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**ESEIAAT**

# TFG ANNEX

**TFG TITLE:** Study of the fabrication of a monocoque structure with composites

**STUDIES:** Bachelor's degree in Aerospace Vehicles Engineering

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**DOCUMENTS PRESENTED:**

1. Annex I: Structural tests

# Annex I: Structural tests

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# List of Acronyms

| | |
|---|---|
| $\delta$ | Displacement |
| F | Force |
| IBM | International Business Machines |
| LE | Leading edge |
| LITEM | [Catalan] "Laboratori d'innovació tecnològica d'estructures i materials" |
| TE | Trailing edge |
| TFG | [Catalan] "Treball de fi de grau" |

# 1 Introduction

The aim of this annex is to present the results obtained in the tests.

For this TFG, it has been though to perform some structural tests in order to complete the information of the manufacturing processes of a monocoque structure using composites. From these tests, it is expected to obtain key values of this kind of structure. These key values are the bifurcation load or critical load of buckling ($P_{cr}$) and the stiffness system matrix ($K$). A value of the last matrix is known as *stiffness against buckling*, so that, making the hypothesis that the weak point of the monocoque structure is the buckling effect on its surface, this value will be direct calculating by using the following expression:

$$K = \frac{F}{\delta} \tag{1.1}$$

Continuing presenting the tests, a specific machine have been used. Firstly, the traction machine will control the movement (so that, the force) and, in the second, third and fourth test, also recording displacement data. This traction machine is in LITEM lab.
Secondly, a catman software (see figure 1.1), provided by IBM [1], have been also used. In this case, in all the tests, it have recorded the load data and, only in the first test, also the displacement data.

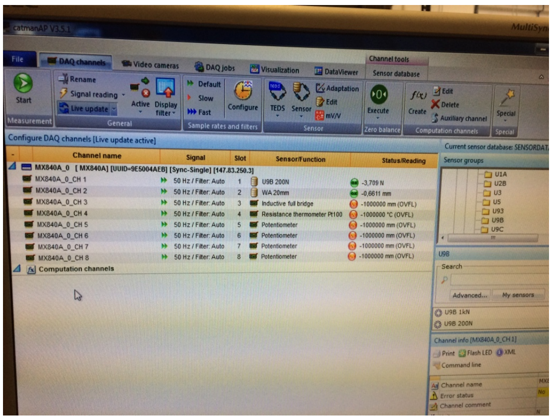

Figure 1.1: Catman software interface.

It was expected that both wings did not support more than 15 kg due to our low confidence to them. But, against all the odds, it really support good values of loads. So that, the first test was resulting to be a trial to the last two, which have offered proper data.

Finally, from now on, all the process will be explained.

# 2 First test

## 2.1 Objectives of the test

The objective of the test is to record the load and the displacement of the wing with a distribute load applied of 10kg. The determination of this mass is arbitrary (based on the confidence in the part).
The final treatment will be a graph of load versus displacement.

## 2.2 Sensors

It has been used two sensors. First of all, a load cell of maximum 200 $N$ [1] to avoid the electrical noise in low loads. As it is known, the load cell have an interference between the electric signal of clock and the one of the measuring mass that makes quite imprecise a load compress in the first 1% t 5% of maximum load. In this load cell case, until a 2N load the lecture of the sensor could be affected by the noise and, consequently, it would not be acceptable.

The second sensor is a feeler that could measure to a maximum of 20 $mm$ [2]. In order to fit the feeler in the bench, a aluminium platen is glued to the specimen (as can be seen in figure 2.1.

## 2.3 Test explication

As it can be seen in figure 2.1, a bag of pneumatic rests of 10kg is held by the traction machine. The load cell is fixed between the traction machine arm and the bag and the value has been reset. Thus, once the bag is starting to be sustained by the wing, the lecture at catman will be positive and of the same value of the load supported by the wing.

It have been decided to test first specimen 2 because its finish quality seemed to be poorer. So that, if the test failed, the better wing should be alive.

The feeler is in contact with the platen which born in the maximum thickness. At the same time, this region is the most requested.

[1] U9B 200
[2] WA 20

Figure 2.1: Montage of the first test.

## 2.4 Results

The test has been cancelled because the wing supported the 10 kg bag without experimenting any structural damage. The next test needs a new concept of montage.

The results of this test are presented in table 3.1.

In figure 2.2, it is possible to see a scale in $0,8\ mm$. It is necessary to keep in mind that this graph is only the beginning of an expected graph. So that, this scale does not mean anything. If the data recorded of load was bigger, this scale would not look as big as look here.

| | |
|---|---|
| **Specimen tested** | 2 |
| **Number of ribs** | 2 |
| **Velocity of the traction machine** | 10 mm/min |
| **Distance between supports (y)** | 560 mm |
| **F** | 93,02 N |
| $\delta$ | 1,69 mm |
| **Moment equivalence at collapse** | Not enough data |
| $P_{cr}$ | Not enough data |
| **K** | Not enough data |

Table 2.1: Table sum-up for the first test.

