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DEVELOPMENT OF A MACHINE PER DROP WEIGHT IMPACT FOR COMPOSITE MATERIALS

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Abstract. *The increasing development of reinforced composite materials occurred in recent years has provided new alternatives to solve various problems about the needs of new materials with combinations of properties. To utilize such materials we perform several mechanical tests, such as tensile, compression, flexural and impact mainly. Knowing that the composite laminates are designed according to the conservative practices for working with loads below the last loading capacity and no need to estimate how much these materials can withstand the damage is justified, then this work, which aims to design a machine drop weight impact to composite materials. Studies have been made about composite materials and impacts on laminated structures. Based on these studies and the state of the art about the design of several drop weight impact machines, a machine impact of simple design was projected. The machine has a projected range of impact energy between 20J and 90J obtained by variation of the drop height of several weights. Additionally we performed an analysis of the tension structure of the machine through a CAD software. A prototype of the machine drop weight impact is being built.*

Keywords: *Composite materials, impact testing for drop weight, impact, damage resistance.*

1. INTRODUCTION

The use of composite materials in structural projects has increased in the current days and its application is being made in many areas of engineering. A main reason to choice this type of material is that, sometimes, conventional metal alloys are not able to fulfill all the needs of designers.

The polymeric matrix composites reinforced with fibers or particles are widely used and quickly appear as possible replacements for conventional metallic materials and structural parts in various industrial applications. The industry aerospace's engineers are constantly searching for structural materials and other characteristics as low weight / stiffness and provide resistance to abrasion and impact, and at the same time are resistant to corrosion. Frequently the most resistant materials are dense and increased resistance or stiffness results in a decrease impact resistance. The use of reinforcements in polymeric materials has been opening many possibilities of application for this type composite material (D'ALMEIDA and MONTEIROB, 1998).

The composite carbon fiber has been used in many aircraft components, from simple panels or primary and secondary structures of fuselage, vertical and horizontal empennages and also panels of primary flight controls. The use of composite materials into the automobile industry is more recent than in the aeronautics field. Initially, they were only produced bumpers and roofs of automobiles. Currently, the composite material is used for the production of hoods, sump, steering columns, propeller shafts, leaf springs, panels, and other applications.

However, the composite have not the ductility of metals and cannot absorb the energy of impacts through small local deformations so as metals. In the best situations it can absorb large amounts of impact energy by mechanisms that degrade and damage the composite (POTTER, 1997). Many could be the reasons of this impact, such as a tool falling from a height of one meter accidentally on a structure or any part that is on track and is thrown by the wheel of the landing gear against the structure during takeoff and landing. Quantify and evaluate the consequences of this impact becomes necessary since it is necessary to know if the impact will damage the material used. Two types of tests are used by most researchers, the test done with small masses under high speed, called "gas-gun" and testing of a projectile mass greater under low speed called free-fall or "drop-test". In this work, the focus of the study is the impact of low speeds, then being developed with bodies in free-fall.

The objective of this work is the development of an impact machine that uses bodies in free fall to test composites materials.

2. PROSPECTIVE ANALYSIS

2.1 Impact in composites

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The According (ROMARIZ, 2008) impact loads can induce a local or global damage the structure. In case of global damage can be cited a hammer when falls on airplane wing, affecting all the wing structure. For local damage a piece that snaps off from the aircraft and hurled the landing gear will hit the aircraft structure, affecting only the place where the piece reached. Extensive research has been done about the impact damage in composite plates reinforced polymer (CPR). The main parameters that need to be known to analyze the damage caused are: material, geometry, mass, velocity, kinetic energy of the impactor and the maximum contact force. Only when these variables are defined it is possible analyze the effects and consequences an impact can do in a composite.

The most common defects that occur in fibrous composites are matrix cracking, fiber rupture, creation and growth of delaminations. These damages are often generated by the presence of internal tensions between the composite layers, or between the reinforcing fibers and the matrix.

2.2 Impact test per drop weight

The drop weight test is very simple and consists in drop a mass of certain height over the structure to be tested, Fig.1. This mass suspended has some potential energy that will be converted into kinetic energy when the mass is released. An advantage this method is the possibility to work with samples of different shapes or even the piece itself, witch allows highly reproducible and excellent precision. The ASTM D7136/D7136M-07 determines the extent of the damage resistance of composite materials reinforced polymer. According to the standard a rectangular flat plate composite material CPR is subjected to a concentrated impact caused by a weight attached to a hemispherical impactor.

