INSTRUCTIONS MANUAL OF THE SWIRL PROPELLER
Summary

1. Purpose ................................................................................................................. 3
2. Trade Reference .................................................................................................... 3
3. Identification ......................................................................................................... 3
   3.1. Identification of the propeller ........................................................................... 3
   3.2. Identification of the blades ............................................................................. 3
   3.1. Identification of the hub ................................................................................ 4
   3.2. Identification of the accessories .................................................................... 4
4. Description of the propeller .................................................................................. 4
   4.1. Characteristics .................................................................................................. 4
   4.2. Carbon hub ...................................................................................................... 5
   4.3. Advantages ...................................................................................................... 5
   4.4. Option edge reinforced with an Inconel part .................................................... 6
5. Installation ............................................................................................................. 6
6. Applications .......................................................................................................... 7
7. Adjusting the blade angle ..................................................................................... 8
   7.1. Attack angle ..................................................................................................... 8
   7.2. Adjustment ....................................................................................................... 8
8. Assembly ................................................................................................................ 9
   8.1. Assembly and adjusting of the propeller ......................................................... 9
9. Maintenance .......................................................................................................... 13
   9.1. Regular maintenance (Customer) ..................................................................... 13
   9.2. General maintenance (Client) ......................................................................... 13
   9.3. Complete maintenance (DUC Hélices) ............................................................. 14
10. Cleaning & Repair .............................................................................................. 14
   10.1. Cleaning products ....................................................................................... 14
   10.2. Repair kit ....................................................................................................... 14
11. Appendices .......................................................................................................... 16
   I. Technical folder of the propeller hub CARBONE FORGE® ................................ 16
   II. Technical folder of the blade SWIRL STANDARD and INCONEL ................... 22
1. **Purpose**

The purpose of this document is to provide all necessary information relating to the use of propeller SWIRL.

2. **Trade Reference**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-03-001</td>
<td>Three-blade SWIRL, right</td>
</tr>
<tr>
<td>01-03-002</td>
<td>Three-blade SWIRL, left</td>
</tr>
<tr>
<td>01-05-001</td>
<td>Three-blade Inconel SWIRL, right</td>
</tr>
<tr>
<td>01-05-002</td>
<td>Three-blade Inconel SWIRL, left</td>
</tr>
</tbody>
</table>

3. **Identification**

3.1. Identification of the propeller

**P/N: TYPE-MODEL-SIDE-OPTION-NUMBER-BALANCING**

- **H**: Propeller
- **SW**: SWIRL
- **FC**: WINDSPOON
- **FLR**: FLAIR
- **G**: Left
- **D**: Right
- **S**: Standard
- **R**: Reinforced structure
- **I**: Inconel
- **PV**: Variable Pitch
- **Balancing value**

3.2. Identification of the blades

**S/N: MODEL-SIDE-OPTION-NUMBER**

- **SW**: SWIRL
- **FC**: WINDSPOON
- **FLR**: FLAIR
- **G**: Left
- **D**: Right
- **S**: Standard
- **R**: Reinforced structure
- **I**: Inconel
- **PV**: Variable Pitch
- **Alphanumeric order**
  - 001…999
  - A001…A999
  - Z001…Z999
  - AA001…AA999
3.1. Identification of the hub

**S/N: TYPE-MODEL-NUMBER/NUMBER**

- **M**: Hub
- **2P**: Two-blade
- **3P**: Three-blade
- **5P**: 5 blades

Alphanumeric order:
- 001…999
- A001…A999
- Z001…Z999
- AA001…AA999

Alphanumeric order:
- 001…999
- A001…A999
- Z001…Z999
- AA001…AA999

There are 2 numbers for the hub because it is an assembly of 2 similar half-hub.

3.2. Identification of the accessories

**S/N: TYPE-MODEL-NUMBER**

- **C**: Spinner
- **P**: Mounting plate

210: Ø 210 mm
250: Ø 250 mm

Alphanumeric order:
- 001…999
- A001…A999
- Z001…Z999
- AA001…AA999

4. Description of the propeller

4.1. Characteristics

This propeller is available in:
- Two-blade model
- Three-blade model

**Available diameter:**

1400 to 1745 mm

**Weight:**
- Two-blade standard: 2.680 kg
- Three-blade standard: 3.520 kg
- Two-blade INCONEL: 2.740 kg
- Three-blade INCONEL: 3.610 kg
This propeller was studied to have a “constant speed” effect. The blades are manufactured with part of carbon plies and their design was carried out to obtain maximum strains in torsion and inflection. It’s why the constant speed effect is not dependent on the blade distortion but on its geometry and its particular profile.

