DESIGN AND FABRICATION OF A LOW SPEED IMPACT TESTER

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ABSTRACT

The impact response of sandwich panels with an improved structure to increase their impact resistance is investigated. In order to compare the impact performance of sandwich structures, a specific and instrumented drop-weight impact tester was designed and developed. The experimental part of this work is an evaluation on composite sandwich panels behavior used in the manufacturing of the UNAM Electrobús chassis. Two different sandwich structures are analyzed: the first type is a structure composed by a glass fiber-polyester matrix composite facesheets and a polyethylene honeycomb core. The second one consists of facesheets made from a glass fiber-epoxy matrix composite laminate and core formed by internal phenolic honeycomb structure. The first structure was specifically designed to improve crashworthiness for transport applications. The main results of this study are evaluated from the absorbed energy performance of the sandwich structures subjected to a single impact, and the development of useful criteria for materials selection.

RESUMEN

El proyecto consiste en diseñar, en un sistema FPGA, una memoria dinámica especial llamada MCS-S (MIDI Capture System-Segmented) para capturar, en tiempo real y en forma paralela, datos musicales que provienen de un conjunto de instrumentos mientras tocan en una orquesta, y obtener su partitura. Dentro del sistema, cada segmento de memoria almacena las notas que corresponden a cada instrumento. El control del sistema prepara automáticamente las celdas de memoria necesarias para cada instrumento e inserta de forma paralela nuevas notas para cada segmento. Los componentes electrónicos del sistema están programados en VHDL para después realizar la implementación en FPGA.

KEYWORDS: Sandwich panels, Composite structures, Low impact behavior

1. INTRODUCTION

Composite sandwich structures are widely used in the aerospace, marine, aeronautics, automotive and recreational industries because of their high bending stiffness, corrosion-resistance, tailorability and stability. However, they are also characterized by 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 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 back by the system. The energy in excess is dissipated through several mechanisms such as fibers breaking, fiber-matrix debonding and delamination in the facesheets; while the core dissipates energy by crushing and shear deformation. [1-5].

Under low-velocity impact loading, the composite facesheet damage is usually invisible to the naked eye and spreads over a larger region inside the plate. A low-velocity impact (1-10 m/s) usually implies that the impactor velocity is so low that the damage can be analyzed as a structure under a quasi-static loading [6]. Robinson and Davies [7] have defined low velocity impact in which through-thickness stress waves in the specimen do not influence the stress distribution at any time during the impact event.

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 [8-10], or with a large mass guided by a rail during its free fall [2-3,11-13]; pendulum impactor that consists of a steel ball hanging from a string [14-15], and gas-gun impactor [16].

The impact tester is useful to determine some important design parameters like: energy to produce incipient damage [11-12], peak impact force, energy perforation threshold [14], and restitution coefficient [17], and also to study the effects that take place when varying some testing specifications as: sample geometry [18], 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 constructed in our laboratories. In designing the device, several important criteria were adhered in order to achieve maximum instrument flexibility and reproducibility. Both the impactor mass and drop height are variable thus providing a wide range of impact energies. The device is capable of accepting a variety of test specimen shapes and sizes and is especially useful where small amounts of material are at hand.

2. EXPERIMENTAL

2.1 The drop-weight impact tester

The drop-weight impact tester developed in our laboratory is able to impact panels or laminates from a maximum height of 2 m, with an impactor probe whose weight could vary from 5 to 25 kg, providing impact energy up to 500 J.

The tower consists of two vertical stainless steal rods mounted on a heavy steel base and each end of the bars is clamped on to the wall. The steel base is attached on a structure. The structure is clamped over a block of reinforced concrete. Over the base is mounted a steel laminate of 2 cm thickness that has a grooved circular opening in the center of 20 cm. In the grooved hole, a sample-holder is clipped by using adjustment bolts. The dropping head is enabling to slide along of the 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 12.7mm and 47.5mm of length; it is attached to the dropping head through mounting base by screws. The photographs of the drop weight impact tester and the impactor probe are showed in the Fig. 1.

