

RESISTANCE – 3 BLADE CARBON HUB

INTRODUCTION :

The three-bladed hub DUC HELICES is produced with the FORGED CARBON 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 manufacturing process, the AUTOCLAVE process.
- Comparison with various hubs made out of aluminum's alloys in term of resistance.

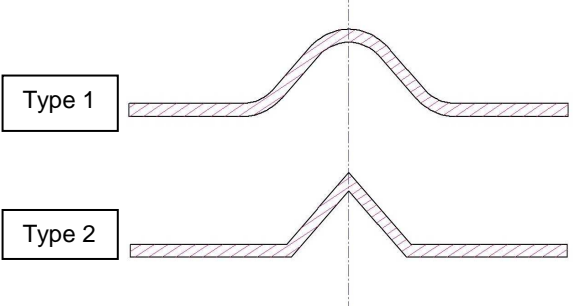
COMPARATIVE FORGED CARBON PROCESS AND AUTOCLAVE PROCESS

DESCRIPTIONS :



The test-tubes tested were produced with the same material (class 180):

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



Type 1

Type 2

DRAPING :

FORGED CARBON process :

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

AUTOCLAVE process :

- isotropic draping and symmetric 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		AUTOCLAVE process	
	thickness	Breaking load	thickness	Breaking load
Arris (type 2)	6.50 mm	9.7 MPa	5.63 mm	8.5 MPa
Curved edge (type 1)	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 these test-tubes with « curved » edge, the FORGED CARBON 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 of 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 aluminum 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 1/2 HUB



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

WEIGHT PARTS :

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

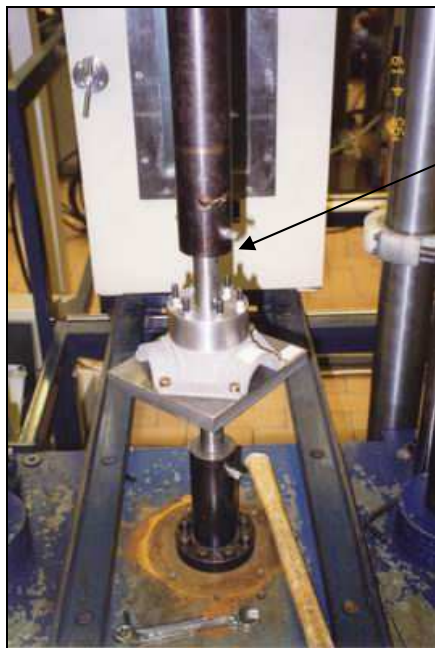
As well as carbon hubs are almost half the weight of aluminum ones (expected, due to different material densities), we can see only few variation of their weight, from a part to another.

TESTING PROCEDURE :

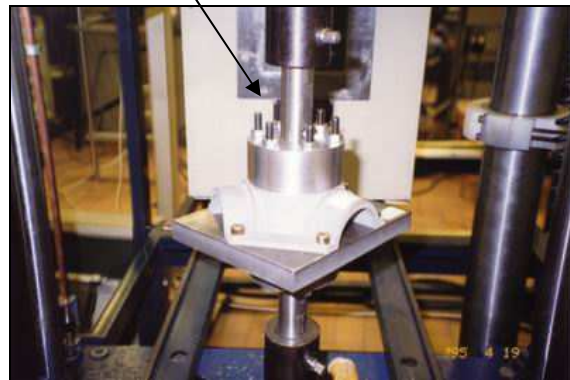
Different kind of loading have been tried. Up to now, we have examined 3 main cases :

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 aluminum half-hub (similar tests for all the parts).



2nd case :

Application of a momentum by tension along an axis bent from the symmetry one .Let's call it symmetry axis bending.



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 test 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 aluminum 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 aluminum 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 aluminum ones. Except for the aluminum n°1 sample, failure load are of the same range. Failure mode seems to be less brittle for composites than or aluminum, and propagation occurs by delaminating of the plies. Also, specific values are higher for composites than for aluminum.

3rd TEST

Compression with strain gages.

Strain unit : $1\mu\text{def} = 10^{-6}$

Part n°	Stiffness (N/ μdef)
Aluminum -n2	111
Aluminum -n3	83
Carbon -n5	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 aluminum alloys, for similar parts dimensions, and hence better specific performances, thanks to the lower density of the material (1.5 compared to 2.9).