sinusoidal, rectangular and triangular profile with the required dimensions were prepared and one of the mould used for preparation of core is shown in Fig. 4. The mould surface is cleaned for any dust, grease & glue present on surface.
- A thin polythene film is pasted with glue to the surface of the mould of both upper and lower part, and then a thin layer of grease is applied on the surface of polythene which helps in the removal of the core from the mould (Fig. 5).
- The calculated amount of resin is weighed and 10% hardener is added the mixture is stirred.
- A layer of resin hardener mixture is applied uniformly using a brush on the surface of the polythene film on lower part of the mould.

- The fiber glass sheet that is cut to required dimension is placed on the resin applied. Resin Hardener mixture is applied on the fiber glass sheet with a brush so that it is properly impregnated with the resin by hand lay up method.
- The above step is repeated for the calculated number of layers to get the required thickness.
- The upper part of mould that has a thin polythene sheet glued to it and a thin layer of grease applied to the polythene surface is placed on to the lower part, making sure both the half of the mould are aligned properly.
- Uniform pressure of around 70 psi is applied on the mould and is cured for 24 hours at room temperature adopted the above data from M.M. Raj et al [6]. After curing the mould is disassembled and the polythene film that acts as releasing agent is removed to get the core.
- The obtained core is cut to required dimension as per ASTM standard using a cutter (Fig. 6).
- Similar procedure is followed to prepare flat face sheets on a flat mould.
- Uniform layer of mixture of hardener and adhesive is applied on the each peaks of the core.
- Face sheet is placed at the top and bottom of the core and a uniform weight is placed over the sandwich and is allowed to cure for 24 hours.

Fig. 4 Mould



Fig.5 Applying Polythene Sheet



Fig.6 Cured Core Cut to Size



Fig.7 Core Bonded With Face Sheets

IMPACT TEST

Impact test is done according to the ASTM standard D5628 for determining the energy required to crack or break the specimen under various specified condition of a free falling dart. Specimens of three types of core geometry and thickness were tested. A free-falling dart is allowed to strike a supported specimen directly. Either a dart having a fixed mass may be dropped from various heights, or a dart having an adjustable mass may be dropped from a fixed height. Fixed mass with various height drop is chosen for the experiment.

3.1 Experimental Procedure

The numbers of specimens to be tested are labelled with a specific ID.

- A constant mass of 11.5 kg is adjusted with the help of bolts at an initial height. The dart with a hemispherical tip having a diameter of 12.7 mm is fixed in the slot provided on the free falling mass.
- The specimen is clamped rigidly on to the fixture with the bolts. Making sure that the clamps are tight so that they are not moved when the dart strikes the specimen.
- In the INSTRON software used to run the test, the details of the test and the specimen were entered, and then the dart connected to the mass is released to strike the specimen. If the mass bounces, it is prevented from striking the specimen again. As the dart strikes the specimen the data of Load, Time, Velocity, Impact energy and Deflection are recorded in the computer.

- By raising the dart, the specimen is removed and inspected the specimen for failures such as crack, debonding, breaking or penetration of dart in the specimen.
- The test was repeated for different specimens by varying the height of the falling mass.

III. RESULTS AND DISCUSSION

4.1 Maximum Load

The maximum load is an index closely related to the load carrying capacity and structural integrity. To identify the behavior of impact load, the maximum loads are obtained.

Fig. 8 shows the peak loads of sinusoidal, square and triangular corrugated specimen as a function of corrugation thickness and impact height. It can be seen that as the thickness of the corrugation increases the peak load also increases for all impact heights of 50 cm, 63 cm and 76 cm. It is observed that the sinusoidal corrugated cored sandwich structure can take larger loads as compared to square and triangular corrugated core because of stress concentration effect is less in case sinusoidal structures.

Similar trend is observed for square and triangular corrugated specimens with different magnitudes.

