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DESIGN OF A COMPOSITE AND IMPACT TESTS

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ABSTRACT

The values of the shift of the center of gravity of the composite plate were analyzed. As a result of this test program, a lot of data and observations have been gathered on the impact behavior of composite boards, which can be used for a more complex understanding of the phenomena that may arise over the lifetime of composite structures.

The values of the shift of the center of gravity of the composite plate were analyzed when impacted with a force F=350 N for both a FE model (in static and dynamic approach)and an actual plate. As a result of this test program, a lot of data and observations have been gathered on the impact behavior of composite boards, which can be used for a more complex understanding of the phenomena that may arise over the lifetime of composite structures.

Keywords::impact, composite, finite element method

1. INTRODUCTION

In the light of the technological and economic development, the lack of energy at the global level, the collapse of the commodity prices and the increase of the population’s aggression on the environment, lis leading to the design of new materials and new nonconventional technologies.

Considering the features and the development of composites [8], [9], [10], a special importance is given to their design through modeling and testing. They may have superior properties and are the result of mixing two or more components.

These materials have been created to replace, to such an extent as possible, the already existing traditional materials (ferrous and non-ferrous), which presented certain disadvantages in terms of performance, processes of fabrication, mass, volume, geometric complexities, significant costs and areas of applications.

An important advantage of composite materials consists of the possibility of modulation of properties and, thereby, answering for a diversity of requirements that engineers can use in the majority of technical areas.

Many composites have anisotropic properties, due to their components (long fibres, materials with one or two dimensions much different in size order, etc.).

From a practical standpoint, composites are made of a matrix (metallic, ceramic or polymeric) and reinforcing elements that grant a composite high sustainability. Matrix is representing a main element of the material, with the task of being the liaison between the reinforcement elements. In principle, the two phases do not react with one another.

The designed properties of composites make them be more useful than traditional materials. Because of that, they began to be used in the top technique: nuclear technique, automotive and naval industry, chemical industry, furniture, aerospace, micro electronics, constructions and medicine (especially as implants).

The production of composites was necessary considering the technical considerations and not least the economic ones. Here the following can mention:

- the opportunity to reduce the consumption of manual labor; to decrease the duration of the technological manufacturing;

-the need to increase safety and reliability in the exploitation of various installations and constructions;

-the opportunity to reduce the consumption of expensive, expensive or deficient materials;

-the importance of creating materials that have special properties, which are not attained by traditional materials.

Composites have, due to their outstanding properties, numerous applications in various fields, such as aerospace and aeronautical structures construction; medical equipment; electronics and energy; consumer goods; construction of machinery, automobiles and ships; chemistry; optics, etc.,

The design of structures is generally based on the features provided by the manufacturers of materials, which are usually in the form of the characteristic voltage-deformation diagrams. These diagrams are based on static models, the properties of the material being obtained during testing quasi static, i.e. the solicitations of deformation of the specimen are very slow. In general, the standards relating to the determination of the characteristics of the material relate to test speeds (deformation) of about 0.001 mm/s/or less (table 4.1).

The characteristics of the materials are usually determined from the characteristic curve of voltage-material deformation type, drawn on the basis of the test with a test machine in quasi-static conditions, i.e. with low warp speeds. However, the behavior of the material may differ substantially from the one manifested when solicited with dynamic loads. In light of the dynamic nature of soliciations that occur in a structure, the designer must be aware of the dynamic properties of the material. Normally, a conventional test machine for materials is not able to apply the high rates of deformation required by the dynamic solicitation.

The Behavior of structures at impact was historically found to be of much interest to many engineers, both for design purposes as well as for the development of constitutive models of the materials tested. However, the mechanical characteristics of the materials were determined over the years in terms of static solicitation, so their strengthwas to be determined just for this type of application to which are subjected the structures.

The purpose of the dynamic tests shall be to determine the characteristics of the material at high speeds of deformation, as is the case of phenomena that occur in practice, such as impact, shock, etc.), ballistic (1).

The differences between the characteristic curves of the materials obtained with different speeds are shown in Fig. 1 [15] and it can be noticed that stress varies with 10% to 30%, depending on strain rate.