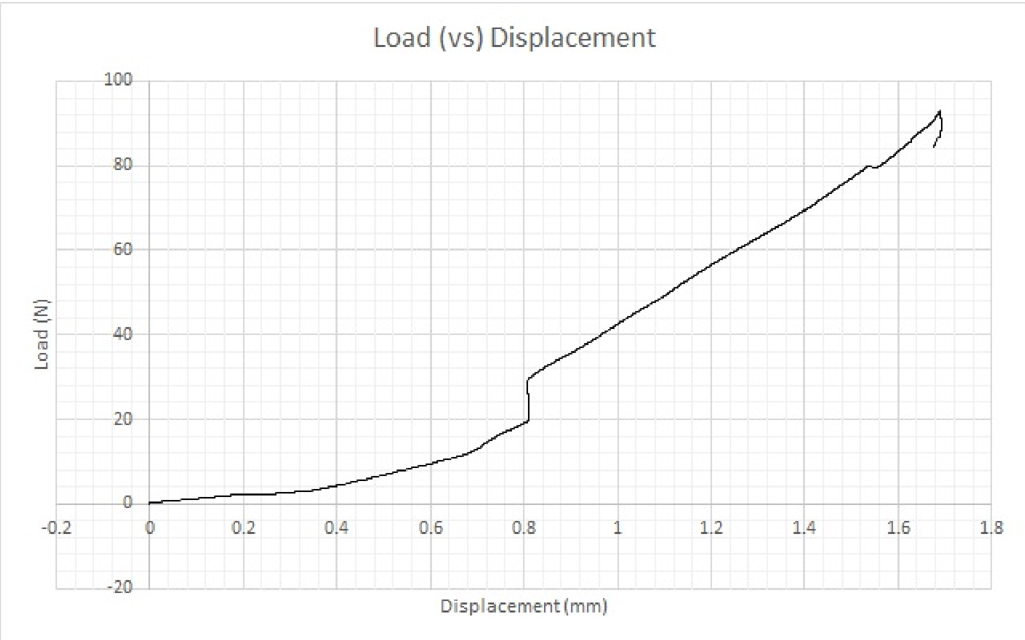


Figure 2.2: Load (vs) $\delta$ of first test.

# 3 Second test

## 3.1 Objectives of the test

The objective of the test is to record the load and the displacement of the wing with a distribute load applied. The load will be constantly increasing using a traction machine running at a speed of 1 mm/min.
The final treatment will be a graph of load versus displacement.

## 3.2 Sensors

It has been used two sensors. First of all, a load cell of maximum 10 $kN$ [3] to avoid the electrical noise in low loads. In this load cell case, until a 100N load the lecture of the sensor could be affected by the noise and, consequently, it would not be acceptable. The cell load has been increased because the offer was only able to read up to 200 $N$ (approximately, 20kg).

The second sensor is the intern counter of displacement of the traction machine.

## 3.3 Test explication

As it can be seen in figure 3.1, from the traction machine arm, a wooden tube of dimensions 200x50x50 mm is used to represent a distribute load. This wooden part is the actuator that interact with the specimen. As the cell load of the traction machine is to big (50 $kN$), the catman software is also needed. The traction machine captures data at a frequency of 5 $Hz$, while the catman software at 50 $Hz$. So that, the volume of data captured from the catman software must be reduced by 10 times. This post-process have been done using Microsoft Excel:

1. In a cell at the same row, function $[= ROW()]$ is used to get the number of the row.
2. Using the function $[= MOD(row; 10)]$, the number of row is divided by de sun-sampling number (it is wanted 1 of each 10 values).
3. Using the filter option of Excel, all the rows that have a solution of step 2 different from 0 are hidden.

[3] U9C 10

Figure 3.1: Montage of the second and third tests.

4. Finally, all the rows with result equal to 0 should be copied and pasted in the right place.

## 3.4 Results

The test has been a success.

| | |
|---|---|
| **Specimen tested** | 2 |
| **Number of ribs** | 2 |
| **Velocity of the traction machine** | 1 mm/min |
| **Distance between supports (y)** | 560mm |
| **F** | 523,36 N |
| $\delta$ | 12,40 mm |
| **Moment equivalence at collapse** | 73,27 Nm |
| $P_{cr}$ | 523,36 N |
| **K** | 42206 N/m |

Table 3.1: Table sum-up for the second test.


Figure 3.2: Load (vs) $\delta$ of second test.

