3rd International Conference
"Advanced Composite Materials Engineering "
COMAT 2010
27- 29 October 2010, Brasov, Romania

STUDY OF COMPOSITE MATERIALS BEHAVIOR UNDER LOW VELOCITY IMPACT

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Abstract: *Low velocity impact is an event frequently observed during service life of composites structures. For example, the front cabin of a high speed train, it can suffer injury from impact with rocks or objects present on the track, birds or other animals, hail etc. Even when following impact damage is not visible in the material, the effect of such damage on mechanical properties of composites must be considered. Therefore, an assessment of possible consequences of impact loads on the mechanical performance of composite structures should be performed.*
The main purpose of the paper is to analyze the low velocity impact behaviour of sandwich materials with COREMAT core and experimental validation of the model proposed using modern calculation methods. The use of software is essential in the evolution of engineering. In aviation products must provide performance and reliability at the highest level. Also, the use of software aims to reduce costs in design, implementation and operation.
Keywords: *sandwich materials, low velocity impact (LVI), delamination, BVID;*

1. NUMERICAL MODEL

The numerical model simulates the behaviour of a sandwich structure with laminated composite faces (4 layers of MAT fibreglass and polyester resin, 0.5 mm thickness per layer), with orthotropic properties (E1 = E2 = E3 = 2100MPa, G12 = G23 = 150MPa, υ12 = υ23 = υ13 = 0.2, ρ = 2160kg/m3), and COREMAT core (4 mm thickness), with E = 800MPa, G = 35MPa, υ = 0.25 and ρ = 630kg/m3. The impactor was considered to be made of steel (E = 2.1e5MPa, υ =0.3), and the mass of 5.74 kg was introduced by density.
The numerical model was analyzed with FEM, using ANSYS LS-DYNA programs, in cases when low velocity impact occurred with energy of 10J and 20J, always produced by the above mentioned impactor. The structure analyzed has a configuration similar to that of the specimens used in the subsequent experimental work. An initial velocity had to be applied to the impactor: 1.86 m/s to simulate the 10 J impact energy, and 2.56 m/s to simulate the 20 J impact energy.
The FE element used to simulate the specimen and the impactor was SOLID146. This is an 8-node element which by default uses reduced integration (one point), this integration level being advantageous due to time savings and robustness in cases of large deformations [1].
The geometry considered is shown in figure 1. The specimen dimensions were 150x100x8 mm, the impactor being represented by a hemispherical body with a diameter of 15 mm. The average size of the hexahedral elements used to mesh the model was 4 mm.
Meshing and boundary conditions (specimen was considered clamped on the edges) are shown in figure 2. Contact type between impactor and specimen was Surface-to-Surface, set automatically by the program [2].
Results obtained from low velocity impact analysis with finite elements are presented in figures 3-6. For the 10 J impact energy the maximum contact force was 2196 N, and for the 20 J impact energy case, the maximum force was 2778 N. The corresponding maximum displacements were 7.68 mm and 12.35 mm, respectively. The maximum von Mises stresses were 89.902MPa and 109.537MPa, respectively, registered in the point of impact, centre of the plate.
The displacements and von Mises stress field at the time step of 9 ms, resulted from numerical analysis of the low velocity impact with 10J energy, are shown in figures 3 and 4. The displacements and von Mises stress field

at the time step of 8 ms, resulted from numerical analysis of the low velocity impact with 20J energy, are shown in figures 5 and 6.

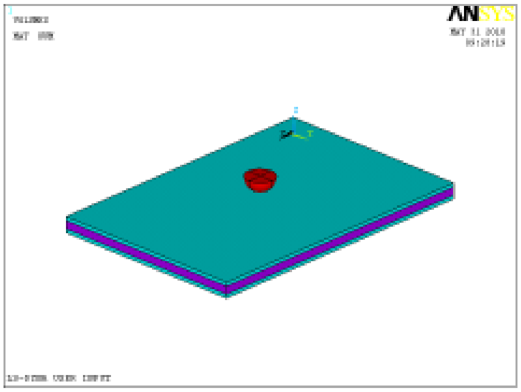

Figure 1: Geometric model.

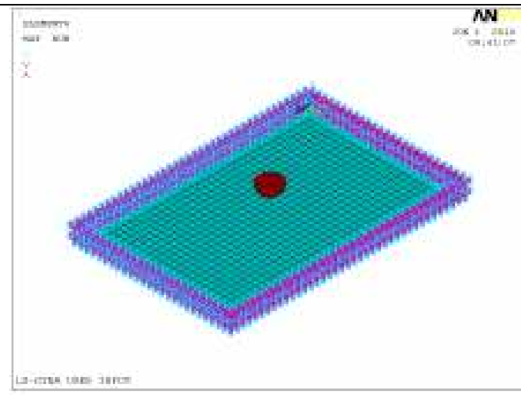

Figure 2: FEM model and boundary conditions.