We have several types of penetration sensor that allow us to have a force capacity of 23 kN. To measure the impact force history, we use PCB ICP® force sensors. The total mass of the impactor probe without load is 5 Kg. PCB Series 480 signal-conditioning amplifier is used to amplify signals from piezoelectric force sensor. The output from the conditioning amplifier is recorded by a digital oscilloscope of 500 MHz (Tektronik TDS540A). The subsequent signals were processed in a PC.

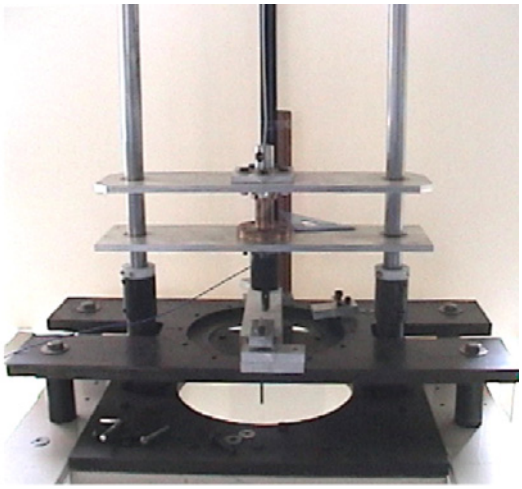
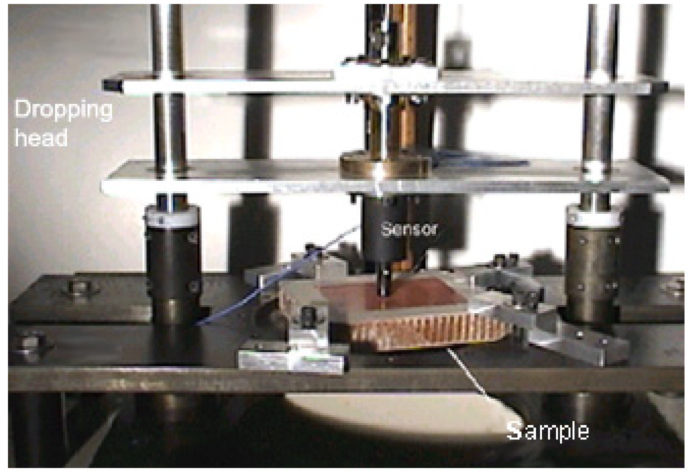



Figure 1. Picture of the impact tester and impactor probe

2.2. Materials

The composite sandwich panels used for the tests were made with: a) random fiberglass/epoxy laminate facesheets and polyethylene honeycomb, (Panel A); b) fiberglass/epoxy laminated with stacking sequence $[90/\ 0/\ 90/\ 0/\ 90]_T$, with 1.5 mm of thickness, and paper phenolic honeycomb, (Panel B). All samples tested with dimensions 115x150 mm were cut from long panels. Fig. 2 shows the geometry and dimensions (mm) of the panel used in the UNAM Electrobús chassis fabrication.

