INFLUENCE OF GRIPPING CONDITIONS ON COMPRESSION TESTING.

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Abstract

Compressive strength (Xc) is one of the most difficult mechanical properties to determine in a composite material due to the fact that compressive test are highly conditioned by anisotropy behavior of composite materials, the appearance of instability phenomenon during the test(buckling, local buckling) or type of gripping conditions of the specimen by the test jaws.

The goal of this experimental study is to observe how the compressive characterization of a unidirectional laminate carbon/epoxy could be affected by using different test configurations, as well as establishing correlation between the results obtained. The different test configurations are obtained through the variation of the following parameters:

- Type of load introduction(Shear or Combined)
- Soft-Load introduction
- Relative position of specimen inside the grips
- Guide system.

1. Introduction

The compressive characterization in composite material didn´t begin to be studied profoundly till the 80's.In 1975 the first compression test was standardized as ASTM D 3410. This test used a Celenease test fixture "which introduce the load by shear" (shear loaded). During the last period of the 80`s the studies focused on compression tests loaded by the ends. Nowadays the combined loaded compression test is gaining prominence. Text fixture as CLC (ASTMD6641-Wyoming test fixture) or HCCF (Zwick patented test fixture) use this sort of load introduction.

Compressive test are highly conditioned by "anisotropy behavior of composite materials, the appearance of instability phenomenon during the test (buckling, local buckling) or gripping conditions of the specimen.

During compressive tests the possible appearance of specimen buckling has to be controlled. All the compression fixtures that have been developed use some kind of guide system which tries to impede the appearance of premature buckling. In the main part of this study, not having used a specific test fixture, the specimen is placed directly inside the jaws in hydraulic grips. This leads us to look for a guide system between the upper and lower grips of the machine.

At the same time, during the compressive tests the appearance of stress concentration in the area where the tab ends is well known. These stress concentration provokes a premature failure of the specimen. To reduce these stress concentrations a new method approved by Airbus, known as “soft load introduction”, is been used. The “soft load introduction” is included in this study by using the HCCF test fixture and special geometric jaws.

The goal of this experimental study is to see how the compressive characterization of a unidirectional laminate carbon/epoxy could be affected by using different test configurations, as well as establishing a correlation between the obtained results. The different test configurations are obtained through the variation of the following parameters:

- Type of load introduction(Shear or Combined)
- Soft-Load introduction
- Relative position of specimen inside the grips
- Guide system.

2. Outline of experiment

2.1. *Test specimen*

This study is carried out over unidirectional laminate Carbon/Epoxy AS4/8552(Hexcel Composite) 2mm thickness. The specimens used in this study are in accordance with AITM1-0008-A2. Three different tab lengths have been used depending on the test configuration: 52.5mm tab length for the tab inside jaw, 57.5mm for tab end jaw, and 65mm for the tests with tab outside jaw and Soft-load jaws.

2.2. *Test parameters*

2.2.1. Load introduction

Different testing standards (UNE EN2850, UNE EN ISO14126 AITM 1-0008) allow shear and combined load introduction, that´s why these test this two methods have been used.

