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EXPERIMENTAL ANALYSIS OF THE SANDWICH COMPOSITES LOADED TO MECHANICAL IMPACT

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Abstract: *This paper presents the experimental analysis of gravitational impact behaviour of sandwich composite plates. The plates (size 280x280mm) are made of two skins, fabricated from fiber-reinforced polymer type E-glass and a polyurethane foam core. The study was carried out for four sizes of plates: thickness of the core, respectively with 10, 15, 20 and 28 [mm]. The study tracked four stages of tests: arming the system, accelerating the impactor, plate impact, returning after impact. Sandwich board is subject to a concentrated impact using a drop-weight device with an impactor spherical. Based on the results the energy absorbed by the plate after the test has been calculated, based on the energy of the impactor in two states: before and after impact. For the experiment equipment was used in the laboratory of advanced materials strength: system-impact, high-speed camera, AOS Imaging Studio application software and Excel Office.*
Keywords: *honeycomb sandwich plates, energy absorption, resistance to impact, high-speed camera*

1. INTRODUCTION

The composite materials have high mechanical properties and specific rigidity and strength that recommend them to be used in transport industry. The foam material and cellular material used as core for sandwich plates have the advantages of lightweight, noise-prevention and impact-proof. The sandwich composites addressed in this study are these types, whose excellent impact energy-absorption capability is very close to be used in shipbuilding. Impact tests for sandwich composite with foam and cellular material core were carried out in the laboratory to examine its mechanical properties.
There are several approaches to analyse impact behavior for composite sandwich panels. For the tests are using Charpy hammer, Drop-Weight and pneumatic systems. Also the impact can be angled vertically or horizontally. The used impactors types are spherical or hemispherical but the most used og them are cillindrical, squares with sharp end or as a projectile impactors. How to place the plate for impact tests can be: supported by into two points [1] ASTM C393 / C393M, in four points or clamped [2]. The plates can be analyzed in terms of depth penetration plate according to behavior aimed plate sandwich can evaluate energy absorption damages at all stages of impact conditions impact, impact energy, size and shape of the impactor and the direction of fibers in the skins structure. In [3] Lister has been investigating the mechanical behavior of some types of sandwiches with the same core (Nomex honeycomb) but with different thicknesses for skins and has tested the plate subjected to three-point bending standards. Gdoutos and Daniel [4] analyzed different ways of failure by indenting a bar sandwich core of PVC, Divinycell H100 and H250, with a density of 100 to 250 kg / m^3, respectively. Tthey were investigated as basic materials and 8-ply unidirectional carbon / epoxy (AS4 / 3501-6) facings. Hassan (and all) [5] approached response laminae of Glass fibers reinforced plastic (GFRPs) at low speed impact. Experimental tests were performed according to ASTM: D5628 for different impact energies initial levels ranging from 9.8 to 29.4 J and specimen thicknesses of 2, 3 and 4 mm. The damage in impact and stiffness of contact have been studied gradually to phase drilling layered compounds which took place in accordance with a force-strain diagram and imaging laminates affected. Olsson R. [6], by using small deformation theory and the theory of contact, studied indentation plates sandwich. Akin (et al) in [7] has experimental studied laminated glass E-glass fibers and epoxy resins at low speed impact. Testing equipment has been specially designed drop-weight. In [8] Olsson (et al) studied ipactul delamination at high speed and low

mass of the impactor. The theory is applied to a series of test cases compared with 3D finite element simulation using LS-DYNA.

2. MATERIALS USED FOR TESTS

In this work, the experimental testing of four types of sandwich plates with thickness skins of 1 [mm] in all cases, and the core thicknesses of 10, 15, 20 and 28 [mm] (fig1) is described. The materials used for skins is epoxy reinforced with E-Glass (3 layers of 0.33 [mm] each). The cores are made of honeycomb made of polypropylene. Sandwich plates sizes are 380X380 [mm] in all cases.

