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# RESISTANCE – 3 BLADE CARBON HUB

## INTRODUCTION :

The three-bladed hub DUC HELICES is produced with the FORGED CARBON's process, process which increases considerably the mechanical resistances of the composite parts. We realized in an office specialized two studies showing the advantages and the performances of the three-bladed hub DUC HELICES:

- § Comparison with another composite manufactoring process, the HERMETICALLY-SEALED's process.
- § Comparison with various hubs made out of aluminium's alloys in term of resistance.

## COMPARATIVE FORGED CARBON PROCESS AND HERMETICALLY-SEALED PROCESS

### DESCRIPTIONS :

The two tested hub were carried out with same material: preimpregnated of class 120.

Reference : T2H / 268 / 300 / EH25 / 35%
Batch : 10108E01
Roller : 1009E001C

### DRAPING :

FORGED CARBON process :

- § isotropic draping and symetrie mirror
- § orientation of the folds : ( 0 ;+45 ;-45 ;90 / 90 ;-45 ;+45 ;0 ) x3 = 24 plies.
- § theoretical thickness : 6.50 mm

HERMETICALLY-SEALED process :

- § isotropic draping and symetrie mirror
- § orientation of the folds : [+45 ;-45 ;0 ;( 0 ;+45 ;-45 ;90 / 90 ;-45 ;+45 ;0 ) x3 ;0 ;-45 ;+45] =30 plies.
- § theoretical thickness : 6.50 mm.

### RESULTS :

| | FORGED CARBON process | | HERMETICALLY-SEALED process | |
|---|---|---|---|---|
| | thickness | Breaking load | thickness | Breaking load |
| Arris | 6.50 mm | 9.7 MPa | 5.63 mm | 8.5 MPa |
| Curved edge | 6.52 mm ( 30 plies) | 34.2 MPa ( 0.8 ) | 6.49 mm ( 24 plies) | 20.5 MPa ( 1.6 ) |
| | | | 6.35 mm ( 30 plies) | 17.8 MPa ( 3.5 ) |

CONCLUSION :

- § The rupture is carried out in delamination and the fibre is little requested.
- § The test-tubes with "curved" edges present definitely higher values of rupture.
- § In the case of theses test-tubes with « curved » edge, the FORGED CARBON's process becomes very interesting.
- § This process allow to obtain parts high performances with a fast manufacture.

## COMPARATIVE FORGED CARBON HUB AND FORGED ALUMINIUM HUB

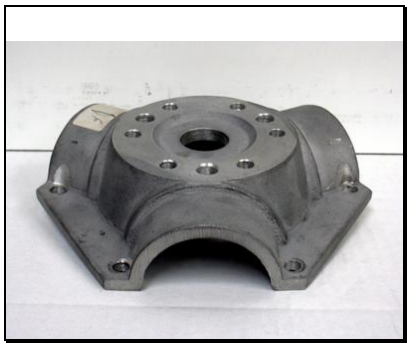
INTRODUCTION :

The objective ot these tests is to evaluate the potential of parts made from the FORGED CARBON process.
The composite half-hubs are compared to parts manufactured from 3 different aluminium grades.
They are found to present comparable performances, while been much lighter.

MATERIALS AND PARTS :

The forged carbon half-hub has been manufactured with a aeronautical preimpregnated carbon fiber of class 180 .

FORGED CARBON ½ HUB



ALUMINIUM ½ HUB

Carbon's reference:

VICOTEX® THR 300 EH15 38%

Draping :

- § Lay up : ( 0 ; +60 ; -60 ; 0 ; +60 ; -60 ; 0 ;……) with a total number of plies of 20.

Aluminium grades :

- § AS 7 G06 with heat traitment 1 : parts n° 1 / 2.
- § AS 7 G06 with heat traitment 2 : parts n° 3 / 4.
- § AS 10 S8 G : parts n° 5 / 6.

WEIGHT PARTS :

| Part n° | Aluminium ( gr ) | Forged carbon ( gr ) |
|---|---|---|
| 1 | 537 | 270 |
| 2 | 509 | 272 |
| 3 | 520 | 268 |
| 4 | - | 270 |
| 5 | 528 | |
| 6 | 525 | |

As well as carbon hubs are almost half the weight of aluminium ones (expected, due to different material densities), we can see only few variation of their weight, from a part to another.

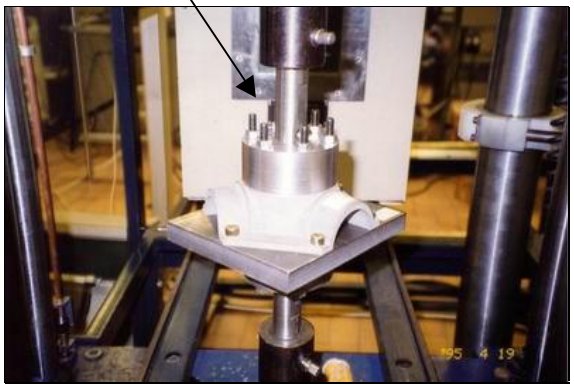
TESTING PROCEDURE :

Different kind of loading have been tried. Up to now, we have examined 3 main cases :

1st case :