However, there have been few investigations on the effect that the loading speed had on the properties of the material. Beginning in the 1950 and 1960 there was a spike in the interest about the study of the mechanical behavior at high speeds. These studies have been imposed, in particular with the rise of interest in the military research that dealt with ballistic applications. Another interest was the aerospace industry that was concerned about the impact from meteorites hitting the aircraft.

In these applications, most of the "soft" materials are subjected to solicitations such as impact, explosion, high-speed collisions.

For their numerical modeling, it is of great importance to use material curves (voltage-specific deformation) to provide the most accurate way of behaving during stresses. Reliable experiments on the study materials aim to determine the specific stress-strain curves that provide the most accurate values for obtaining real structures responses.Compared with quasi-static experiments, the dynamic characterizations of materials, especially the "soft" ones at high speed of deformation is still under study and acquires great importance with the rise in the number of impact phenomena.

The layered composite materials reinforced with fibres are composed of a matrix (polymer) and reinforcing material. Heavy construction composites are entirely different substances which can be combined in such a way that their individual properties reach optimal ocaracteristics. Typically, it involves pairs of materials in which one has a load-bearing function, while the other aims to contribute to the acquisition of the momentum of inertia.

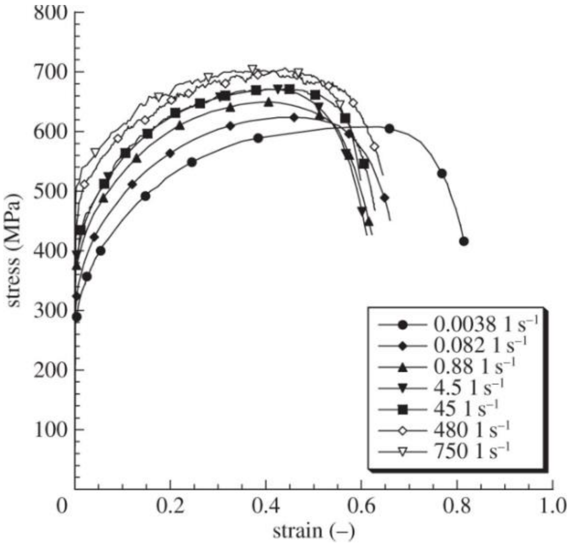


Fig. 1. Characteristic curves of materials for various testing speeds [15]

Table 1. Testing regimes used non-deformation speed

Deformation rate, [s^{-1}]	$\dot{\varepsilon} < 10^{-5}$	**$10^{-5} < \dot{\varepsilon} < 10^{-1}$**	**$10^{-1} < \dot{\varepsilon} < 10^{2}$**	**$10^{2} < \dot{\varepsilon} < 10^{4}$**	**$10^{4} < \dot{\varepsilon}$**
Physical phenomenon	Flowing	Quasi-static	Intermediate	High speed	Impact
Inertia forces	Negligible		Important		
Type of test	Isothermal		Adiabatic		
Equipment used	Conventional machines (hydraulic or electromechanical)		Special operating servohydraulic system	Hopkinson bar type systems	Impact expanding ring

2. THE MANUFACTURE OF COMPOSITE PLATE

There is a wide choice of coverings of plastics reinforced with glass fibres, giving resistance to compression and shear, having high strength and that are ultra lightweight.In the year 1930 in England, Glasgow, there were first manufactured glass fibres [1], [2], but the reinforcement of phenolic resin with glass fibers had as an impediment the high working pressure at which composite material had to be made, a pressure at which the glass fibers deteriorated.The researches were directed towards the discovery of new resins which require low processing pressures. Thus arose the polyester resins with superior characteristics to the phenolic ones. At the same time, it has been given great importance to the study of appropriate catalysts and accelerators that improve the fiber resin bond. Thereafter, the layered laminates of unsaturated polyester resins, reinforced with glass fibers, become the main competing metals [1].

The most commonly used resins to obtain thermoplastic composites are: nylon, polyethylene, polypropylene, acrilații, vinyl etc. They are poured by injection and armed with short, chopped fibers Among the resins used to make thermoplastic composites are unsaturated polyester resins, esters, phenolic resins, silicone resins, epoxy resins, etc. For the fabrication of laminated and reinforced fiber composites, acrylates, polyesters, polyamides are used more often [2], [3].