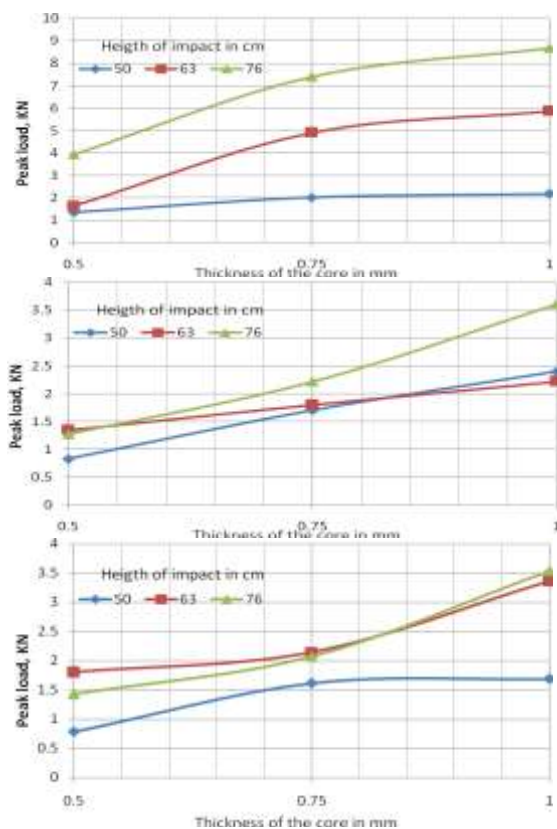


Fig.8 Effect of corrugation thickness and impact height on peak load of a) Sinusoidal b) Square and c) Triangle Corrugated Sandwich

4.2 Maximum Energy

The maximum energy is an index closely related to the maximum energy absorption. To identify the behavior of impact energy absorption, the maximum energy is obtained.

Fig. 9 shows the maximum energy of sinusoidal, square and triangular corrugated specimen as a function of corrugation thickness and impact height. It shows that the maximum energy of the 0.5 mm thick corrugation is very low and as the impact height is increased the maximum energy also increases. The maximum energy of the 1 mm thick corrugation is more compared to 0.5 mm and 0.75 mm thickness. It is observed that the square corrugated cored sandwich structure can absorb more energy as compared to sinusoidal and triangular corrugated core because square shape has higher shear resistance area compared to sinusoidal and triangular structures so it has higher energy absorption capacity.

Similar trend is observed for square and triangular corrugated specimens with different magnitudes.

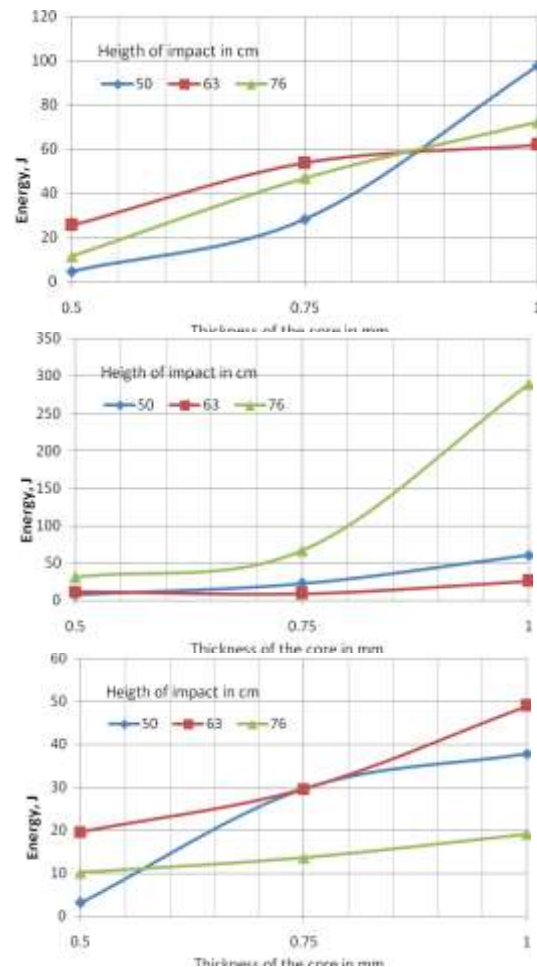


Fig.9 Effect of corrugation thickness and impact height on maximum energy of a) Sinusoidal b) Square and c) Triangle Corrugated Sandwich

4.3 Maximum Deflection

The maximum deflection is an index closely related to the maximum displacement of the specimen due to Impact load. To identify the behavior of deflection, the maximum deflection is obtained.

Fig. 10 shows the maximum deflection of sinusoidal, square and triangular corrugated specimen as a function of corrugation thickness and impact height. It shows that as the thickness is increased the deflection decreases for all impact height. It is observed that the sinusoidal corrugated core sandwich structure has minimum deflection as compared to square and triangular corrugated core.