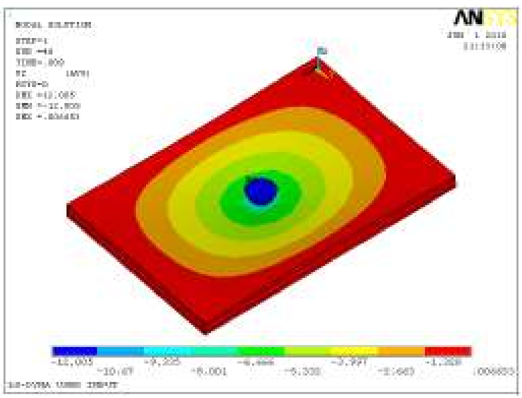

Figure 3: Displacement at low velocity impact with E = 10 J.

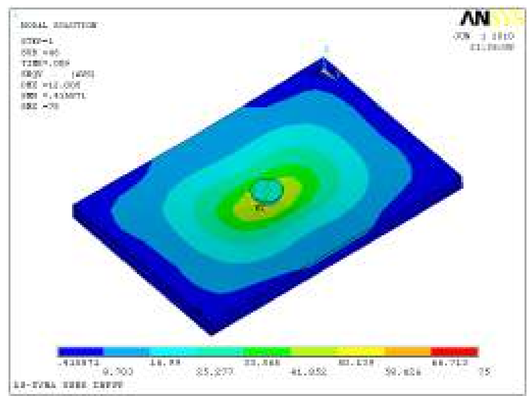

Figure 4: Von Mises stress at low velocity impact with E = 10 J.

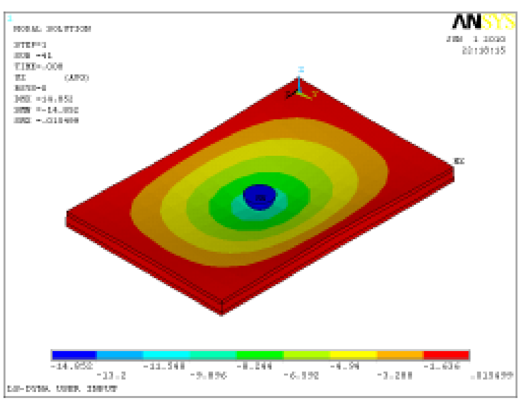

Figure 5: Displacement at low velocity impact with E = 20 J.

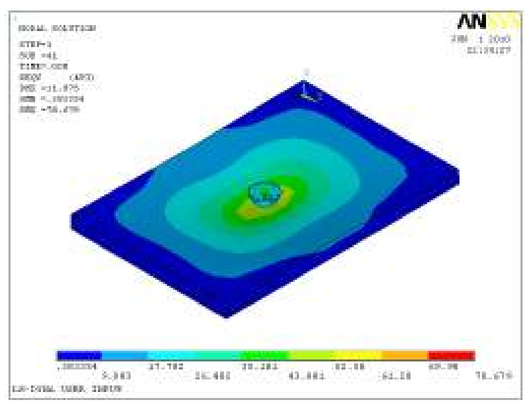

Figure 6: Von Mises stress at low velocity impact with E = 20 J.

The results obtained with FEM analysis have been further on compared with experimental results, presented in the next section.

3. EXPERIMENTAL TESTING

The scope of the tests was to analyze the impact behaviour of sandwich composite materials subjected to low velocity impact. Low velocity impact does generally not lead to perforation of composite materials, but affects in

various ways their integrity. Low velocity impact testing is often able to give indications of the extent and form of the damage [3].
The samples were sandwich plates with COREMAT core and layered composite faces reinforced with MAT glass fibre fabric, with 150x100x8 mm dimensions. Cutting and preparation of the samples were made in the laboratory [4].
Experimental tests of low velocity impact were conducted with the experimental setup presented in figure 7.

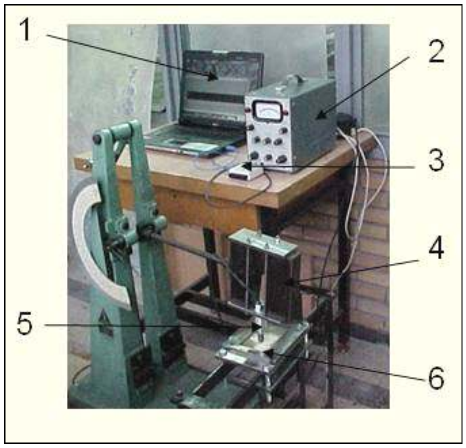

Figure 7: The experimental setup

The experimental setup consists of:
1. Computer for data acquisition using the LabView platform;
2. Analogic HBM bridge;
3. Acquisition card NI DAQ USB-6009;
4. Impact hammer with mass of 5.74 kg;
5. Force transducer;
6. Specimen support;

The formula used to calculate the experimental parameters is shown in equation 1.

$$E = mgh \tag{1}$$

where: m-hammer mass, g-gravitational acceleration, h-impact height.
The experimental parameters are presented in Table 1.