In figure 3.2, the behaviour of this specimen can be seen, and it is as expected. The behaviour of the specimen has been as expected. It has collapsed due to buckling effects, so that, the $P_{cr}$ has the same value than $F$: $431,66\ N$. As it can be seen the graph, before the final collapsing of the specimen, there are 2 small losses of load. They can be originated by a relocation of some parts or by a starting damaging process of epoxy.

The hypothesis –that a weak point of the structure was the buckling mode– was correct. In this case, the graph presents some irregularities by decreasing load's values in determined points. Again, the reasons of them could be a relocating of internal structure.
In addition, the structure has not failed suddenly and the internal structural seems to remain intact. The failure is produced at the edges of the wood piece that reproduces a distributed load. Furthermore, this fracture is in the $x_{body}$ axis sense (from LE to TE). As it is not the expected wrinkle during a flight (which should be 45° or in the $y_{body}$ direction), if this specimen was flying, it might not collapsed yet.

In table 3.1, the ultimate tensile strength, the bifurcation force ($P_{cr}$) and the $K$ value are presented. Furthermore, in figure 3.3, the mechanism of failure can be seen.


Figure 3.3: Mechanism of failure of the second specimen.

# 4 Third test

## 4.1 Objectives of the test

The objective of the test is to record the load and the displacement of the wing with a distribute load applied. The load will be constantly increasing using a traction machine running at a speed of 1 mm/min.
The final treatment will be a graph of load versus displacement.

## 4.2 Sensors

It has been used two sensors. First of all, a load cell of maximum 10 $kN$ to avoid the electrical noise in low loads. In this load cell case, until a 100N load the lecture of the sensor could be affected by the noise and, consequently, it would not be acceptable. The cell load has been increased because the offer was only able to read up to 200 $N$. The same as the second test.

The second sensor is the intern counter of displacement of the traction machine.

## 4.3 Test explication

As it can be seen in figure 3.1, from the traction machine arm, a wooden tube of dimensions 200x50x50 mm is used to represent a distribute load. This wooden part is the actuator that interact with the specimen. All the treatment of the test is the same as for the second test.

## 4.4 Results

The test has been a success.

In figure 4.1 can be seen that this specimen has the same behaviour against the load as the second specimen. So that, the hypothesis –that a weak point of the structure was the buckling mode– was correct. In this case, the graph presents some irregularities by decreasing load's values in determined points. Again, the reasons of them could be a relocating of internal structure.
The structure collapses at the mentioned load but it is not a fragile fracture, so that, it would support a longer load cycle by decreasing little by little the load. Apparently, the internal structure remains intact. The wrinkle –that shows where the buckling effect is produced– is originated in the LE and with an orientation of 45º.

| | |
|---|---|
| **Specimen tested** | 1 |
| **Number of ribs** | 1 |
| **Velocity of the traction machine** | 1 mm/min |
| **Distance between supports (y)** | 560mm |
| **F** | 431,66 N |
| $\delta$ | 10,76 mm |
| **Moment equivalence at collapse** | 73,27 Nm |
| $P_{cr}$ | 523,36 N |
| **K** | 40005 N/m |

Table 4.1: Table sum-up for the third test.

To conclude with the analysis, the value of $K$ is quite similar and the use of two ribs seemed to not affect. The reason why this growth is so small could caused by the deformation of the foam used in the edges of the wings was bigger in one case than in the other. For example, if in the second specimen, the foam has compressed more than in the first specimen, then the value calculated of $K$ is lower than the real value.

In table 4.1, the ultimate tensile strength, the bifurcation force ($P_{cr}$) and the $K$ value are presented. Furthermore, in figure 4.2, the mechanism of failure can be seen.


Figure 4.1: Load (vs) $\delta$ of third test.


Figure 4.2: Mechanism of failure of the second specimen.

# 5 Conclusions

The conclusion of the tests can be easily developed.

Firstly, the shear condition tested is more demanding than in real flights because, in real flights, pressure is distributed along the wingspan, not only in a central region and gathered in the 20-40% of the chord. Due to this reason, the mechanism of failure is not the same as would had happened in a real flight.
Furthermore, it has been seen that the number of ribs affects the ultimate load but it seems to increased less than expected the value of $K$. The most reasonable meaning of these results is the fact that the foam located in the edges have deformed more in one test than in the other. Therefore, as the results are not clear, more tests must be performed to achieving the best solution.

Secondly, the structure has answered really good to the efforts and, in addition, has overpassed the expectations. However, it has to be mentioned that the structure could be oversized: the weight of the fibreglass can be reduced and the thickness of the ribs can be also reduced.

# 6 References

[1] IBM, "Catman software. Knowledge Centre." [Online]. Available: http://www.ibm.com/support/knowledgecenter/ssw_aix_61/com.ibm.aix.cmds1/catman.htm