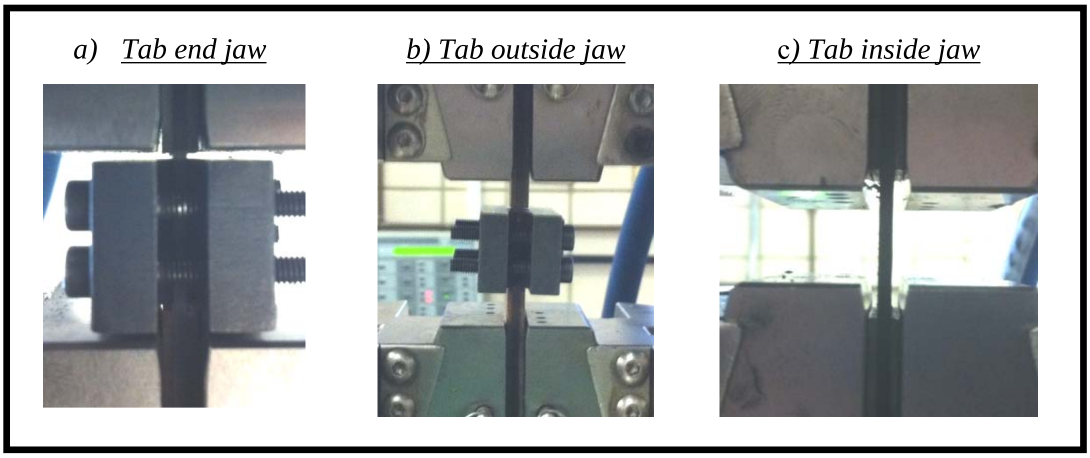
2.2.2. Guide System

All the tests (except HCCF configuration) have been performed on a conventional hydraulics universal testing machine. Not having used a specific test fixture, specimens were placed directly over the jaws. The possible appearance of buckling has to be controlled. That’s why a guide system has been developed for the machine jaws. This guide system consists of a ring with two profiles united to the sides. The ring is centered and clipped to the lower of the machine, leaving the lateral profiles oriented to the upper part. When the piston tries to move laterally during the test, the profiles will encounter the upper jaws avoiding the misalignment of the jaws.

Figure 1: Guide system set-up.

2.2.3. Tabs positioning.

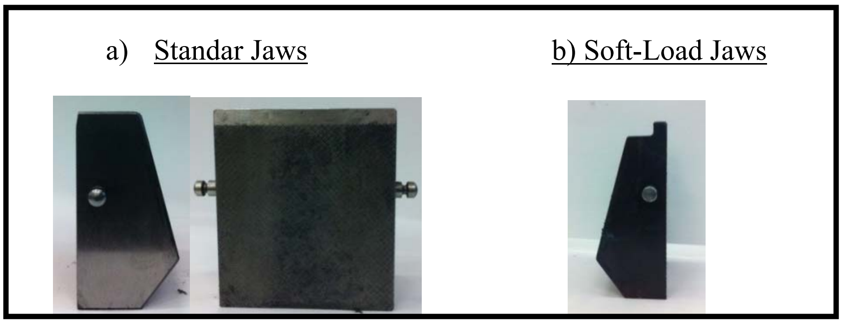
This parameter refers to the position between the tab's end and the jaw's end. Following picture shows the three different configurations used in this study.



a) Tab end jaw *b) Tab outside jaw* *c) Tab inside jaw*

Figure 2: Tabs test configuration.

In the standard jaws the grip length doesn't extend to the end of the jaw, existing a chamfer in the top edge of the jaws. The possible influence of the chamfer over the result pretends to be displayed in this study.



a) Standar Jaws b) Soft-Load Jaws

Figure 3: Jaws.

According to AITM1-0008-A2, when testing specimens around 2 mm thickness ,the use of an antibuckling device is obligatory. When the *tab inside jaws* configuration is used, the gap between the jaws is not enough to set-up the antibuckling device, that´s why it hasn't been used in this configuration. To study the chamfer influences, test with *tabs end jaws* configuration have been performed with and without antibuckling device.

2.2.4. Soft-Load Introduction

In this study two different soft-load fixtures have been used: HCCF test fixture and soft-load jaws for Instron 8801 (Figure 3).

3. Test configurations

Combining the different parameters following test configuration are obtained.

				Acronym
Test Configuration	**Combined Load**	Guide	Tab inside jaw	*CGI*
			Tab end jaw	*CGE*
			Tab outside jaw	*CGO*
			Soft-Load jaw	*CGS*
		Unguided	Tab inside jaw	*CUI*
			Tab outside jaw	*CUO*
			Soft-Load jaw	*CUS*
	Shear Loaded	Guide	Tab inside jaw	*SGI*
			Tab outside jaw	*SGO*
			Soft-Load jaw	*SGS*
		Unguided	Tab inside jaw	*SUI*
			Tab outside jaw	*SUO*
			Soft-Load jaw	*SUS*

Table 1: Configuration Summary.