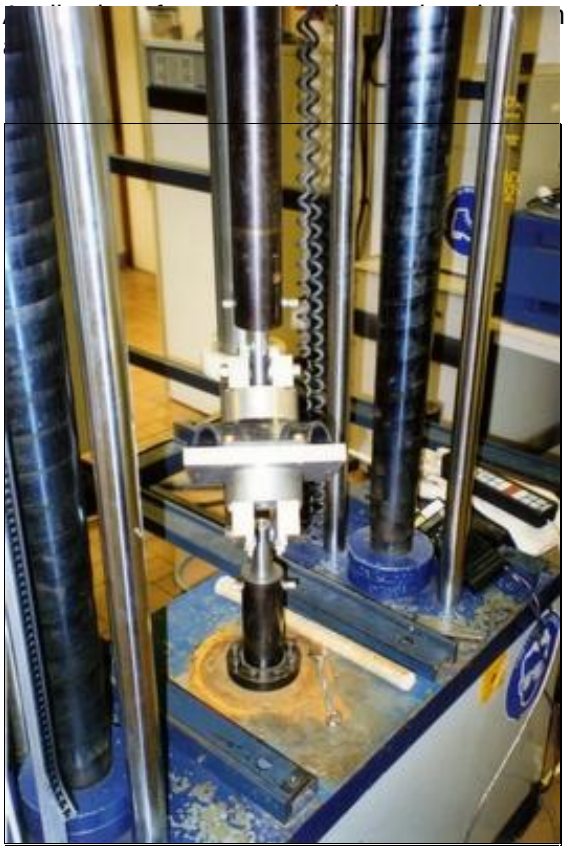
Tension (up to about 15 kN), then compression (up to about 70 kN) of the hub along its symmetry axis

Tension / compression on aluminium half-hub ( similar tests for all the parts ).



2nd case :

axis bent from the symmetry one .Let's call it symmetry




slope of the hub compared to the jack

For these 2 cases, we have exploited the results in terms of apparent stiffness and fracture load when possible. Effectively, the load cell capacity being limited, we had to interrupt the best before breakage of the part in most of the cases. Also, we achieved several times failure of the bolts and nuts in the fastening tools during the test. The load and crosshead displacement only was measured, then we could observe a global stiffness of the part, taken on the linear portion of the curves.

3rd case :

compression along the hub symmetry axis, up to 100kN.We equipped the parts with strain gages on their plane flange, in order to obtain local strain state. (same apparatus as for 1st case)

the specific performances of the parts have been obtained here by dividing the properties by the weight of the part.

RESULTS :

For tension and compression along the symmetry axis, no failure has been observed, either on aluminium or on composite hubs.

## 1st TEST

ALUMINIUM PARTS :

| Part n° | Weight (g) | Tension stiffness (N/mm) | Specific tension stiffness (N/mm/g) | Compression stiffness (N/mm) | Specific compression stiffness (N/mm/g) |
|---|---|---|---|---|---|
| 2 | 509 | 29400 | 58 | 55500 | 109 |
| 3 | 520 | 28600 | 55 | 49000 | 94 |
| 6 | 525 | 27800 | 53 | 58800 | 112 |

FORGED CARBON PARTS :

| Part n° | weight (g) | Tension stiffness (N/mm) | Specific tension stiffness (N/mm/g) | Compression stiffness (N/mm) | Specific compression stiffness (N/mm/g) |
|---|---|---|---|---|---|
| 3 | 268 | 28600 | 107 | 50000 | 186 |
| 4 | 270 | 23330 | 86 | 52600 | 195 |

We can notice that the overall tension stiffness of the parts are comparable with those obtained with aluminium alloys. However, considering the lower weight of carbon parts, specific performances are much higher.

## 2nd TEST

ALUMINIUM PARTS :

| Part n° | Weight (g) | Tension stiffness (N/mm) | Specific tension stiffness (N/mm/g) | Failure load (kN) | Specific failure load (N/g) |
|---|---|---|---|---|---|
| 1 | 537 | 7410 | 13.8 | >43.9 | - |
| 5 | 528 | 7410 | 14 | 37.4 | 71 |

FORGED CARBON PARTS :

| Part n° | Weight (g) | Tension stiffness (N/mm) | Specific tension stiffness (N/mm/g) | Failure load (kN) | Specific failure load (N/g) |
|---|---|---|---|---|---|
| 1 | 270 | 9610 | 35.6 | 40.5 | 150 |
| 2 | 272 | 8000 | 29.4 | 38.9 | 143 |

On this kind of test, the carbon parts show same or even higher stiffness than the aluminium ones. Except for the aluminium n°1 sample, failure load are of the same range. Failure mode seems to be less brittle for composites than or aluminium, and propagation occurs by delamination of the plies. Also, specific values are higher for composites than for aluminium.

## 3rd TEST

Compression with strain gages.

Strain unit : 1µdef = $10^{-6}$

| Part n° | Stiffness ( N/µdef ) |
|---|---|
| Aluminium –n°2 | 111 |
| Aluminium –n°3 | 83 |
| Carbon –n°5 | 47 |

## CONCLUSION :

We have seen that this process allows to manufacture shaped parts, with good health and respecting the reinforcement directions in the structure. The tested mechanical properties of the forged carbon hubs are comparable to those obtained from forged aluminium alloys, for similar parts dimensions, and hence better specific performances, thanks to the lower density of the material (1.5 compared to 2.9).