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IMPACT RATE EVALUATION OF COMPOSITE SANDWICH PLATES USED IN SHIPBUILDING

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Abstract: *Low weight of ship hull structure is the target in the design process. Lower hull weight enables the possibility of low consumption and thus low emission of the ship. By using the last technologies in composite structures field, many structures have been built from light materials with high performances.*
Response of several composite sandwich plates to impact dynamic loads and to a quasi-static simulation of rigid spherical indenter has been evaluated and compared.
In this paper, the important aspect of dynamic loading of composite sandwich structures is presented. The dynamic response of composite sandwich plates is analyzed by impacting the plates at mid-skin surface with a steel sphere. The numerical analysis was performed by using AUTODYN 3D solver from ANSYS.
Keywords: *sandwich structures, numerical simulation, impact behavior, honeycomb core, foam core*

1. INTRODUCTION

In the last decades composite materials are being used extensively in the construction of ships and marine structures. Composites have a higher stiffness and strength by weight than other materials, such as steel or aluminum. Composite materials are used in various structures of the commercial or pleasure craft. So, the result is a lighter ship that can achieve a higher rate of low emission than the same type of ship built of aluminum or steel. Therefore, the lighter weight keeps fuel costs down, involving significant savings for a ship.
Problems of collision and crashing are very important for ship structures and sandwich structures that have shown good capabilities in absorbing energy. Therefore it is necessary to acquire more and more, better knowledge on the impact behavior of ship structures made out of composite sandwich. Core deformation and failure are important factors for the energy absorption capability of composite sandwich structures. After fracture of the skin, the impacting object may damage and penetrate into the core. In the case of honeycomb cores, damage consists of crushing or buckling of cell walls in the area surrounding the impact point. In foam cores, damage looks like a crack for low-energy impacts.
Impact behavior studies are performed to predict how composites respond to collisions with piers, loads from breaking waves, damage from running aground and debris from possible underwater explosions. The impact testing reveals important data, such as the ductile-to-brittle transition point and residual strength after contact with huge forces.
In [8] Abrate studies the needed speed of a projectile to penetrate the panels made out of layered composites and sandwich. Brenda L.Buitrago studies in [3] the impact behavior of the sandwich panels made out of carbon fibers AS4 and epoxy resin 8552 with core of aluminum 3003. A comparison between experimental and numerical tests produced a gap of 2%. Kilchert has studied impact with small and big speed on sandwich plates with various cores (ex.honeycomb, foldcore) with experimental and numerical methods with package software PAM Crush. The thesis investigates the numerical modeling of sandwich structures with aramid paper foldcore and fiber composite face sheets in quasi-static and impact load cases. For that purpose, existing approaches reproducing cellular sandwich structures on the basis of shell-based meso-models are adapted to aramid paper foldcores. The author focused on the strain rate effects in the material model in case of dynamic loading, on modeling and friction.

2. SANDWICH MATERIAL

The sandwich panels used in this study consist of three main parts:

- Two face sheets of composite glass fibres /Epoxy resin with the nominal face thickness of 1mm;
- A honeycomb polypropylene core and polystyrene core;

The sandwich panels have a square shape of 340mm x340mm. The total thickness of the panel is 22mm. The indenter is a steel sphere, with the diameter of 60mm.

3. RESULTS AND DISCUSSION

3.1 Results for composite sandwich plates with honeycomb core

In the tables 1 and 2 the types of specimens made out of composite sandwich with core of honeycomb used for collision with a steel indenter and impact conditions are presented so for low velocity and high velocity. The results such as impact energy, maximum displacement and total time are presented. As is it seen, the bigger velocity leads to bigger energy and bigger displacement for the same impact time.