4. Experimental results and discuss

Configutaion	Failure Load			Strength		
	Mean F	S	cv%	Mean σ_{gro}	S	cv%
	N	N		MPa	MPa	
SUO	**27326**	768	2.81%	**582**	12	2.01%
SGO	**31153**	2018	6.48%	**667**	41	6.16%
CUO	**29083**	1596	5.49%	**607**	34	5.55%
CGO	**35436**	2301	6.49%	**757**	38.9	5.14%
SUI	**32635**	879	2.69%	**688**	20	2.91%
SGI	**46851**	2119	4.52%	**983**	33	3.31%
CUI	**29380**	823	2.80%	**625**	18	2.88%
CGI	**44328**	1436	3.24%	**973**	32	3.29%
CGEAntibuck.	**44627**	2411	5.40%	**976**	52	5.29%
CGEwithout Antibuck.	**39096**	2584	6.61%	**844**	50	5.92%
CUS	**25074**	1046	4.17%	**540**	33	6.11%
CGS	**49385**	3140	6.63%	**1041**	69	6.64%
SUS	**25054**	897	3.58%	**531**	20	3.84%
SGS	**47730**	3636	7.62%	**1007**	69	6.85%
HFCC	**49634**	2440	4.92%	**1078**	45	4.20%

Table 2: Results Summary.

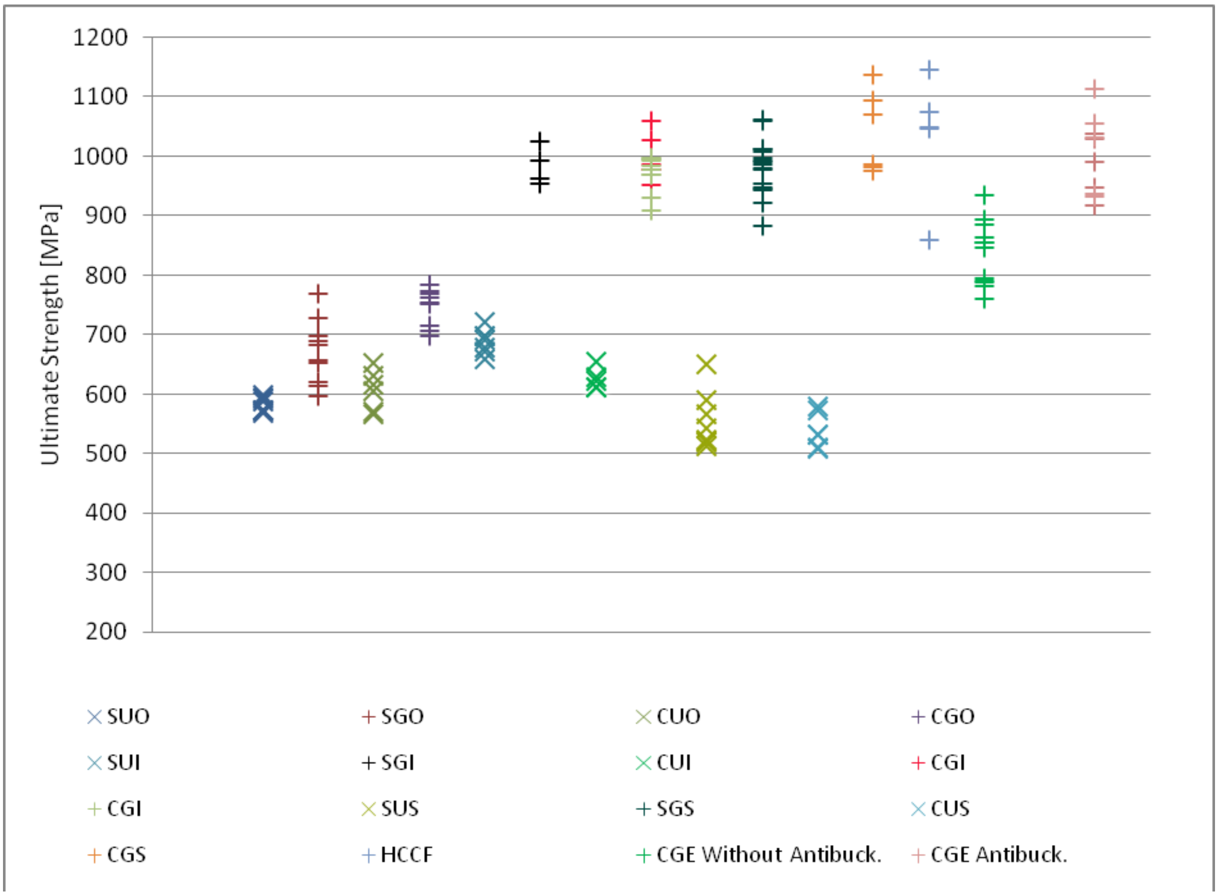


Figure 4: Ultimate strength graph.

