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DESIGN AND FABRICATION OF EQUIPMENT FOR LOW VELOCITY IMPACT TESTING OF COMPOSITE SANDWICH PANELS

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ABSTRACT

Polymer composite sandwich panels are being utilized increasingly as primary load-carrying components in aircraft and aerospace structures. Serving in this capacity, these structures are subjected to impacts such as tool drops, hail, bird strikes, and runway debris. Unlike for their solid metallic counterparts, predictions of the effects of low-velocity impact damage are difficult and are still relatively immature. Sandwich panels in particular are sensitive to localized impact. For making a systematic study of impact on composite sandwich panels under these conditions, suitable equipment was designed and fabricated.

This article describes the salient features of indigenously developed test equipment for testing localized, penetrating impact on sandwich panels. The size of the sandwich panels in question are 150 X 150 mm^2 with a typical thickness of 16 - 25 mm. The impact velocities are in the region 2 - 6 m/s, with an impactor mass between 2.5 and 12.5 kg, and two types of impactors were used: hemispherical impactor with diameter of 12.5 mm and flat impactor of 25 x 25 mm. Using this equipment laminated composites, sandwich panels and polymer sheets can be tested to assess the resistance to falling weight in the low velocity region. The piezeo - electric sensor of the tester facilitates evaluation of absorbed load and absorbed energy and thus the performance of sandwich structure subjected to single impact, which in turn is useful for the development of useful criteria for materials selection.

Keywords: Sandwich panels, impactors, glass fiber, absorbed energy, impact energy.

1. INTRODUCTION

Composite sandwich structures are widely used in aerospace, marine, aeronautics, automotive and recreational industries because of their high bending stiffness, corrosion resistance, tailorability, and stability. 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 a wide spectrum of impact loads during in-service use. Therefore, in applications where the event of an impact needs to be considered, like in the civil transportation, it is of fundamental importance to predict the impact resistance of candidate materials. Generally, when the sandwich structure is subjected to an impact, part of the energy associated to the impact is used for the elastic deformation on the material and returned by the system. The energy in excess is dissipated through several mechanisms such as fibers breaking, fiber-matrix debonding, and delamination in the face sheets; while the cores dissipates energy by crushing and shear deformation [1-5]. In dealing with laminated composite sandwich panels, the behaviour of the core and the interface between the face sheet and the core play a crucial role in the way the impact energy is absorbed and dissipated.

In general, there are three types of impact machines used in experiments, namely: drop-weight impact rig, which is suitable to simulate low velocity impact by a small mass [6 - 8], or with a large mass guided by a rail during its free fall [9 - 11]; pendulum impactor that consists of a steel ball hanging from a string [12] and gas-gun impactor [13]. The impact tester is useful to determine some important design parameters like energy to produce incipient damage, peak impact force, energy perforation threshold, and restitution coefficient [14], material properties, stacking sequence, boundary conditions, nose impactor dimensions, and weight and drop height, among others. An instrumented impact tester with a free-falling guided mass has been developed and constructed. In designing the equipment, several important criteria were adhered in order to achieve maximum instrument flexibility and reproducibility. Both the impactor mass and drop height are variables thus providing a wide range of impact energies. The equipment is capable of accepting a variety of test-specimen shapes and sizes and is especially useful where there is a restriction in size of the specimen to be tested.

2. SALIENT FEATURES OF DROP WEIGHT TESTER

The drop-weight impact tester developed in our laboratory is able to impact sandwich panels or laminates from a maximum height of 1.5m, with an impactor probe whose weight could vary from 2.5 to 12.5 kg, providing maximum energy up to 180 J. The equipment consists of two vertical stainless steel rods mounted on a heavy steel base. Over the base is mounted a steel laminate of 20mm thickness that has a grooved rectangular opening in the center. In the grooved hole, a sample holder is clipped by using adjustment bolts. The dropping assembly is enabling to slide along the steel rods by cylindrical guides to minimize friction. The impactor probe consists of three components: a dropping head, a base for mounting penetration probes and a penetration impactor. The stainless steel penetration impactor rod with a hemispherical impactor nose has a diameter of 12.5mm and 50mm length; it is attached to the dropping head

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through mounting base by screws. Another impactor of 25 x 25 mm flat type was is also used for testing. The photographs of the drop weight impact tester and the impactor probe are shown in Figure-1.