Table 1 The experimental parameters

m[kg]	**E [J]**	**h [m]**
5.74	10	0.177
	20	0.355

For data acquisition it was used a 4s time window, with a rate of 5000 acquisitions per second, thus achieving 20000 sample data to highlight and record the impact force time history.
Processing and storing data from crash tests were carried out using the LabView program (figure 8).

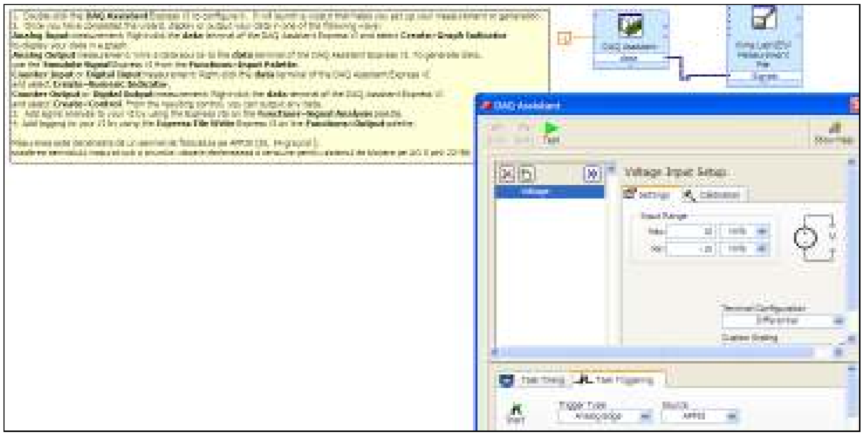

Figure 8: LabVIEW block diagram.

The impacted samples are presented in figures 9 and 10.

Figure 9: Plate subjected at impact with E = 10 J. **Figure 10**: Plate subjected at impact with E = 20 J.

The comparison between the results obtained with FEM analysis and during the experimental tests of low velocity impact at the two energy levels is presented in figures 11 and 12.

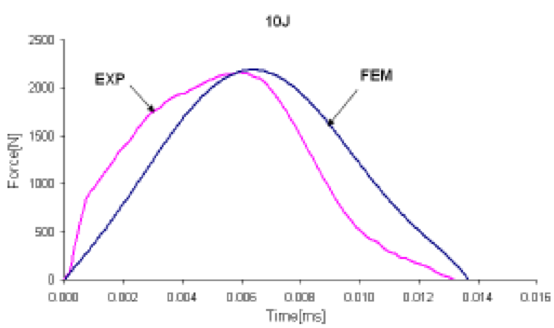

Figure 11: Force history comparation for impact with E = 10 J.

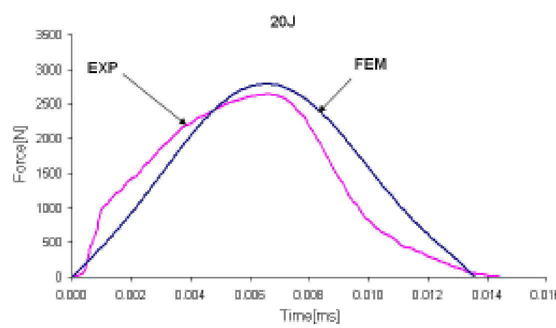

Figure 12: Force history comparation for impact with E = 20 J.

4. CONCLUSIONS

The damage induced in composite structures by low velocity impact tests (impact energy of 10J and 20J) is in the class of BVD (Barely visible impact damage), a concept used to give an indication of initial damage, recommending to achieve non-destructive inspection of the impacted structure. The impact force initiates and develops various damages in the composite material, such as matrix cracking, delaminations and fibre breaking, depending upon the impact energy level. Even confined in the BVD class, damages can significantly affect the residual strength.

The numerical results, presented together with experimental results, show that the contact time is approximately the same. It is to note that for lower impact energy, numerically and experimentally obtained contact forces coincide. At the impact with 20J energy, the difference between the contact force obtained by numerical analysis and experiment is bigger because at higher impact energies, nonlinearities in the contact area are predominant.

ACKNOWLEDGEMENT

This paper is supported by contract number POSDRU/6/1.5/S/16.

REFERENCES

[1]***, ANSYS USER GUIDE, Swanson Analysis Systems Inc., September 15, 1994.
[2] ***, ANSYS LS-DYNA Users's Guide, Swanson Analysis Systems Inc., September 15, 1994.
[3] Cartie D. D. R., Irving P. E. Effect of resin and fibre properties on impact and compression after impact performance of CFRP Composites, Part A: Applied Science and Manufacturing Volume 33, Issue 4, April 2002, Pages 483-493
[4] D7136 – Standard test method for measuring the damage resistance of a fibre reinforced polymer matrix composite to a drop weight impact event. Annual Book of ASTM Standards 2005, pp.430-445.