Phenolic resins are used to obtain varnishes, adhesives, corrosion protection, as casting resins and as press resins. Their main properties are: high mechanical strength and stiffness, dimensional stability, high temperature resistance, corrosion resistance and humidity, good dielectric properties, resistance to solvent action. They have mechanical, chemical and electrical characteristics that place them at the forefront in the hierarchy of base materials used in composite development. The hardened epoxy resins are very harsh materials, their hardness being approximately seven times higher than that of phenolic resins. During curing, these resins suffer a relatively small contraction (max. 25%). Their chemical structure ensures good adhesion between the reinforcement material and the matrix. Epoxy resins also have other properties that recommend them, such as: high resistance to solvents and acids, high dielectric strength, resistance to electric arc, good thermal stability (260 °C), very low water absorption. Due to their qualities, the aerospace industry is the area where they are most used. The disadvantage of these resins is their high price.

In our country both unsaturated polyester resins, used for the production of varnishes and putties (Polestral type), as well as reinforcement resins (Nestrapol type) are produced. The main characteristics of Nestrapol 220 are

-tensile strength: 50 MPa;
-resistance to compression: 165 MPa;
-shock resistance: 50 MPa;
-flexural strength: 90 MPa;
-the specific elongation: 5%;
-module of elasticity: 3900 MPA.s

The properties of these fibers also depend on the chemical composition of the glass. In this respect, a number of chemical glass compositions have been developed and tested, but only a few of them have been marketed to create glass.

Choosing the reinforcement material for the intended purpose requires knowledge of the conditions it has to meet:

- tensile, bending and shock resistances significantly higher than those of the array which they arm;
- modulus of elasticity greater than that of the matrix;
- chemical resistance to the matrix;
- a form appropriate to the needs;
- the surface to which the matrix adheres best.

The most commonly used reinforcement are: glass fibres, carbon fibres, asbestos fibers, silica fibers, fibers of quartz, and boron fibers, graphite fibre [2], [3], [4].

Glass fibers obtained by spinning, have the following main characteristics:

-high resistance values for tensile, compression and shock;
-very good dimensional stability;
-high resistance to corrosion;
-are not hygroscopic, do not rot and burn;
-good thermal stability (at 370°C retains approximately 50% of the values of physico-mechanical properties that we have at the usual temperature);
-good thermal and Electrical insulators.

When pulling the fibers through the strip, the base strand is called the strand. From it you can make a series of products like: rowing, mat, fabrics, etc.

Although research into high-performance reinforcement fibers has yielded very good results, their price could only be reduced to a very small extent. An essential factor contributing to the reduction in demand for glass fibers was the appearance of carbon fibers, which since 1970 have been widely used as reinforcement material.

At present, worldwide, for several reasons, carbon fibers are most often used for reinforcing materials. One of the main strengths of their use is the production technology, which, although more complex, is easier to produce for mass production. A second consideration is related to the very good properties of these fibers. In our country carbon fibers are used only rarely and only in the aeronautical industry.

The rowing is a set of parallel base fibers or parallel and non-woven filaments. Depending on the processing techniques, several types of rowing are produced: rowing for chopping, rowing for wrapping, rowing for weaving and rowing for continuous impregnation. By grinding the base fibers (slips), short fibers are obtained which are subsequently treated to ensure compatibility with polyester resins. irrespective of the complexity of the structure .

The placement of fibers in lamellas or lamine groups is based on the mechanical performance pursued for the structure made of the material (stiffness, resistance to certain stresses, etc.). Layered is characterized by the number of lamels entering it, as well as by the θ angle indicating the orientation of the fibers in the laminate.

Each lamina has assigned a local coordinate system *Olt*, where *Ol* axis is parallel to the direction of the fibres, and *Ot* axis is perpendicular to the direction of the fibres contained in the plan of the lamina [1], [2], [3].

Physical characteristics and mechanical properties of elastic composite material can be estimated based on the characteristics of each of the constituents (the mixing rule) [1], [3].

