DELAMINATION OF COMPOUND MATERIALS LAMINATED BECAUSE OF MACHINING

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Abstract

The necessary methodology for the study of the delamination of laminated composite materials was to developed, starting with the practice of manufacture of the laminated compounds so finally, performing an analysis of the experimental data obtained in the inspection of laminated specimens.

Keywords

Laminate 1; Delamination 2; Machining 3; PLA (Polylactic acid) 4; CF (Carbon Fiber); CM (Composite Materials) 5.

INTRODUCTION

Currently, the research and application of composite materials (CM) has a great upswing thanks to the manipulation of its properties. Mainly, we can find them in the aerospace and automotive industries.

The use of CM in airplanes has become an alternative by their properties of resistance to impact, corrosion, flexibility and mainly their low weight are ideal for a greater structural performance of the airplane. Although, the manufacture of these materials can be laborious, the finishing of the surfaces and their easy handling can result in a better aerodynamic resistance.

The application of CM in the aerospace industry has been significant. However, these materials present two major disadvantages: their high production costs and manufacturing processes. In Mexico, the aerospace industry is growing, therefore the research focuses mainly on manufacturing industry.

In the automotive industry, the application is already consolidated because it offers a wide variety of benefits to the consumer, including: durability, fuel savings (due to its low weight), and greater safety.

The use of CM in the last 20 years has had an annual growth of 5.7%, which means that in 2006 the production exceeded 10 million tons [1].

There are several fields of application of these materials; next we have the main sectors:

- Electronics: The use of these materials makes them more economic and practical.
- Construction: In this sector, the application achieves more practical and durable assemblies; so, the use of these have become popular.
- Medicine: This sector depends on these materials, since their work equipment is made of CM, in addition of allowing to prolong lives, as in the case of artificial hearts.
- Transportation: The use of composite materials in the automotive and aerospace sector has already been mentioned.
- Leisure: Mainly we can find them in sports equipment (clothing).

However, the use and application of laminated CM has forced to investigate the forms of failure and breakage. In this case, the most usual form is delamination, which consists of a break of the composite laminate along the plane that separates the different layers [2]. So, that break increases the amount of shear stress due to the reduction in stiffness which causes the failure.

The machining of CM is the main cause of delamination failure due to the homogeneity of the materials, the properties of the matrix and the direction of the fibers.

The techniques that cause greater delamination are drilling and milling, as they can cause a separation or fracture of laminate, in the same way causes the temperature increase, causing thermal damage to the material.

The traditional manufacture of composite materials involves many complex processes, which means that production time and costs are large. Currently, there is an alternative where you can automate all stages in a single process, in which the material is deposited at elevated temperature and compacted on a flat surface, where it cools and solidifies, obtaining geometries without the use of molds this method is carried out on a 3D printer.

MANUFACTURING AND MACHINING OF COMPOSITE MATERIALS

Manufacturing of composite materials

The technique used for the manufacture of the pieces was 3D printing this process consists in the placement of material by layers in a base, creating a physical model from a digital model.

The aerodynamic profile was built with NACA 23015 for the specimen, manufactured with two different composite materials: carbon fibre and polylactic acid. In Table 1 the properties of the materials are shown.

Table 1: Properties of the materials used in the manufacture of the specimen.

		Printer used: Prusa 3i xl MakerMex		
	Properties	**Polylactic Acid (PLA)**	**Carbon Fiber (CF)**	**Units**
1.	Printing temperature	195	210	° C
2.	Initial printing temperature	185	200	° C
3.	Final printing temperature	180	195	° C
4.	Diameter of the filament	2.85	2.85	mm
5.	Print speed	50	50	mms^{-1}
6.	Height of the layer	0.2	0.2	mm
7.	Thickness of the wall	0.8	0.8	mm
8.	Filling density	50	50	%

Machining of composite materials

The Figure 1 shows the specimen manufactured in the printer 3D, in which a solid profile was manually machining a groove in the center of the specimen at a speed of 100 rev min^{-1} for the PLA and 200 rev min^{-1} for CF; with a 26/64-inch drill bit. This is for comparing the compression resistance with a manually machined profile with a manufactured with slots from the software.

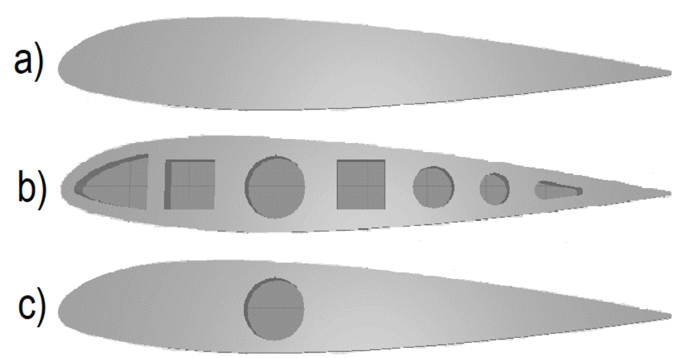

Figure 1: a) The solid specimen is observed. b) The specimen designed from the software and printed with the slots is observed (Manufacturing specimen). c) Solid specimen, manually machining.

OBTAINING AND DISCUSSING RESULTS

To perform the compression tests, the INSTRON® 8872 system was used. With an axial capacity of 25 kN. The assembly of the specimens is shown in Figure 2; where to this, the load is applied by means of a steel plate mounted on the jaw and the flat base of acrylic.

Figure 2: Assembly of the specimens: a) specimen, b) Steel compressor, c) base of acrylic.

Specimen

During the compression test, the specimens were used with the geometry recommended by the NACA 23015 standard, which dimensions for each type of specimen, weight and material are specified in Table 2.

Table 2: Specimen specifications.