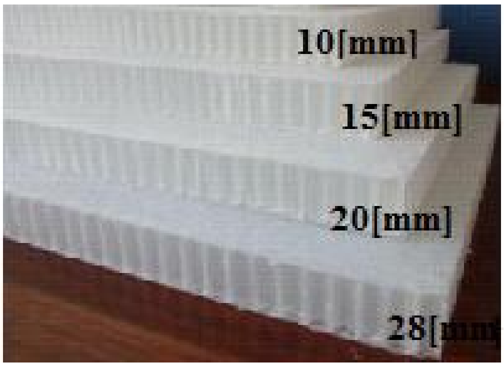


Figure 1: The used cores

Figure 2: Roving with thickness of 0,33[mm]

3. EXPERIMENT

For the experiment the gravitational impact system have been used. This system has five main components: the frame, impactor, sandwich plate holder, LVDT (displacement transducer) (fig. 4) high-speed camera (fig5).
The system has the impactor with the mass of 5 [kg] (Figure 3).
The impactor geometry is a sphere made of steel. The displacement of the sphere is guded by a special path guide.The distance falling impactor is H = 1180 [mm]

Figure 3: The gravitational impact system

Figure 4: The location of Displacement transducer (LVDT)

The output parameters measured during experiment are:

- Maximum displacement measured with the transducer;
- The absorption energy estimated with equation (3);
- The speed measured with High-speed camera (Figure 5).

Figure 5: High-speed camera

3.1 The used method for estimating the absorption energy

The four phases of the impact experiment are:

1. System arming. This phase represent the activities phase in which the plate is mounted to the mounting system, and the maximum height of the impactor is positioned and ready to impact. In this phase, the total energy of the impactor is equal to the potential energy being its maximum height
2. Accelerating phase. In this phase the impactor is in free fall, as the impactor accelerating potential energy turns into kinetic energy. When the plate is reached by the impactor, it has the maximum velocity Vimpact and kinetic energy is determined with (1);
3. The elastic/plastic deforming of the plate. At this stage, the kinetic energy impactor is fully transferred to the plate, which is deformed so elastic and plastic. The plastic deformations are producing the damage in the structure of the composite plate in the form of cracks, delamination, fiber breakage. Plastic deformation produced absorption irreversible energy, which can not be transferred back impactor;
4. Returning after impact. At this stage the elastic deformation energy accumulated by plate is transferred back to impactor in form of kinetic energy. When detaching the test plate, kinetic energy impactor will speed V_{return} is determined with the equation (2).

The energy absorbed by plate, is the difference of kinetic energy impactor that has the before and after impact, according to the equation (3).

$$V_{impact} = \frac{D_{impact}}{dt} + \frac{1}{2} \cdot g \cdot dt \quad (1)$$

$$V_{revenire} = \frac{D_{return}}{dt} + \frac{1}{2} \cdot g \cdot dt \quad (2)$$

$$E_{abs} = \frac{1}{2} \cdot m \cdot \left(V_{impact}^2 - V_{return}^2\right) \quad (3)$$

where

V_{impact} is the impactor speed before impact, [m/s].

D_{impact} is the impactor displacement before impact, [m]. The movement is determined by measuring the distance traveled by a point on the video images of two reference frames, which have a time interval dt. The second reference video frame is the nearest to the moment of impact;

$Vreturn$ is the impactor speed after the impact returning, [m/s].
The time between two video frames, in [s], is determined by:

$$dt = \frac{n}{fps} \tag{4}$$

fps represents the number of frames per second of high speed camera, set and n number of frames set fair to accurately measure displacement (1,2,4 frames);

$g = 9.81 m/s^2$ is the gravity acceleration [m/s^2];

E_{abs} is the energy absorbed by the plate [J]. System consists of test impactor plate, it is considered that the plate is mounted on a rigid support plate and the energy absorbed by the difference between the kinetic energy impactor that has kinetic energy before impact and that is after the impact. The friction guides, friction with the air, Impactor deformation, vibration, acoustic wave system components and energy challenge vibration in question are neglected;
m is impactor mass, [kg].