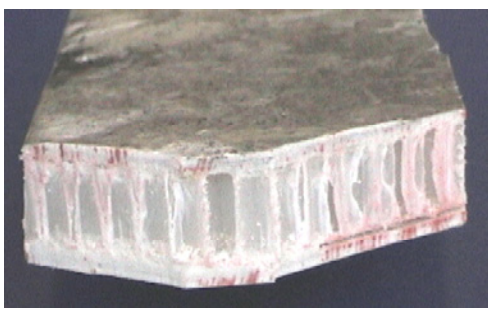
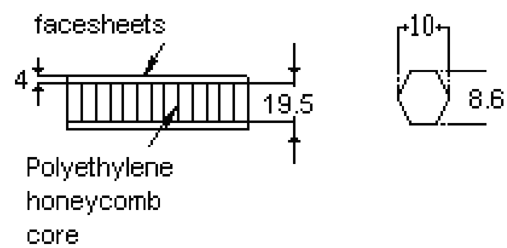
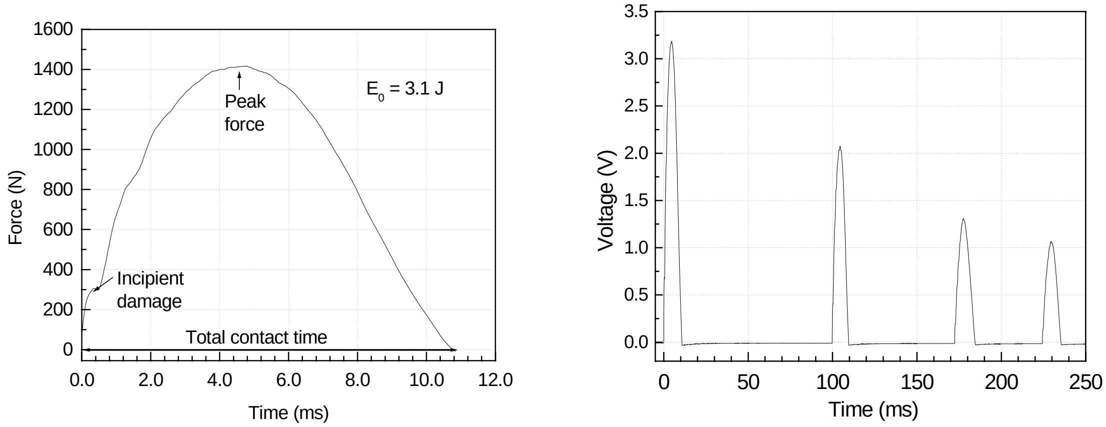



Figure 2. Picture and schematic diagram of a flat sandwich panel A

3. EXPERIMENTAL PROCEDURE AND RESULTS

The impact tester characteristics allow varying both, free-falling height and weight. The tests were carried out by using impact energy range from 2 to 5 J (approximate damaging material sample energy). Once boundary conditions, the weight and free-falling height are known, the test starts sensing the impact force signal by means of the gauged impactor, then this signal is stored and digitized by the oscilloscope for its later analysis in a personal computer. During each test, the dropping head is released at a height to impact the center of the panel.

Figure 3 shows the load history curve for a sandwich panel A sample when the applied impact energy, Eo, was 3.1 J. In this picture can also be seen the principal characteristics of this curve. The load-time trace can be integrated numerically to produce a second curve that is proportional to the area under the load history. Energy history curves can be obtained by the method described in Reference [19].



a) *b)*

Figure 3. a) Force history curve as a function of time,
b) impacts series curve (first impact and successive rebounds) of a Panel A

3.1 Force history

The panels A and B were impacted with the same impact velocity (1.27 m/s) and load (5 kg), the motion on the impactor was along the normal direction l to the mid-plane of the panel sample. Two edges were simply supported, and the other two were fixed on the base. The force histories are shown in the Fig 4. In this case, the panel A did not present visual damage in the contact area; meanwhile, panel B presented local plastic deformation.