Because of the extra flat profile and a small cord, we obtain an excellent output as well:
- In performance
- In noise
- In consumption

4.2. Carbon hub

The hub used is a carbon hub identical to DUC FC WINDSPOON propeller, made out of FORGED CARBON PROCESS® which makes it possible to obtain exceptional mechanical resistances.

4.3. Advantages

Thanks to the “constant speed” effect, we have very little variation of the RPM engine between static and dynamic.

This propeller makes it possible to have more performances on the whole of flight to knowing:
- Better effectiveness on the takeoff and in rates of rise due to the engine speed more raised
- Much lengthening-piece in cruising,
- A great comfort of use.
4.4. Option edge reinforced with an Inconel part

The SWIRL blade is available in two versions:
- STANDARD SWIRL BLADE
- INCONEL SWIRL BLADE

The INCONEL SWIRL blade has the characteristic to be protected on the level from the leading edge with Inconel reinforcement.
The Inconel is refractory stainless with a very high hardness of surface.

5. Installation

WARNING

Make sure the ignition is turned off before starting any type of work on the propeller. Do not run the engine without propeller, engine damage will result.

IMPORTANT

The spinner is an important element for cooling the engine (DUC spinner in standard version or version TURBO).
The aircraft must not fly without a propeller spinner. The version DUC TURBO spinner is particularly suitable for engines JABIRU cooled air, limits variations in temperature between the engine off at full throttle and cruise flight, but also statically or on a taxiway.

Fitting a different spinner will be an addendum to this manual of instruction approved by DUC Hélices Company to confirm its compatibility with the mounting of the propeller.
### 6. Applications

<table>
<thead>
<tr>
<th>Engine</th>
<th>Type</th>
<th>Reducer</th>
<th>Recommended propeller</th>
<th>Blade diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3 AXIS - TRACTOR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 912</td>
<td>4 strokes</td>
<td>2.27</td>
<td>Three-blade SWIRL std or Inconel, Right</td>
<td>ø 1660 mm</td>
</tr>
<tr>
<td>ROTAX 912 S</td>
<td>4 strokes</td>
<td>2.48</td>
<td>Three-blade SWIRL std or Inconel, Right</td>
<td>ø standard</td>
</tr>
<tr>
<td>ROTAX 503 / 582</td>
<td>2 strokes</td>
<td>2.58 / 2.62</td>
<td>Two-blade SWIRL std or Inconel, Left</td>
<td>ø 1660 mm</td>
</tr>
<tr>
<td>ROTAX 503</td>
<td>2 strokes</td>
<td>3</td>
<td>Three-blade SWIRL std or Inconel, Left</td>
<td>ø 1660 mm</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>2 strokes</td>
<td>3</td>
<td>Three-blade SWIRL std or Inconel, Left</td>
<td>ø standard</td>
</tr>
<tr>
<td>JABIRU 2200</td>
<td>4 strokes</td>
<td>Direct drive</td>
<td>Three-blade SWIRL std or Inconel, Right</td>
<td>ø 1620 mm</td>
</tr>
<tr>
<td>JABIRU 2200</td>
<td>4 strokes</td>
<td>Direct drive</td>
<td>Three-blade SWIRL std or Inconel, Right</td>
<td>ø 1520 mm</td>
</tr>
<tr>
<td>JABIRU 3300</td>
<td>4 strokes</td>
<td>Direct drive</td>
<td>Three-blade SWIRL R std or Inconel, Right</td>
<td>ø 1620 mm</td>
</tr>
<tr>
<td>HKS</td>
<td>4 strokes</td>
<td>2.58</td>
<td>Two-blade SWIRL std or Inconel, Left</td>
<td>ø from 1660 to 1700 mm</td>
</tr>
<tr>
<td>CONTINENTAL 0200</td>
<td>4 strokes</td>
<td>Direct drive</td>
<td>Three-blade SWIRL std or Inconel, Right (hub of 140 hp)</td>
<td>ø 1660 mm</td>
</tr>
<tr>
<td>VOLKSWAGEN</td>
<td>4 strokes</td>
<td>Direct drive</td>
<td>Three-blade SWIRL std or Inconel, Right or Left according to the engine adaptation</td>
<td>ø from 1520 to 1620 mm</td>
</tr>
<tr>
<td>LIMBACH</td>
<td>4 strokes</td>
<td>Direct drive</td>
<td>Three-blade SWIRL std or Inconel, Left</td>
<td>ø from 1520 to 1620 mm</td>
</tr>
<tr>
<td><strong>3 AXIS – PUSHER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 912</td>
<td>4 strokes</td>
<td>2.27</td>
<td>Three-blade SWIRL, Left</td>
<td>ø standard</td>
</tr>
<tr>
<td>ROTAX 912 S</td>
<td>4 strokes</td>
<td>2.48</td>
<td>Three-blade SWIRL, Left</td>
<td>ø standard</td>
</tr>
<tr>
<td>ROTAX 503 / 582</td>
<td>2 strokes</td>
<td>2.58 / 2.62</td>
<td>Two-blade SWIRL, Right</td>
<td>ø standard</td>
</tr>
<tr>
<td>ROTAX 503 / 582</td>
<td>2 strokes</td>
<td>3</td>
<td>Three-blade SWIRL, Right</td>
<td>ø standard</td>
</tr>
<tr>
<td><strong>PENDULARS - PUSHER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 503 / 582</td>
<td>2 strokes</td>
<td>2.58</td>
<td>Two-blade SWIRL, Right</td>
<td>ø standard</td>
</tr>
</tbody>
</table>
7. Adjusting the blade angle