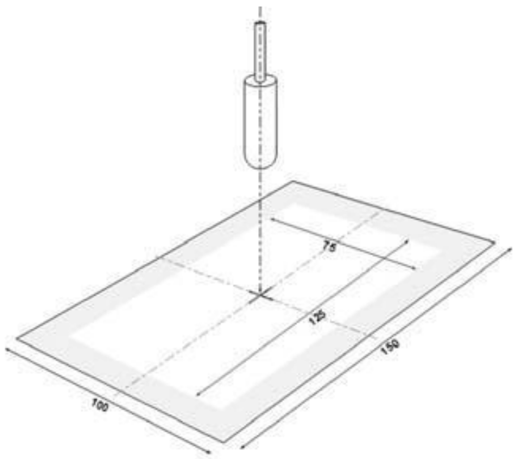

Figure 1. Schematic representation the impact test per drop weight. Source: (Silva, 2011).

2.3 Machines and equipments for drop weight impact

The machines drop weight can be tower type or bench depending on their ability and application. The drop heights vary from 50cm to several meters, depending on the equipment. The speed at impact can reach 11m/s. The impacting mass is released from a height and can fall for a rail system with low friction, such as towers or guide tube. There towers fixing systems which allow specimens of various shapes, allowing test manufactured components. In general, these machines are backed by load cell systems and accelerometers to measure parameters of impact tests. Any testing machine drop weight is composed of the following structural components: guide rail, latch mechanism, crosshead, impactor; velocity detector, stop block, base plate, Fig. 2.

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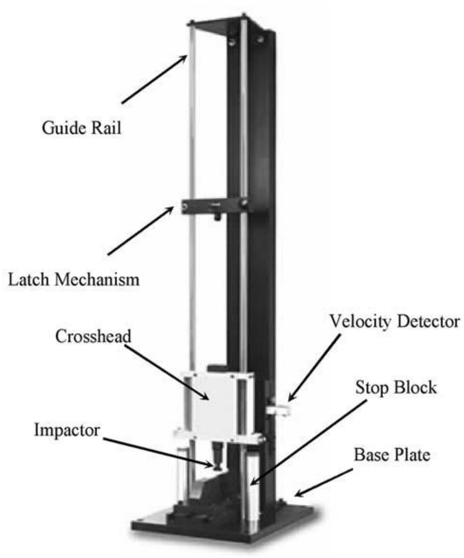

Figure 2. Machine Impact Norm. Source: (ASTM D7136/D7136M-07, 2005)

3 MATERIALS AND METHODS

The design of a device is a specialized process in problem solving. This work, the procedure developed by a number of main stages and in chronological order.

Figure 3 is a schematic flow diagram of the design methodology with its main phases.

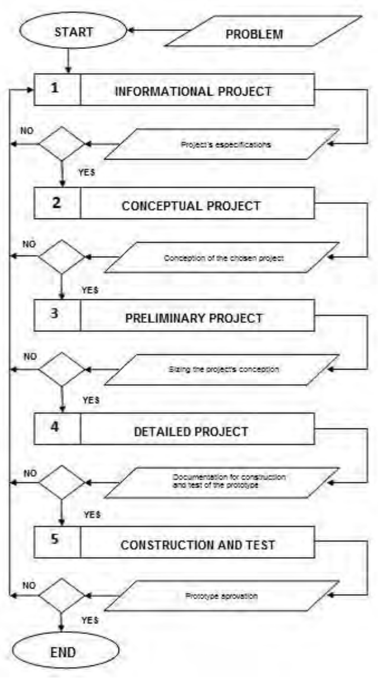

Figure 3. Schematic flow diagram of the design methodology.

- Informational Project: is the interpretation and limitation of available requirements clearly and objectively. Therefore, met all possible information necessary to develop the work;
- Conceptual Project: seeks to present in the form of sketches, diagrams, schematic drawings to visualize the idea that best attend the demand of the project;
- Preliminary Project: seeks to establish material and thickness to resist the efforts requested in accordance;
- Detailed Project: with manufacturing processes and norms current in the country, for their operational safety and reliability the product, detailing the documentation for the construction the prototype;

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- Construction of the prototype: use is made of available resources in terms of manufacturing and assembly, to obtain the physical shape and sized established in previous phases;
- Validation Test: to know it meets design specifications and, consequently, the initial demand obtains the physical shape and sized established in previous phases.