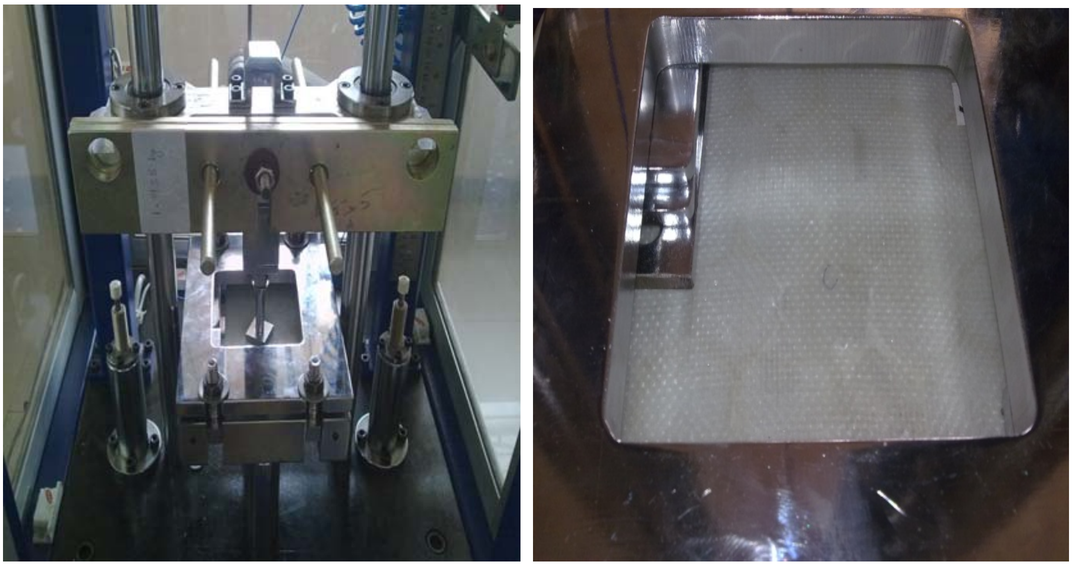

Figure-1. Impactor assembly and specimen fixed in the grooved rectangular opening.

To measure the transient impact force history, PCB ICP force sensors were used. High speed data acquisition system was developed and the data thus acquired were analyzed using a software developed using Visual Basic and C++ in order to calculate the various impact response parameters like peak load, impact velocity, absorbed energy and depth of penetration. Figure-2 indicates the complete set - up of falling weight impact test equipment.

The impact test equipment characteristics allow varying both, free fall height and weight. The tests were carried out by using impact energy ranging from 2 J to 50 J (approximate damaging material sample energy). Once the boundary conditions, weight, and free-falling height are known, the equipment starts sensing the impact force signal by means of pizeo - electric sensor fixed to the impactor and then the data is acquired by the DAQ (Data Acquisition System) and later processed with the aid of software (IMPACT) developed using Visual Basic and C++. The processed data is later displayed wherein the absorbed load and the absorbed energy are as a function of time as indicated in Figures 3 and 4.

Figure-2. Falling weight impact test equipment.

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The mass of the impactor and the drop height are the variables, allowing for a wide range of impact energies. The specimen was constrained on all the edges during the low-velocity impact event. The specimens can be impacted at various energy levels to achieve barely visible damage (BVD), face sheet penetration (FP), and damage levels in the middle of these two types. The Data Acquisition System is so designed to adjust the sweep rate for collecting the data, which facilitates discerning various events that occur during impact in the face sheet and core in a sandwich panel. For example, from Figures 3 and 4, it can be seen that the absorbed load and absorbed energy is more for top face sheet as compared to bottom face sheet. This indicates that the top sheet is slightly thinner than the bottom face sheet.