7.1. Attack angle

The values hereafter mentioned are theoretical values and the number RPM engine in statics must be checked.

<table>
<thead>
<tr>
<th>TWO-BLADE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>JABIRU 2200</td>
<td>/</td>
<td>17°</td>
</tr>
<tr>
<td>Rotax 503</td>
<td>2.58</td>
<td>16°</td>
</tr>
<tr>
<td>Rotax 582</td>
<td>2.58</td>
<td>18°</td>
</tr>
<tr>
<td>Rotax 503</td>
<td>2.62</td>
<td>18°</td>
</tr>
<tr>
<td>Rotax 582</td>
<td>2.62</td>
<td>20°</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THREE-BLADE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>JABIRU 2200</td>
<td>/</td>
<td>17°</td>
</tr>
<tr>
<td>JABIRU 3300</td>
<td>/</td>
<td>18°</td>
</tr>
<tr>
<td>Rotax 912</td>
<td>/</td>
<td>20°</td>
</tr>
<tr>
<td>Rotax 912 S</td>
<td>/</td>
<td>24°</td>
</tr>
<tr>
<td>Rotax 503</td>
<td>2.62</td>
<td>13°</td>
</tr>
<tr>
<td>Rotax 582</td>
<td>2.62</td>
<td>15°</td>
</tr>
<tr>
<td>Rotax 503</td>
<td>3</td>
<td>15°</td>
</tr>
<tr>
<td>Rotax 582</td>
<td>3</td>
<td>17°</td>
</tr>
<tr>
<td>VOLKSWAGEN</td>
<td>/</td>
<td>on request</td>
</tr>
<tr>
<td>Continental 0200</td>
<td>/</td>
<td>25°</td>
</tr>
</tbody>
</table>

The chock is carried out with the adjusting-tool plated on the under-surface (leading edge in top) to 20 cm of the blade tip. The attack angle is formed by the vertical and the leading edge of the blade. For that, place your aircraft so that the carries – propeller plate is perfectly vertical.

7.2. Adjustment

The wheel to adjust the angle of attack

Reading of the angle of attack

The under surface of the blade, leading edge uppermost. Blade in horizontal position
8. Assembly

8.1. Assembly and adjusting of the propeller

The assembly process of the propeller blades on the hub is as follows:
(Same procedure for two-blade and three-blade DUC propellers)

Upon receipt of your package, make sure that all parts are included!

- Blades
- 1/2 hub
- Clamping washer
- Spacer
- Bolts (short and long)
- Nuts and washers.

- Pale one of the half hub on a table.
- Put the spacer in the center of the half hub.

- Put the 2 or 3 blades in their slots.
- Make sure that the DUC logo is facing you.

- Put the 2nd half hub over the assembly.

- From the back of the hub insert the 6 assembly bolts.
- Put on the assembly nuts and do up moderately.
- If assembling the propeller spinner, include the support plate.

- Be careful you get the washers in the correct order.

- Put the propeller on the propeller or the spacer adjustment corresponding tighten moderately.

- Position your aircraft so that the propeller carrier plate is completely vertical.
  - Measure this with the leveler on the adjusting tool.

- Unscrew the assembly bolts enough to enable you to turn each blade easily in its slot.
- Place the first blade horizontally.

- Take the adjusting tool in your hand, press the level, put the tool right at 20 cm of the tip of the blade (see photo page 4).
- Make sure that the tool is flat and steady against the inside skin of the blade, leading edge uppermost,

- Turn the wheel with your thumb to adjust the angle of attack.