Table 1: Low velocity impact for honeycomb polypropylene core

Specimen	Indenter type	Indenter mass [Kg]	Impact velocity [m/s]	Impact energy [J]	Displacement [mm]	Time [s]
1	Steel ball	1.5	3.65	10	8.73	0.0025
2	Steel ball	1.5	5.10	20	12.20	0.0025
3	Steel ball	1.5	6.32	30	15.07	0.0025
4	Steel ball	1.5	7.30	40	17.32	0.0025
5	Steel ball	1.5	8.16	50	19.29	0.0025
6	Steel ball	1.5	8.94	60	21.02	0.0025
7	Steel ball	1.5	9.66	70	22.61	0.0025

Table 2: High velocity impact for honeycomb polypropylene core

Specimen	Indenter type	Indenter mass [Kg]	Impact velocity [m/s]	Impact energy [J]	Displacement [mm]	Time [s]
1	Steel ball	1.5	30	675	70.91	0.0025
2	Steel ball	1.5	35	918	82.71	0.0025
3	Steel ball	1.5	40	1200	156.23/237.06	0.0025

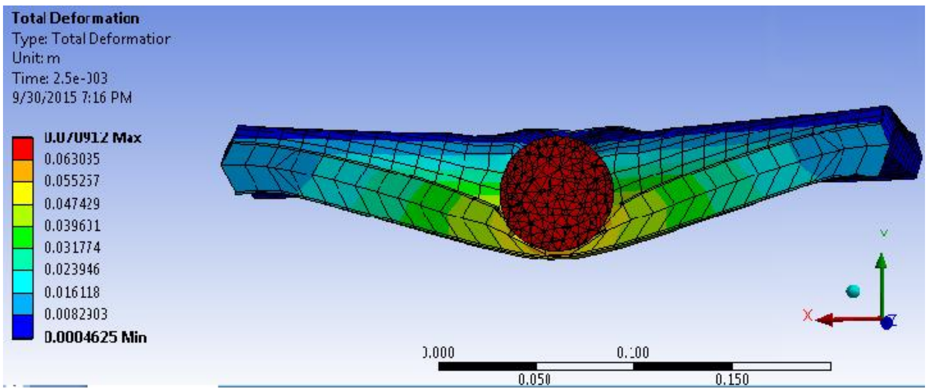

Figure 1: Plate deformation during collision. Velocity v= 30[m/s], honeycomb, E=675 [J]

In Figures 1 and 2 the deformation maps and deforming shapes of the composite plate with core made out of honeycomb, for speeds of 30[m/s] and 40[m/s] are illustrated.

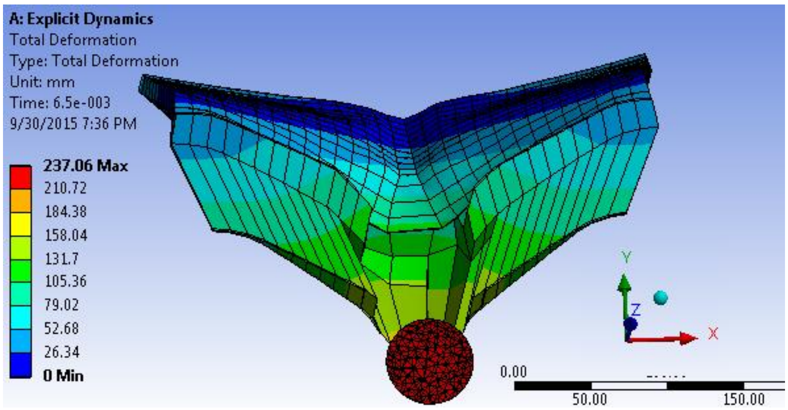

Figure 2: Plate deformation during collision. Velocity v= 40[m/s], honeycomb, E=1200 [J]

3.2 Results for composite sandwich plates with polystyrene core

In the tables 3 and 4 the types of specimens made out of composite sandwich with core of polystyrene used for collision with a steel indenter and impact conditions are presented so for low velocity and high velocity. The results such as impact energy, maximum displacement and total time are presented. As is it seen, the bigger velocity leads to bigger energy and bigger displacement for the same impact time.