Similar trend is observed for square and triangular corrugated specimens with different magnitudes.

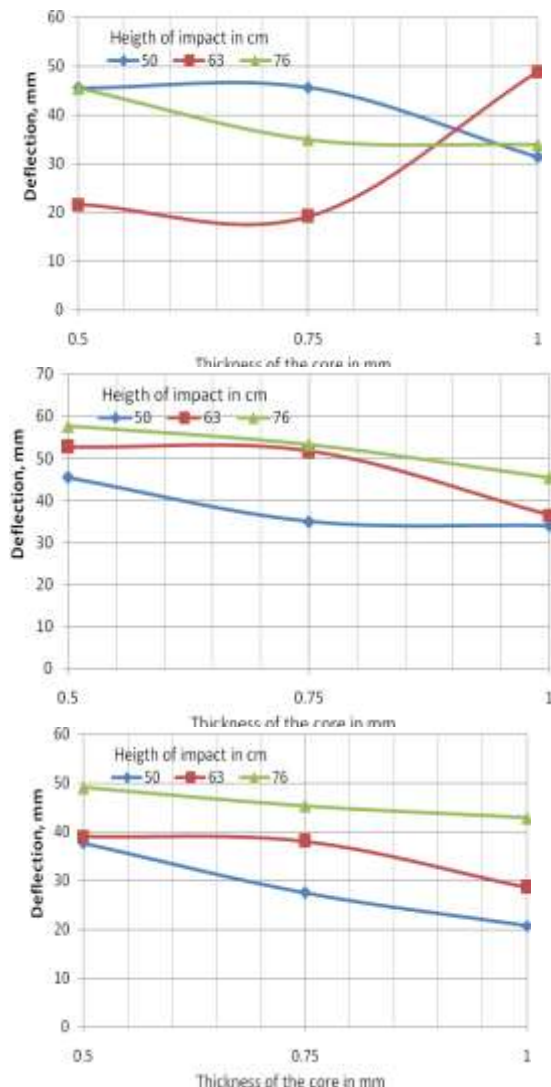


Fig.10 Effect of corrugation thickness and impact height on maximum deflection of a) Sinusoidal b) Square and c) Triangle Corrugated Sandwich

4.4 Damage Studies

Fig. 11 and 12 shows the damage caused on a sinusoidal corrugated specimen due to impact. From Fig. 11 which shows the top side of the specimen after impact it can be seen that the upper face sheet is clearly penetrated by the dart crushing the face sheet and corrugation, the bright white area around the hole is due to the failure of the matrix and the light shade around this area represents the delamination caused due to impact. Fig. 12 shows the lower face sheet, it can be seen that the dart caused lesser damage and there is a crack in the center surrounded by the bright white area where the matrix has failed also delamination is more compare to the top skin which can be seen as the shaded area around the impact position. The sandwich structures have higher structural damping properties hence the energy needed for the initiation of damage and for the propagation of damage is comparatively large compared to plane structures. This improves the impact behavior of sandwich structures.



Fig.11 Image of Damage of Sinusoidal Core Top Side



Fig.12 Image of Damage of Sinusoidal Core Bottom Side

IV. CONCLUSIONS

The Impact test was conducted according to ASTM standards for the corrugated core sandwich structures with sinusoidal, square and triangular profile having the thickness of 0.5 mm, 0.75 mm and 1.0 mm. The results were evaluated and compared the performance of these sandwich structures. With this method impact load, sandwich deflection, impact velocity & impact energy absorption were evaluated.

The following conclusions were drawn from the impact test:

- The sinusoidal corrugated core with 1 mm thickness has the maximum load carrying capacity of 8.6 kN under the impact height of 76 cm whereas the square and triangle corrugated core sandwiches have almost the same load carrying capacity of about 3.5 kN.
- The maximum energy absorption of 285 J is seen in the case of square corrugated core specimen of 1 mm corrugation thickness. From the results conclusion can be drawn that the sandwiches with thicker corrugated core have more energy absorbing capacity.
- The deflection of the 0.5 mm thick corrugated core specimens is more as compared to the 0.75 and 1 mm thick corrugation specimens. The maximum deflection is seen in the case of 0.5 mm thick square corrugated core specimen under the impact height of 76 cm and least deflection is produced by sinusoidal core under impact height of 63 cm. It can be concluded from the results, that lesser the thickness of corrugation higher will be the deflection under same impact load.

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