For a lamina you can define the following sizes:

-the percentage by weight of fibres, $M_{(f)}$, as the ratio between the mass of fibres contained in a defined volume of composite material and the total mass of the same volume;

- the percentage mass of the fibers, Mf, as the ratio between the mass of fibers contained in a defined volume of composite material and the total mass of the same volume;
- the percentage of the matrix: Mm = 1 - Mf;
- the fiber percentage, Vf, as the ratio between the volume of fibers contained in a defined volume and that volume;

-: the percentage volume of the matrix: Vm = 1 - Vf;

- mass of fibers per unit area, m_{0f} (kg/m^2).

If indexes M_f and M_m represents the fiber and matrix mass, respectively, and ρ the similar densities, then between defined relationships exist:

$$V_f = \frac{\dfrac{M_f}{\rho_f}}{\dfrac{M_f}{\rho_f} + \dfrac{M_m}{\rho_m}} \tag{1}$$

$$M_f = \frac{V_f \cdot \rho_f}{V_f \cdot \rho_f + V_m \cdot \rho_m}. \tag{2}$$

An epoxy resin was used for the panel, and unidirectional glass fiber was used as reinforcing material for the core. The plate is made of fiberglass reinforced plastic and has a strong structural bond between the faces of the shells.

The author has made a prototype (Fig. 5.2) with the dimensions of 368 x 368 mm, which has two coatings, also called "coatings", which form the structure. The glass fiber impregnation was made with epoxy resin. 9 layers of unidirectional glass fiber fabric were used. The final thickness of the product is less then 3 mm..

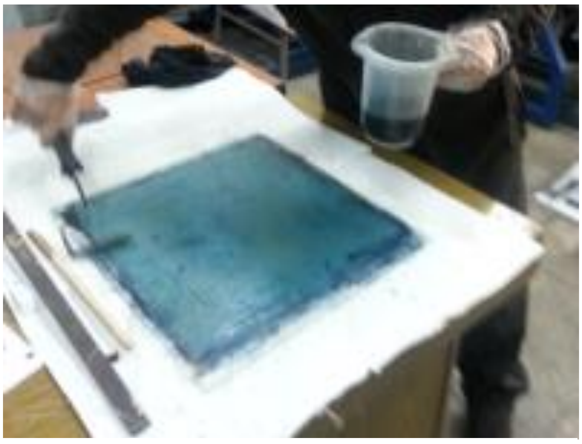


Fig. 2. Manufacturing of composite sheets - Use of the roller for extracting air between layers

3. THE FE MODEL

FEM calculations to determine behavior in both situations: static and dynamic test.

The calculation was performed with ANSYS, AUTODYN, Explicit Dynamics. The results of the dynamic calculation are given below.

The stresses and deformations that appear in the composite plate have been determined.

The model is Lagrangian, isothermal (22 °C), without friction and form by two bodies and it has 3010 nodes and 2429 elements.

Material Date: Structural Steel and Epoxy_EGlass_UD (unidirectional).

The composite sample has the following dimensions: 0.36 x 0.36 x 0.003 [m].

Penetrator velocity just before the impact is 1 m/s

Load is applied in the center of the plate, F = 350 N (step applied). The load is applied in the tangent point between the ball and the plate.

The plate is fixed on the side edges.

Total time of the simulation was 1×e-2 s.

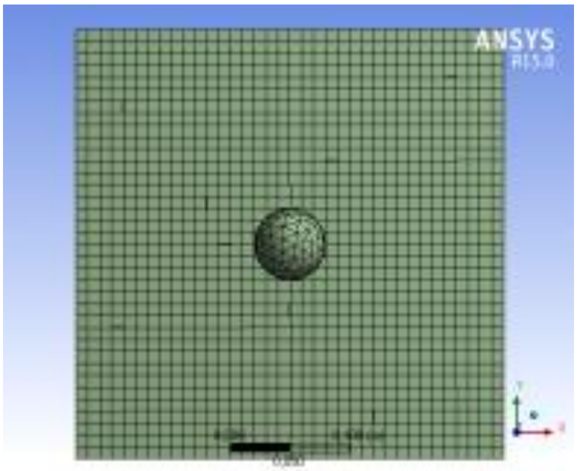


Fig. 3. The meshing of the model

Table. 2 Structural steel strain-life parameters

Strength coefficient, Pa	Strength exponent	Ductility coefficient	Ductility exponent	Cyclic strength coefficient Pa	Cyclic strain hardening exponent
9.2e + 008	-0.106	0.213	-0.47	1 e + 009	0.2