The influence of using a guide system is clear. Looking at the results a common pattern is observed, the absence of guides when the test reaches 20 kN approximately, the head of the piston starts to show a significant lateral displacement provoking a premature bending of the specimen. This phenomenon makes the specimen fails much before it reaches its real ultimate compressive strength. The comparative graph in figure 6 shows how the ultimate compressive strength in the configuration without guide system is 50% less than the ones with guide system.

Figure 5: Unguided test buckling.

The *tabs inside jaws* configuration has a similar ultimate compressive strength with and without guide system. The increment of the span length makes the buckling load decrease substantially provoking the failure of the specimens at lower load level.

As for the load introduction method, it seems there is not a significant different between shear and combined loaded test results.

Results show that *tabs inside jaws* configuration and *tabs end jaws* with antibuckling device configuration have similar ultimate compressive strength. However, when *tabs end jaws* configuration is used without antibuckling device, a decrease of the ultimate compressive strength is observed, about a 10% decrease in comparison with the configurations named above.

Regarding failures mode, it has been observed that the use of antibuckling device leads the specimen to fail generally at the end of the gauge region, where the tabs end. When antibuckling device hasn't been used the failure occurs more centered in the gauge region.

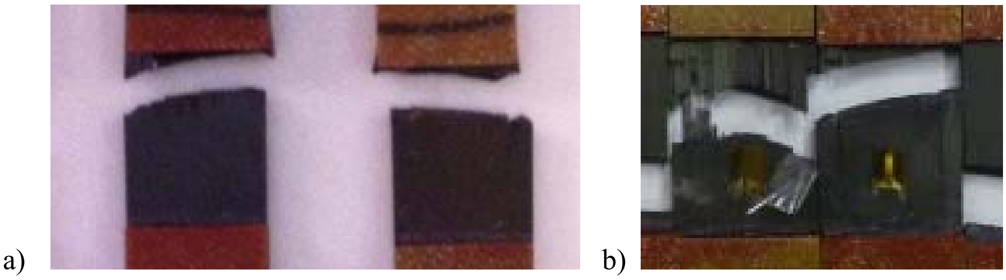


Figure 6: Failure mode with/without antibuckling device.

Another failure mode pattern has appeared with the use of conventional jaws. The chamfer generates a non-gripping region where the tab is liable to open up at the moment of the failure. It generally brings the failure to start inside the tabs, increasing the possibilities to provoke a non-validated failure mode.

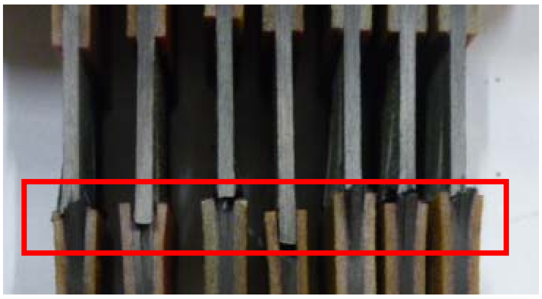


Figure 7: Chamfer failure mode.

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5. Conclusion

In a compression test program, the use of universal testing machine, which has a cantilever hydraulic piston as actuator, is limited by the piston lateral displacement instead of the load cell capacity, as it could be thought primarily. After seeing what the results show, it's indispensable the use of a guide system to achieve a real characterization. In this particular study the results would have been faked, with a reduction up to 50%.

Another fact to bear in mind it's the geometry of the jaws used. As an example we will display the chamfer in the conventional Jaws. The chamfer generates a non-gripping region of 10mm length. Take into account that Span length is 25 mm, so with this increment almost doubles the span length. Also, it generally brings the failure to start inside the tabs, increasing the possibilities to provoke a non-validated failure mode.

Regarding soft load introduction fixtures, results show that its use increases the ultimate compressive strength values in 5-10% in relation to other configurations.

6. References

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