3.2 The measuring impactor displacement procedure (D_{impact} and D_{return})

1. Uploading video application AOS Imaging Studio
2. Perform calibration by marking the image of the two calibration points 1 and 2 (points whose distance was measured before experiments - ex .: thickness, spikes sensors etc.) and set the value of distance between points the application in the appropriate field (Fig. 6)
3. Running the movie until you reach impactor plate and mark a milestone on the image first measurement point.
4. It runs on a film frame number set (n) frames and mark a milestone on the second image measuring point.
5. Note the displacement value *x* or *y* axis direction.
6. Fill values in Excel file

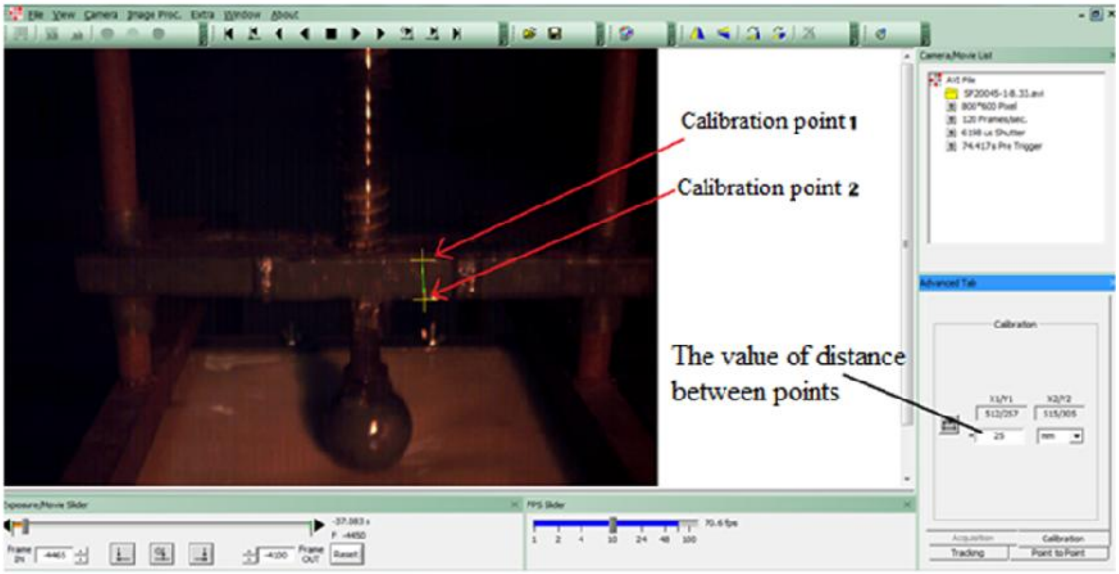


Figure 6: The system calibration with the application AOS Imaging Studio

4. RESULTS AND DISCUSSION

In Table 1 are displayed the values obtained using displacement transducer. The results were processed in software Catman. The main parameter thus obtained was denoted $W_{max.}$ maximum displacement.
In the Tables 2, 3 and 4 are displayed the values are processed using the upper equations and adapted by Newton-Cotes [9] representing the first three contacts with sandwich plate considered the most important in computing. The remaining contacts were considered as rezidues. The most important parameter was calculated as energy absorbed by the plate. According to the equation [10] $E_{residual} = E_{total} - E_{absorbed}$. In 7 figure are presented plates to the damage occurred after impact.