Table 3: Low velocity impact for polystyrene core

Specimen	Indenter type	Indenter mass [Kg]	Impact velocity [m/s]	Impact energy [J]	Displacement [mm]	Time [s]
1	Steel ball	1.5	3.65	10	8.39	0.0025
2	Steel ball	1.5	5.10	20	11.46	0.0025
3	Steel ball	1.5	6.32	30	13.84	0.0025
4	Steel ball	1.5	7.30	40	15.65	0.0025
5	Steel ball	1.5	8.16	50	17.05	0.0025
6	Steel ball	1.5	8.94	60	18.40	0.0025
7	Steel ball	1.5	9.66	70	19.63	0.0025

Table 4: High velocity impact for polystyrene core

Specimen	Indenter type	Indenter mass [Kg]	Impact velocity [m/s]	Impact energy [J]	Displacement [mm]	Time [s]
1	Steel ball	1.5	60	2700	58.88	0.0025
2	Steel ball	1.5	65	3168	140.82	0.0025
3	Steel ball	1.5	70	3675	159.82	0.0025

In Figures 3 and 4 the deformation maps and deforming shapes of the composite plate with core made out of polystyrene, for speeds of 60[m/s] and 70[m/s] are illustrated.

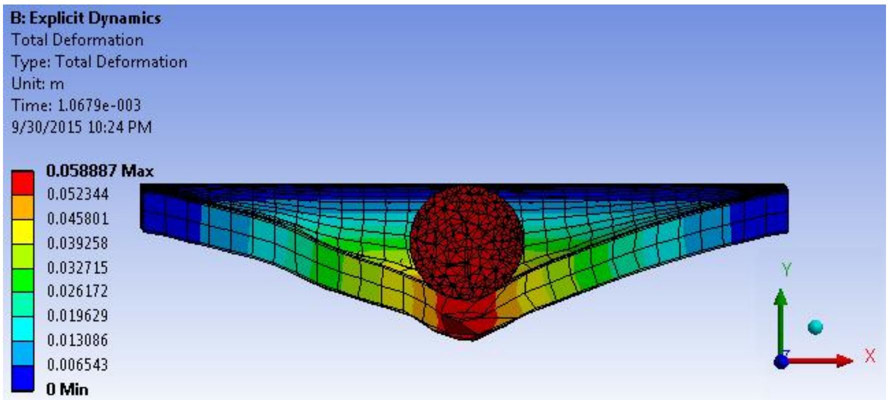

Figure 3: Plate deformation during collision. Velocity v= 60[m/s], core: polystyrene, E=2700 [J]

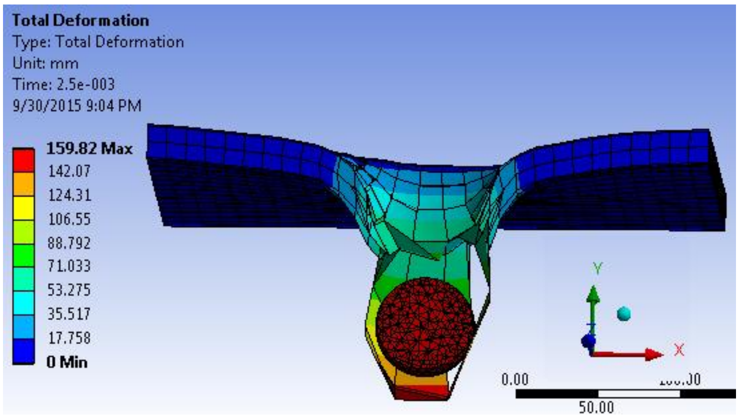

Figure 4: Plate deformation during collision, Velocity v= 70[m/s], core: polystyrene, E=3675 [J]

Variations of impact velocity versus maximum displacement of the sandwich panels for core made out of honeycomb and polystyrene are illustrated in Figure 5.
As it is seen, in the case of core made out of polystyrene the same maximum displacement is obtained for a bigger speed (almost double) than the speed for core made out of honeycomb. Also, the energy absorbed by the composite sandwich plate with core of polystyrene is bigger than the energy absorbed by the composite sandwich plate with core of honeycomb.