Structural steel isotropic elasticity

Young's modulus, Pa	Poisson ratio	Bulk modulus, Pa	Shear modulus, Pa
2. e + 011	0.3	1.6667e + 011	7.6923e + 010

Table 3. Epoxy_EGlass_UD > PHP-building responsive elasticity (density 2000 kg/m^3)

Young modulus X directions, Pa	Young modulus Y directions, Pa	Young modulus Z directions, Pa	Poisson ratio XY	Poisson ratio YZ	Poisson ratio XZ	Shear modulus XY, Pa	Shear modulus YZ, Pa	Shear modulus XZ, Pa
4.5e + 010	1e + 010	1e + 010	0.3	0.4	0.3	5. e +009	3.82e+009	5.e + 009

Epoxy_EGlass_UD > Php-building responsive strain limits

Tensile X direction	Tensile Y direction	Tensile Z direction	Compressive X direction	Compressive Y direction	Compressive Z direction	Shear XY	Shear YZ	Shear XZ
2.44e-002	3. 5e-003	3.5e-003	-1. 5e-002	-1. 2-002	-1.2-002	1.6e-002	1.2e-002	1.6e-002

Epoxy_EGlass_UD > Php-building responsive stress limits

Tensile X direction Pa	Tensile Y direction Pa	Tensile Z direction, Pa	Compressive direction X, Pa	Compressive direction Y, Pa	Compressive Z direction, Pa	Shear XY, Pa	Shear YZ, Pa	Shear XZ, Pa
1.01e+009	3.5e+ 007	3.5e + 007	6.75e + 008	-1.2e + 008	-1.2e + 008	8e+007	4.61e+007	8.e+007

Epoxy_EGlass_UD > Puck Constants

Compressive inclination XZ	Compressive inclination YZ	Tensile inclination XZ	Tensile inclination YZ
0.25	0.2	0.3	0.2

Epoxy_EGlass_UD > Additional Puck Constants

Interface weakening factor	Degradation parameter, s	Degradation paramete,r M
0.8	0.5	0.5

Epoxy_EGlass_UD > Tsai-Wu Constants

XY Coupling coefficient	Coupling coefficient YZ	Coupling coefficient X
-1	-1	-1

4. RESULTS FROM DYNAMIC AND STATIC SIMULATION

Due to the material anisotropy, the stress distribution is assymetrical, as in Fig. 5 (at moment 1.47×10^{-3} s). Also, the stress is higher on the fromt surface of the plate. In Fig. 5, the impactor is transparent. Figure 4 presents the evolution of equivalent maximum stress (von Mises), during the impact. From this plot, one may notice that the impactor is rebonded and after that the stress in the plate is decreasing.

Based on the values obtained for the maximum displacement can determine the coefficient of amplification dynamics.

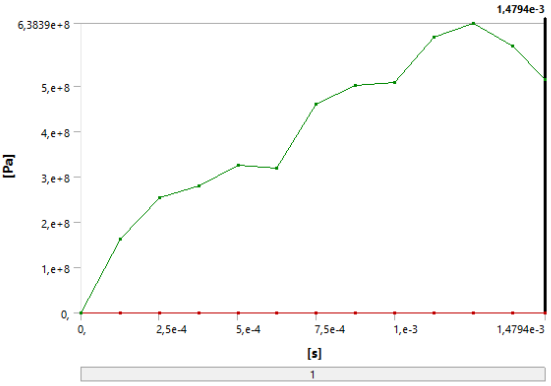
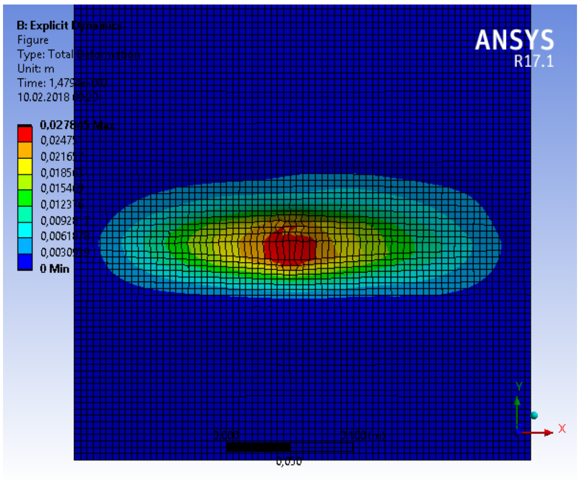
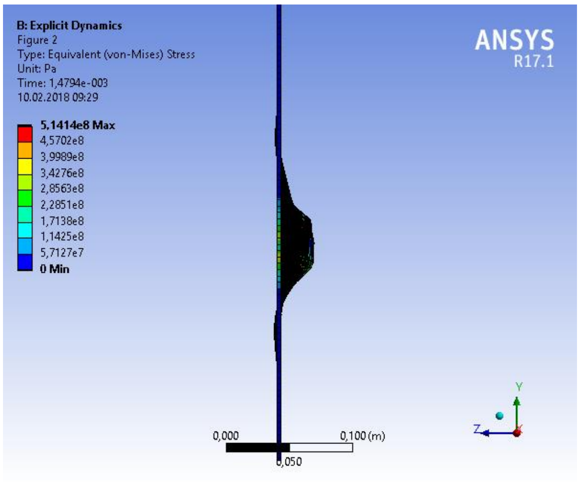