Table 1: Rezultatele testelor experimentale cu sistemul gravitațional

Nr.	Plate type	Maximum displacement $W_{max,}$ [mm]
1	SP10/0,33x3	2,486
2	SP15/0,33x3	1,921
3	SP20/0,33x3	2,181
4	SP28/0,33x3	1,599

Table 2: Results of experimental tests obtained with high speed camera. The first contact with plate

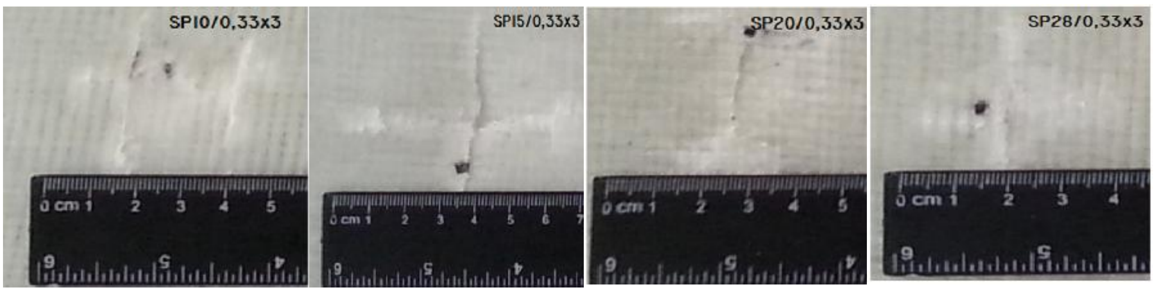
Impact method	Plate type	dt	$D_{impact1}$	$V_{impact1}$	$D_{return1}$	$V_{return1}$	E_{abs1}
		[ms]	[mm]	[m/s]	[mm]	[m/s]	[J]
Gravity Impactor	SP10/0,33x3	8.33	40.44	4.85	19.64	2.36	45.02
Gravity Impactor	SP15/0,33x3	8.33	40.44	4.85	23.24	2.79	39.46
Gravity Impactor	SP20/0,33x3	8.33	40.44	4.85	13.95	1.67	51.91
Gravity Impactor	SP28/0,33x3	8.33	40.44	4.85	17.22	2.07	48.24

Table 3: Results of experimental tests obtained with high speed camera. The second contact with plate

Impact method	Plate type	dt	$D_{impact1}$	$V_{impact1}$	$D_{return1}$	$V_{return1}$	E_{abs1}
		[ms]	[mm]	[m/s]	[mm]	[m/s]	[J]
Gravity Impactor	SP10/0,33x3	8.33	19.05	2.29	9.52	1.14	9.81
Gravity Impactor	SP15/0,33x3	8.33	22.14	2.66	12,17	1.46	12.32
Gravity Impactor	SP20/0,33x3	8.33	13.37	1.61	8,14	0.98	4.05
Gravity Impactor	SP28/0,33x3	8.33	16.12	1.94	11,87	1.42	4.29

Table 4: Results of experimental tests obtained with high speed camera. The third contact with plate

Impact method	Plate type	dt	$D_{impact1}$	$V_{impact1}$	$D_{return1}$	$V_{return1}$	E_{abs1}
		[ms]	[mm]	[m/s]	[mm]	[m/s]	[J]
Gravity Impactor	SP10/0,33x3	8.33	4.21	0.51	2.38	0.29	0.43
Gravity Impactor	SP15/0,33x3	8.33	11.63	1.40	6.11	0.73	3.53
Gravity Impactor	SP20/0,33x3	8.33	7.58	0.91	0	0	2.07
Gravity Impactor	SP28/0,33x3	8.33	10	1.2	5.55	0.67	2.49



a) **b)** **c)** **b)**

Figure 7: Plate specimens after the gravitational impact

5. CONCLUSIONS

Mechanical impact strength is the quality of a plate which allows it to resist against failure when forces act suddenly. The paper presents the experimental tests in the field of damage assessment of sandwich composites plates, having various types of materials for core and various core thicknesses. Results of damage characteristics, and impact parameters (deformations, speed, and energy) have been presented and show the plate behavior under impact loading, as expected. The mechanical behavior of sandwich plates as well as properties of the impactor has to be taken into account in the case of using the plates for strength structures. The experimental modeling and testing procedure can be used at an appropriate procedure in the design process of sandwich plates.

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