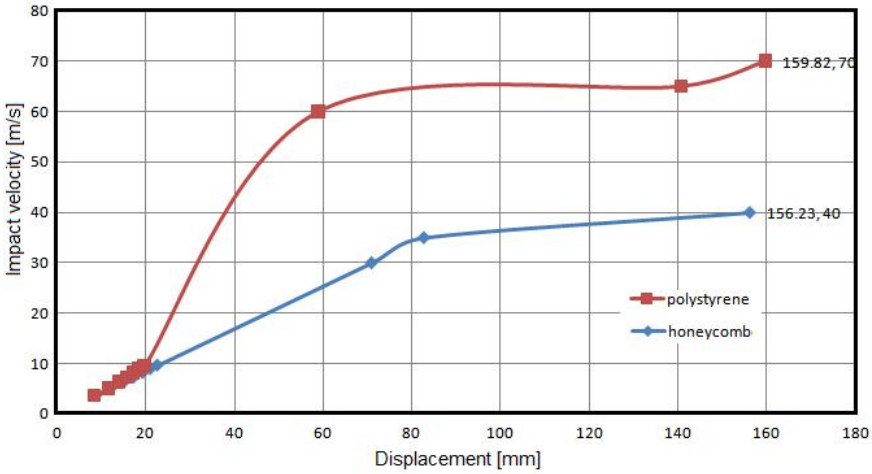

Figure 5: Variation of maximum displacement after collision versus indenter speed

3.3 Impact rate (Impact multiplier)

The deformation δ_d obtained in a plate loaded by impact (dynamic loading) is bigger than the deformation δ_s obtained in the same plate by loading with the same force but in static action.
The coefficient (ratio) ψ calculated as ratio between dynamic deformation δ_d and static deformation δ_s .
The ratio ψ shows also the values of the impact effects (stresses and strains).

$$\psi = \frac{\delta_d}{\delta_s} \tag{1}$$

In the case of the studied plates, the variations of the impact multiplier for the both types of cores versus impact velocity are illustrated in Figure 6.
As it is seen, the impact multiplier in the case of polystyrene is bigger than the impact multiplier in the case of honeycomb.

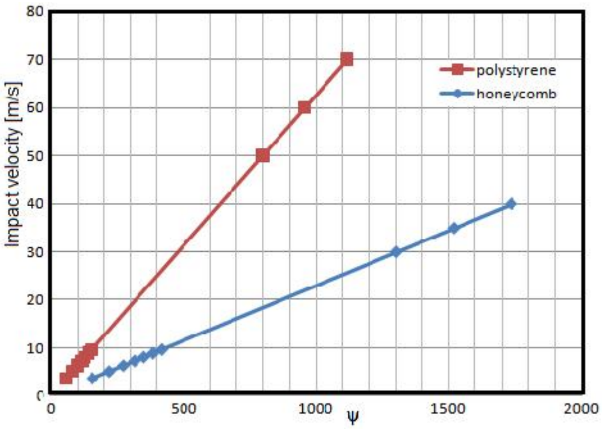

Figure 6: Variation of impact multiplier versus impact velocity for the both cores types

4. CONCLUSIONS

In the paper the response of two types of composite sandwich plates (with core made out of polystyrene and honeycomb) to dynamic loads and to a quasi-static simulation of rigid spherical indenter has been evaluated and compared.

The modality to crashing of the material and also the type of the damage are depending on the indenter mass, geometry and material structure. Important parameters for impact phenomena are the indenter speed and the indenter energy. The two types of speeds have been used: low speeds (from 3.65m/s to 9.66m/s) and high speeds (greater than 30m/s). In static analysis the behavior of the panel with core made out of honeycomb was better than the behavior of the panel with core made out of polystyrene. That is for a force of 15N, the displacement for honeycomb was 0.054mm and for polystyrene was 0.401mm. In dynamic analysis the behavior of the both panel types was vice versa. The sandwich composite panel with core made out of polystyrene has a better dynamic behavior than the sandwich composite panel with core made out of honeycomb. In this case, the panel crashed for an indenter speed of 70m/s.

Also, the cut-out made by the indenter penetration is cleaner for the entrance face than the exit face. The exit cutout has in all cases an delamination. This delamination is extended on an area of couple cm from the main cutout, in fibers direction. Since the number of layers is increasing, the energy is increasing.

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