Specimen	Material	Weight [gr]	Length [mm]	Height [mm]	Thickness [mm]
Solid	PLA	4.765	100	16	5
	CF	4.524			
Bore	PLA	4.493	100	16	5
	CF	4.188			
Manufacturing	PLA	3.717	100	16	5
	CF	3.447			

Experimental procedure

For each type of specimen, it was calibrated with a preload application close to zero, in the same way a zero advance. In the Table 3 the average of the load in the specimens during the compression tests is presented, later, with a reliability factor of 95%, the load average is obtained. These results can be found represented in Figure 3, where the bars indicate the average of the load and the line shows the variation with the reliability factor.

Table 3: Load in the specimens.

Specimen type	Load variance [N]	Load [N]
PLA Manufacturing	883.60	839.42
CF Manufacturing	705.012	669.80
PLA Solid	1468.03	1394.60
CF Solid	1796.17	1706.40
PLA Bore	836.06	794.25
CF Bore	807.45	767.08

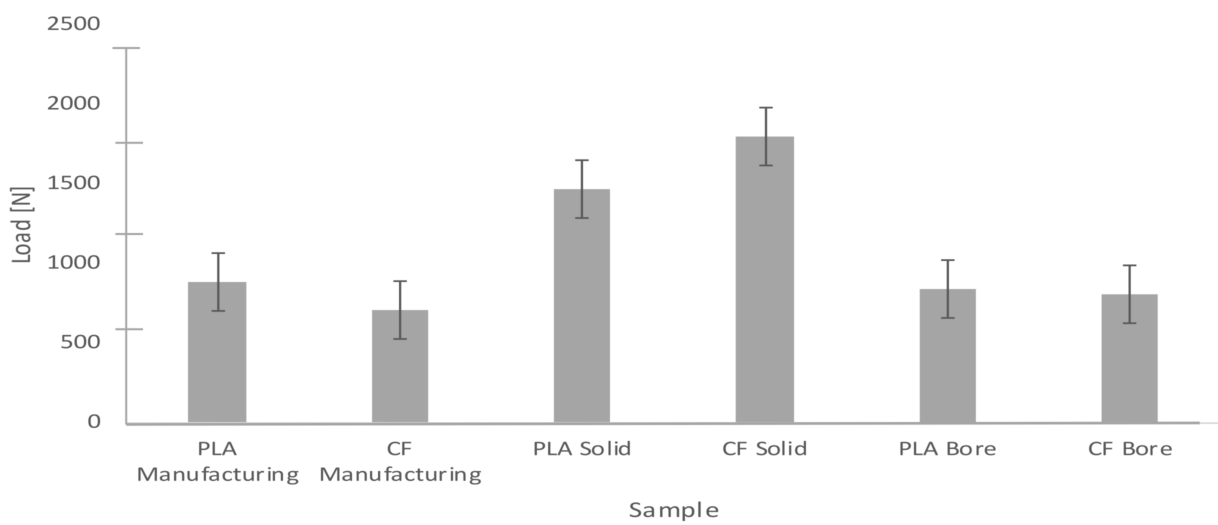

Figure 3: Maximum compression strength of different samples.

FUTURE APPLICATIONS

This article is mainly focused on the application in the aerospace industry, where the wing of an airplane is designed at scale with these materials. It is suggested a rigorous test for importing the design of any aerospace piece.

CONCLUSIONS

The failure of composite materials laminated under compression influences the type of material, since specifically for these tests, it is observed how the PLA tends to delaminate, with a load greater than 800 N. This due to the loss of tangential tension transmission capacity between the layers of the compound, since a fracture occurs between the sheets [3]. While at CF no delamination was observed with a load greater than 1.5 kN. However, for this material it is observed that under compression tends to break the material. Figure 4 shows delaminations in the samples after being compressed.

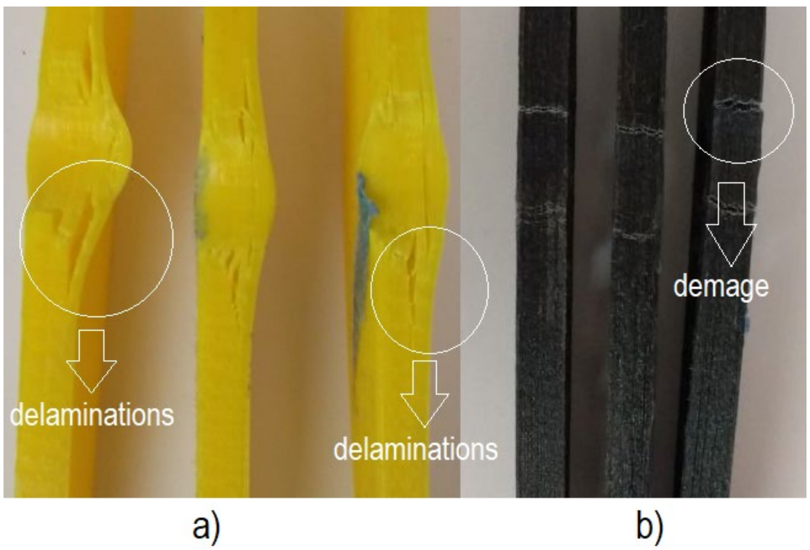

Figure 4. a) In the PLA sample, the delamination occurred during the tests is observed through the circles. b) In the CF sample, damage breakage is observed.

The prediction of failure in composite materials is a complex issue, although they show a similar behavior in the deformation curve, they do not occur in the same point. This is due mainly to the concentration of stress at one point caused by machining.

Finally, the obtained results show that the CF has a greater lightness in comparison with the PLA, in the same way it has a greater rigidity and resistance to the delamination. However, machining with this type of material must be manually and with a low angular velocity, otherwise, due to its very low melting point, the material is carbonized.

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