4 RESULTS AND DISCUSSIONS

4.1 Development of an impact machine for composite materials

4.1.1. Informational Project impact machine for composite materials

For the development of the impact machine, we analyzed the progress of this test in the last decades. We analyzed several machines on the market, technical standards and academic articles. A constant among all jobs is lack of detailed design of the machine, which forced us to research and develop different solutions' machine.

Table 1 presents the equipment studied in the phase of information project.

Table 1. Equipments studied in phase Informational Project.

EQUIPMENT	INVENTOR / COMPANY	OBSERVATIONS
University of Prague		Structure made of aluminum, positioned behind the guides (Tower Type).
INSTRON CEAST 9310		Structure tower, located on the sides the guides. (no protection for the operator).

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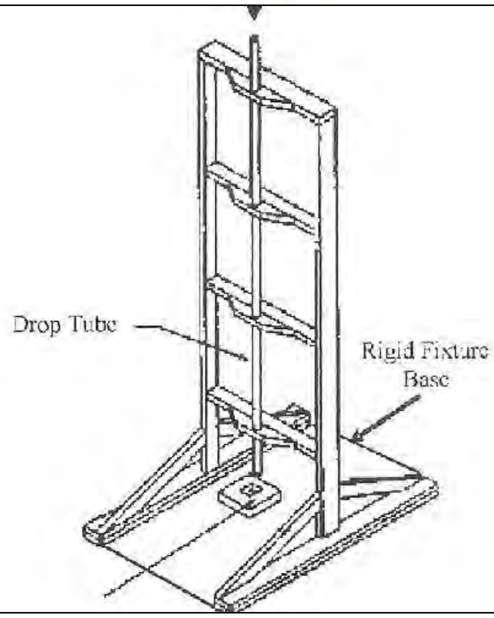
INSTRON CEAST 9340		Structure box, with protection for the operator and the environment under controlled temperature.
Norm ASTM D7136/D7136M-07		Symmetrical structure of simple formatting and easy construction.

Based on studies, it is possible realize the project of an impact machine per drop weight, it is very important to study the following subsystems that make up machine:

1) Mechanism guide for the impactor, which should permit the drop weight without acting high friction between the impactor and these guides.
2) Subsystem composed of the impactor and weight associated with it, this system is most important, since it will define the parameters of the test.
3) Subsystem supports and guides the sample attachment base.
4) Subsystem for attaching the assembly impactor with weight and also permits the variation in height of drop, allowing the energy interval for the test.
5) Subsystem base for the sample.
6) Subsystem against the second impact, allowing more accurate results in the test.
7) Subsystem data acquisition speed and impact force.

4.1.2. Analysis of the impact energy of the machines studied.

The norm not specify the height fall of the impactor and therefore impact energy that the sample will be subject, so a study of the machines on the market, setting the range of energy that these machines use in their essays, Fig 4. These data were obtained from 14 scientific studies, including PhD theses, master's dissertations, journal articles, and professional machines for mechanical tests.