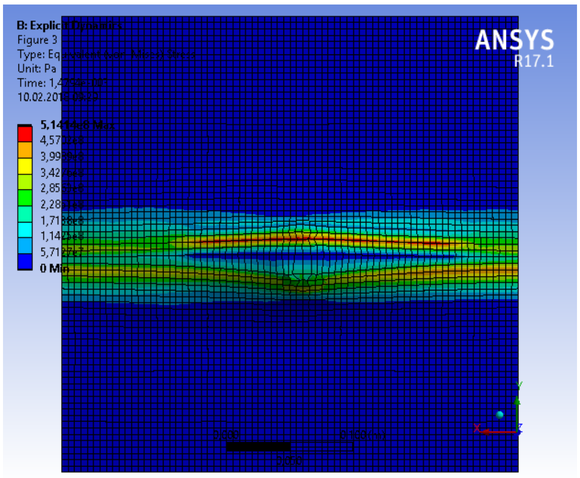
Fig. 4. Evolution of the maximum stress (von Mises)in the plate



a) Front view



b) lateral view



c) back view

Fig. 5. At time moment t=1.47×10^{-3} s

Based on the values obtained for the maximum displacement, the dynamic amplification coefficient can be determined.

For the same force (F=350 N) acting in both situations, the values given in the table were obtained.

Table 4. The maximum values of maximum travel

Type of request	**Maximum displacement (mm)**
Static	4.7
Dynamic	7.4

The dynamic amplification coefficient (the impact multiplier) is determined by the formula

For maximum values obtained in the two tests, we obtain a dynamic amplification factor of 1.57.

5. EXPERIMENTAL WORK

Using the dynamic test bench, dynamic tests were performed on the composite composite plate elastic field to determine the behavior in both situations: static and dynamic testing. The glass fabrics were supplied by Raymond, code T160, having surface mass of 160±11% g/m^2 and the bonding between layers were done with high performance epoxy laminating system from Resoltech, code 1050 and the used hardener was 1055 and the bonding mix obey the technological guide of the producer.

The deformations occurring in the composite plate were determined.

The board was inserted into the gripping system (which was considered to be an embossing on the contour for the plate). A static force of 350 N was applied to the center of the plate.

Upon testing, a displacement of 4.85 mm, measured with the displacement transducer, was obtained.

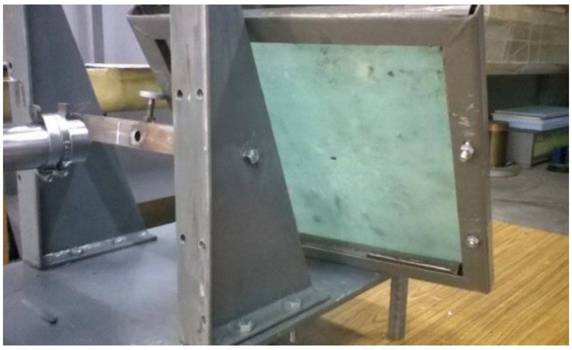


Fig. 6. The plate positioning

Fig. 7. Measuring device for deformation

The force of the impact was measured with a force transducer for different values of the cylinder pressure developed. For system calibration were performed 5 measurements.