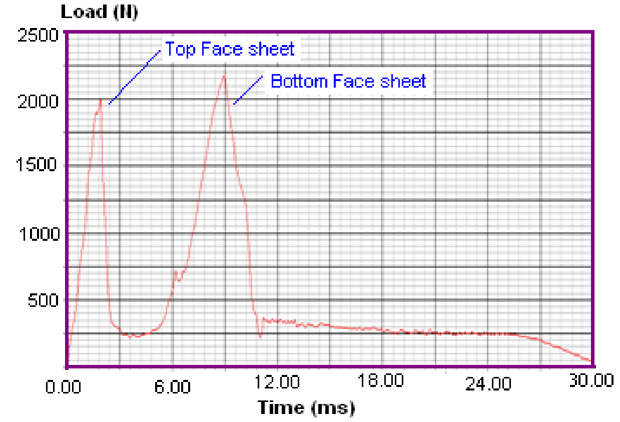


Figure-3. Absorbed load versus time.

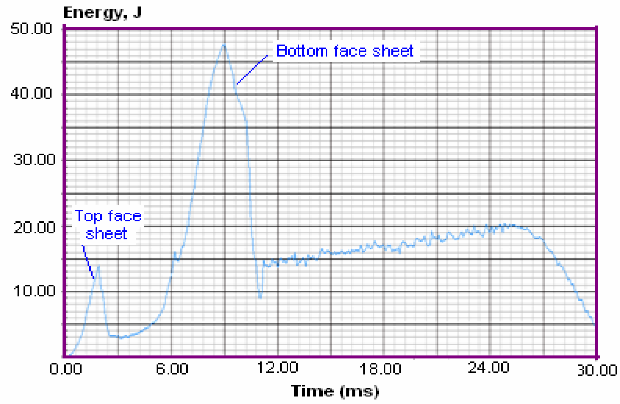
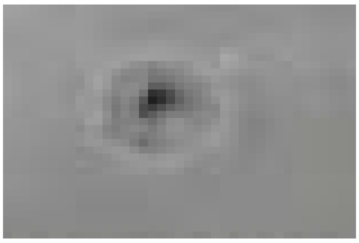


Figure-4. Absorbed energy versus time.

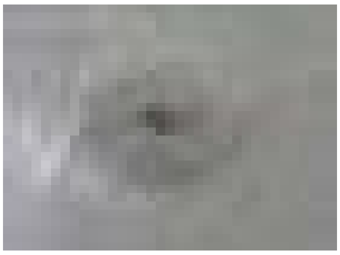
The Falling weight impact tester can be very effectively used to assess the damage in different laminated composites with different types of indentor. The damage type in a FRP Honeycomb core sandwich panel is indicated in Figure-5. In this case, flat indentor was used and one can observe how the cracking takes place in the top face sheet. Similarly, damage in sandwich panels with Polyurethane core with hemispherical indentor was analyzed and is shown in Figure-6. In this case, the way the indentor penetrates in top and bottom face sheets can be seen. The bulging effect in the bottom sheet is shown in Figure-6.

Figure-5.

Damage in the top face sheet in FRP Honeycomb sandwich panel with Flat impactor.



Top face sheet



Bottom face sheet

Figure-6.

Damage in the top and bottom FRP face sheet with Polyurethane Foam as core with hemispherical impactor.

3. CONCLUSIONS

A low cost low velocity falling weight Impact tester has been indigenously developed and fabricated. In this equipment, the mass can be varied from 2.5 to 12.5 Kg and the velocity can be varied from 2 to 6 m/s. The type of indentor can be either of hemispherical end type or with flat type depending on the type of laminated composites to be tested. The transient sweep rate can be suitably adjusted to discern different types of damage events that occur in the specimens. The outputs are computerized plots of absorbed load versus time and absorbed energy versus time.

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