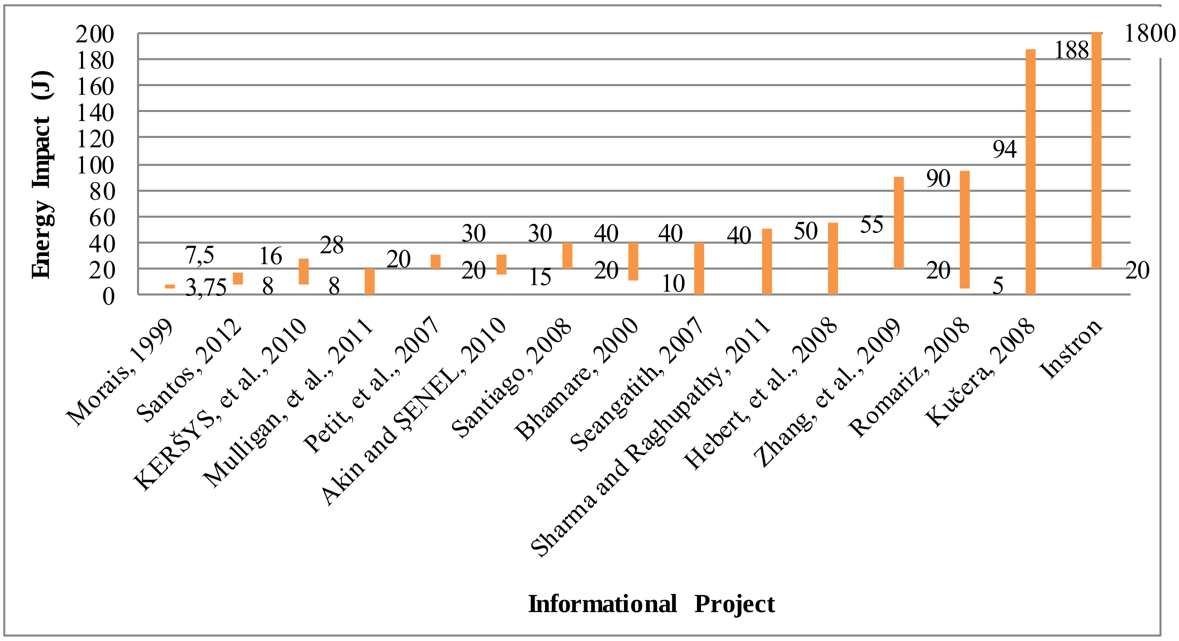


Figure 4. Graphic impact energy of machines researched.

For this study is not considered the machines of INSTRON that work with levels up to 1800J impact energy. It was observed that most machines, about 87%, has a range of impact energy above 20J, as shown in Fig 5.

The purpose of this work is investigate various types of composite materials, so defined a range of impact energy between 20J and 90J, because most failures in composites occurs in this range. Other important aspect is the impact velocity, however we define that the test would have to low velocity impact.

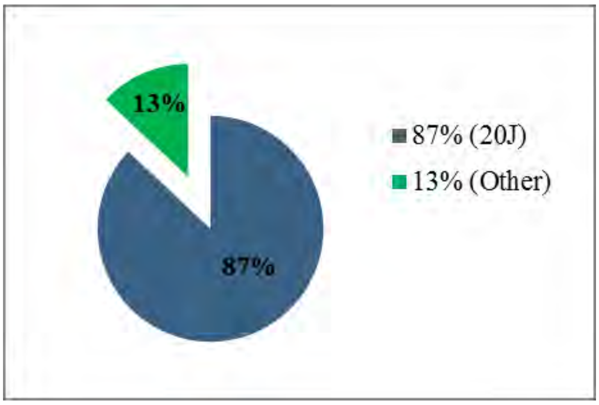


Figure 5. Graph of machines with impact energy above 20J.

4.1.3 Conceptual project of impact machine for composite materials

After the study done in the informational project and defined the variables of the project, we developed a conception for the machine per drop weight impact for composite materials, using software AUTODESK INVENTOR 2013 (student version).

Figure 6 (a) shows the machine of impact per drop weight ready for the test, and (b) shows the impact on the specimen.

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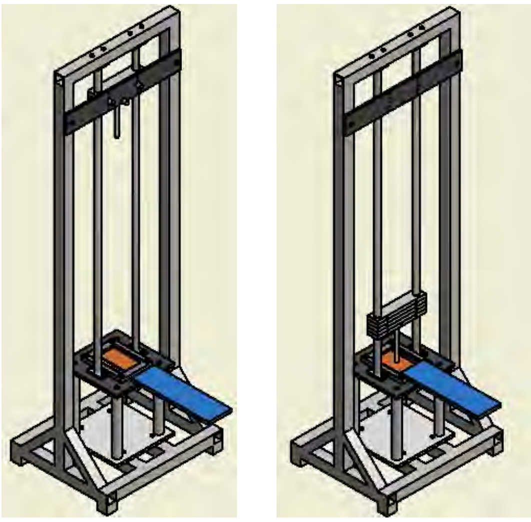


(a) (b)

Figure 6. (a) Machine ready for testing. (b) Impacting the specimen.