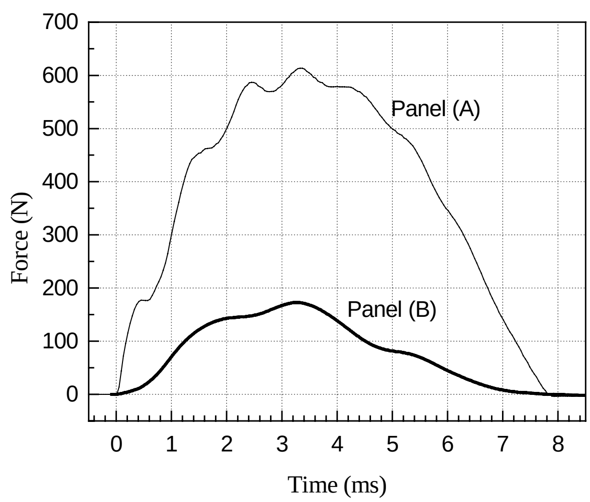


Figure 4. Force histories of the panels A and B at the same impact velocity

Figure 5 shows the force histories of panel A at three different impact velocity levels. At low velocity (1.27 m/s), the impact damage on the facesheet is insignificant and the panel A responds elastically since the loading and unloading curves are almost symmetric with respect to the pick force. As the impact velocity increases (3.89 m/s), the unloading curve extends to the right, indicating that the facesheet panel begins to suffer irreversible damage. To higher impact velocity (4.25 m/s), the panel becomes softer, but there still is not perforated.

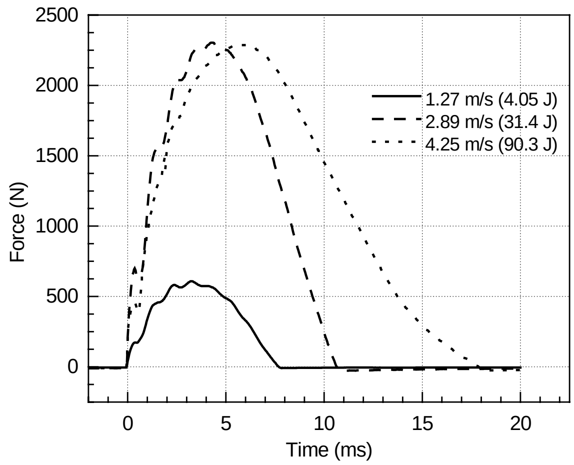


Figure 5. Force histories at three impact velocities on sandwich panel A

3.2 Characteristics of impact

By examining the force and energy histories, it was concluded that the peak force, incipient damage force, contact duration, and absorbed energy are the most important characteristics for the sandwich panels subjected to impact loading.

In Figure 6, it is observed that there is a linear relationship between kinetic energy of impact and incipient force of tests carried out on samples of panel A. As the energy increases, the contact area becomes more notorious, indicating irreversible damage. Normalizing the impact energy with respect to the contact area (E_1), we found a parameter that gives us the material capacity to absorb the impact energy without visible damages. For panel A samples, the E_1 average value was too large, this assures a good behavior under rude conditions of load. The values of E_1 for the two types of panels show that the panel A is 50 times stronger than panel B. For instance, the first was chosen to manufacture the UNAM electrobús chassis.

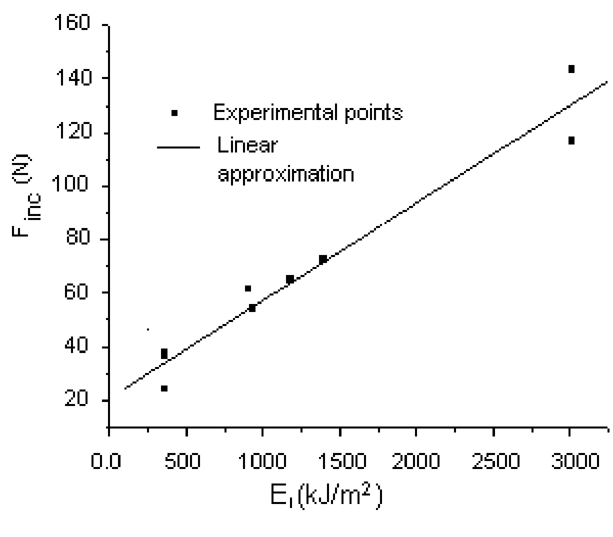


Figure 6. Linear fit between impact energy and incipient force

4. CONCLUSIONS

A device of low cost has been developed, in which we carried out investigations on the incipient energy, restitution coefficient and rupture energy of composite materials. In addition, with simple modifications, it can be adapted to make tests on metallic samples.

5. ACKNODLEDGEMENTS

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