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Behavior of composite and polycarbonate plate under impact.

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Abstract.

The use of filled composite materials in passive safety structure has significantly increased recently because of their low specific mass, stiffness and energy absorption capacities. However those new light weight materials are supposed to exhibit equal or higher performances than classical ones. Therefore interesting applications by using those materials can be thought about like in the manufacturing of aeronautical helmets.

Constituted of an outer shell and an inner foam structure, helmet must protect pilots from an impact by absorbing energy as much as possible and avoid contact between head and impactor. Nowadays different standards describe the minimum required performance for shock attenuation and penetration resistance of helmets [1]. These standards are based on acceleration time history measurements recorded from an accelerometer located at the headform center of mass. For aeronautical standard, acceleration peak value is the only one parameter concerning shock attenuation. Its value must not exceed 300 g, where g = 9.81 m.s-2. Concerning penetration resistance, no contact can be accepted between the penetrating striker and the headform.

The outer shell of the helmet has to resist penetration in order to absorb and to extend the input energy over the foam. The most important part of energy is dissipated by polymeric foam through collapse processes under impact [2]. Nevertheless a significant part of energy (one third [3, 4]) can be dissipated by the plastic deformation of the shell and the occurrence of damage mechanisms.

To obtain different dissipative phenomena, various materials were studied:

a) Three different kinds of polycarbonate were used. This type of material is well known for its large viscoplastic deformations without any significant hardening. In other words it is a very good candidate for helmet application because of high specific energy dissipation and a stress cut-off effect. Moreover a larger affected zone is expected for filled polycarbonate because of an extension due to the addition of silicon.

b) Damage like fiber failure, decohesion, delamination and matrix failure are expected for composite material to dissipate energy [5]. Carbon fiber was chosen with thermoplastic matrix (Polyamide and Polyurethane) to dissipate energy by plasticity and damage. This means that a higher tensile strain is expected.

c) Aramid fibers were chosen because of their high tensile strain (εr=4.5%). Consequently a larger affected zone is expected to dissipate as much as possible energy. An epoxy matrix was loaded with carbon nanotubes in order to increase branching and micro-cracking and also increase dissipated energy.

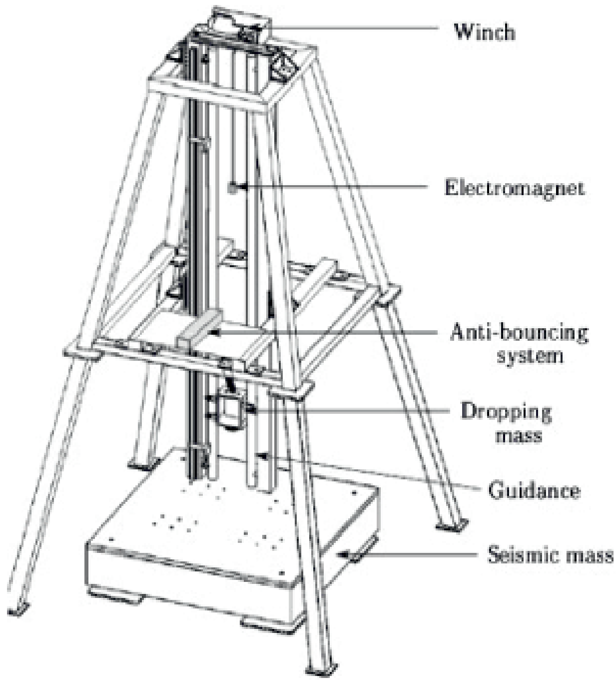

Figure 1 : Drop tower

Experimental tests were performed to evaluate the response of selected material under low velocity impact. The drop tower naturally emerged as the most suitable experiment. The drop tower available in the LAMEFIP laboratory (Figure 1) is equipped of two columns guiding the falling hemispheric impactor. A winch with an electromagnet is used to lift the projectile (from 1kg to 20kg) to the desired height (up to 3 m). An anti-bouncing device is implemented to avoid a second shock [2]. The drop tower is equipped with a force transducer, a displacement laser sensor and a high speed video camera. During the test, specimen was held with clamped edge condition in a 70mm circle fixture. Samples are square plates with size of 100x100mm and variable thickness. Plate samples are used with these boundary conditions to create similar damage to those existing on impacted helmet without working on complex structure. The composite plate thicknesses depend on the number of layers; it varies between 2 and 4 layers. So thickness variations are ranging from 0.57 to 1.04 mm. A 1.770 kg steel impactor with a hemispherical shape and a diameter of 16 mm was used for the tests. The falling height is 50 cm, equivalent to a theoretical kinetic energy of 8.7 Joules.

The final aim of this work is to quantify the dissipated energy in each composite material as a function of the damage mechanism revealed.

References:

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