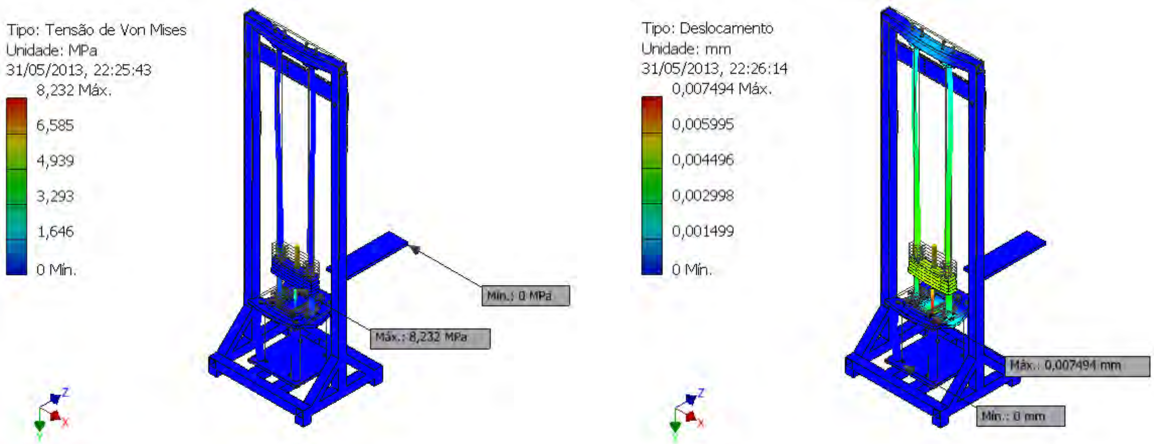
4.1.4 Preliminary project of impact machine for composite materials

After approval of the conception, there is the beginning phase of dimension the machine. For sizing this project was used the standard ASTM D7136/D7136M-07 where data are specified on dimensions of the specimen (100 x 150 mm) as well as impact energy chosen, the weight and the height of fall thereof. Dimension of construction materials was chosen, dimensioning of the device, estimated the cost of materials and the simulation of a critical nature of some components.

4.1.5 Computer simulation of the impact machine for composite materials

The efforts simulation confirm the integrity of the device. Simulations were performed in software AUTODESK INVENTOR 2013 (student version).

Figures 7 show an analysis on the impact machine per drop weight for composite materials in which force was exerted 1kN, where this is justified by the low significance of the results with forces of 0.1 kN (weight associated with the impactor and using a safety factor of 10).



(a) (b)

Figure 7. (a) Analysis of maximum tension in the impact machine. (b) Analysis of maximum deformation on impact machine.

It is noticed that for Fig. 8 the maximum strain (8,232 MPa) occurred the weight of the impactor, near the region where the force was applied, showing that utilize a common steel to provide a yield strength around 210 MPa will satisfy the needs of the project. The maximum deformation observed in Fig. 8 was 0.007494 mm, which is an also suited requirement of the project. Another observation is that both locking pins as screws behaved satisfactorily, which shows the viability of the components.

4.1.6 Construction and test of impact machine for composite materials

The machine drop impact weight composite materials was constructed from this study, as shown in Fig 8. Structural square profile tubular steel was used for the structure, and plates and steel bars used in the manufacture of weights and slide guides. Vibration dampers and Impact have been used to support the machine of impact.

(a) (b)

Figure 8. (a) Front view the machine. (b) Back view the machine.

The tests impact machine was performed on a fiberglass plate, Fig. 9. It can be seen the impact energy was large enough to specimen, causing permanent damage.

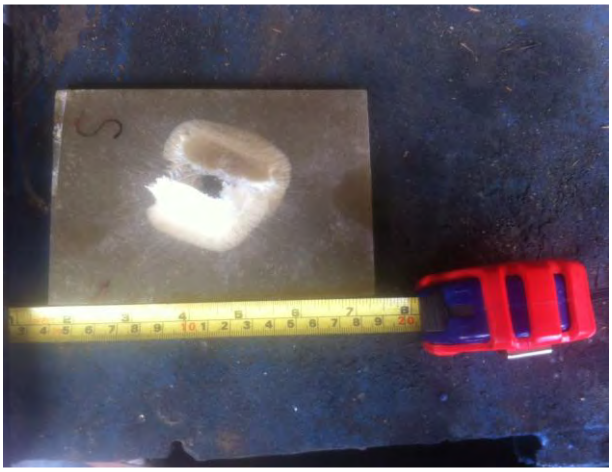


Figure 9. Speciment impacted the test.

The next step of the project will be the instrumentation of the impact machine, where can obtain much information such as impact energy, energy absorbed by the specimen, impact velocity, among other variables. Another improvement is the automation of the system against second impact, which is currently manually.

5 CONCLUSION

With the project presented in this study was possible to build a impact machine for use in tests by dropping weight into composite materials. For the realization this project, considered the following aspects: existing standard, locking system weight impactor, fastening systems components, uniform distribution of tensions, project cost, simplicity of fabrication machine, material to be used, purpose of the project, among others.

With this machine it was possible to realize the test impact by dropping weight to evaluate the aspect of damage resistance of composite laminates.

6 ACKNOWLEDGEMENTS

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