During the dynamic test, the variation in time of the displacement of the point of impact was measured with the displacement transducer. Also, the entire impactor path was recorded with the high speed camera (1000 frames/s).

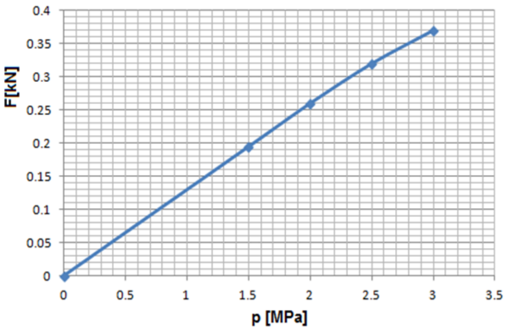


Fig. 8. Calibration diagram, based on Table 5

Table 5. Changes in the impact loading force as a function of pressure in the cylinder

P, MPa	**F1**	**F2**	**F3**	**F4**	**F5**	**Fav**
	kN					
1.5	0.236	0.193	0.198	0.149	0.1962	0.194
2.0	0.280	0.271	0.267	0.262	0.2431	0.265
2.5	0.222	0.285	0.389	0.367	0.3339	0.319
3.0	0.349	0.337	0.342	0.371	0.3482	0.349

Fig. 9. Dynamic test-equipment used

Figure 9 shows the recording equipment used during the dynamic test.

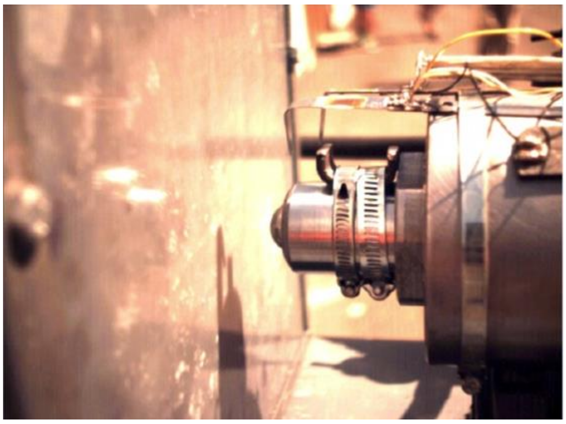
Figure 10 presents the start and end moments of a test. The pressure in the cylinder was 3 MPa.

For this value, during calibrarilor, in accordance with Table 5, a concentrated force of 350 N was obtained by a maximum displacement of 7.84 mm.

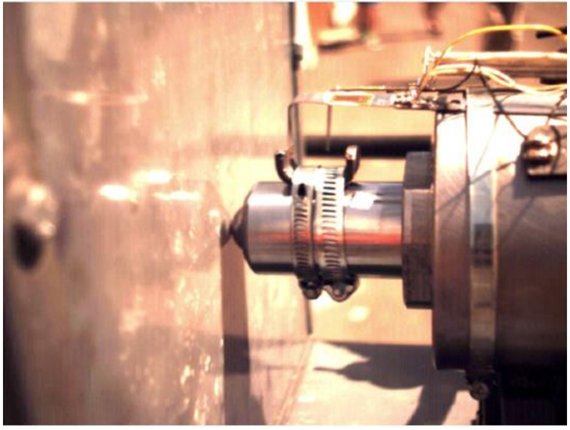
From the results obtained during the experiment, the coefficient of dynamic gain (multiplier impact) was obtained as 1.62.

6. CONCLUSIONS

The values of the shift of the center of gravity of the composite plate were analyzed when impacted with a force F=350 N for both a FE model (in static and dynamic approach)and an actual plate. As a result of this test program, a lot of data and observations have been gathered on the impact behavior of composite boards, which can be used for a more complex understanding of the phenomena that may arise over the lifetime of composite structures.



a) the dynamic Test) at time t = 0



b)

Fig. 10. Dynamic test at time t = 0.022s, hitting the surface of a leaf

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