- Hold the foot of the blade and turn slowly until the bubble of the tool is completely in the middle and level.

<table>
<thead>
<tr>
<th>Tightening</th>
<th>Rotax 2ST+4ST</th>
<th>Continental O200</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>2.5 Kg/m</td>
<td>3 Kg/m</td>
</tr>
<tr>
<td>2nd</td>
<td>25 Nm</td>
<td>30 Nm</td>
</tr>
</tbody>
</table>

The tightening of the bolts on the propeller is carried out in 2 stages:
- 1st tighten the bolts moderately,
- 2nd tighten with a torque spanner.

**Warning!**

Tight again your propeller after 1 hour of use or after each step modification, and after 1 hour this step modification.
Warning!

Tight again your propeller after 1 hour of use or after each step modification, and after 1 hour this step modification.

If you note anomalies of assembly or operation, not undertake flight and contact immediately DUC HELICES company.

The accessories of assembly and the DUC propeller must be fitted in accordance with our technical notes.

The non-observance of these data would release from any responsibility the DUC HELICES company.

The potential for SWIRL blades fitted on Rotax engines has been evaluated to 800 h. Thank you to return the complete propeller, for control, after 800 h of flight.

For JABIRU engines, this potential has been evaluated to 600 h. Thank you to return the complete propeller for control after 600 h of flight.
9. Maintenance

9.1. Regular maintenance (Customer)

For a safety use of the SWIRL propeller, it is necessary that the user performs regular maintenance to detect any abnormalities. This maintenance is usually just a simple check.

Frequency of checking: Each pre-flight
Control methods:  
- Visual inspection
- Manual handling
Checkpoints:  
- Fixation of the propeller: Manually maintaining the tip of a blade of the propeller, shake it firmly to feel if a too much clearance appears in the setting of the propeller.
- Degradation of material: Check visually the entire propeller without dismantling (blade root, Inconel leading edge, surface of the blade, spinner, hub, etc.)
- Fixation of the spinner: Check visually the fixation screws of the spinner. A marking paint can be made between each screw and spinner to have a means of visual inspection of proper tightening the screws.

Possible problems:  
- Too much clearance in the propeller fixation
- Degradation of surface / Crack apparent
- Screw unscrewed or damaged
Corrective actions:  
Depending on the importance:
1. See paragraph 10 Maintenance & Repair
2. Tighten the screws to proper torque
3. Replace(s) damage component(s)
4. Contact DUC Hélices to define a solution

9.2. General maintenance (Client)

A general maintenance by the customer must be made at lower frequency.

Frequency of checking: Every 100 hours or annually
Control methods:  
- Visual inspection
- Torque wrench
Checkpoints:  
- Fixation of the propeller: By removing the spinner of the propeller, check the proper tightening of the screws to the wrench. These screws of the hub should be tightened to proper torque, defined in the installation instructions attached. A marking paint of all the screw/washer/hub after tightening can be done to help make a visual check outside of the general maintenance.
- Degradation of material: Check visually the entire propeller (blade root, Inconel leading edge, surface of the blade, spinner, hub, etc.)
Possible problems:  
- Too much clearance in the propeller fixation  
- Degradation of surface / Crack apparent  
- Screw unscrewed or damaged  

Corrective actions:  
Depending on the importance:  
1. See paragraph 10 Maintenance & Repair  
2. Tighten the screws to proper torque  
3. Replace(s) damage component(s)  
4. Contact DUC Hélices to define a solution  

9.3. Complete maintenance (DUC Hélices)  
After many hours of use (potential) defined by DUC, the propeller must be returned to the company for a full expertise of all components of the propeller.  

For Rotax engines, the potential for SWIRL propeller was estimated at **800 hours**.  

For Jabiru engines, the potential for SWIRL propeller was estimated at **600 hours**.  

The possible degradation of the propeller components may vary depending on the location of use.

10. Cleaning & Repair  

10.1. Cleaning products  

This product cleans perfectly your propeller and leaves a film that will protect it. A clean propeller is more efficient than a propeller sale:  

**REDUCING CONSUMPTION**

10.2. Repair kit  

Repairs are limited to filling small nicks in the blades. These repairs can be made from cuts of maximum dimensions following:  

- Leading edge:  
  - 2 mm deep  
  - 30 mm in length  

- Intrados/Extrados:  
  - 0.5 mm deep  
  - 30mm in length
Kind of products

<table>
<thead>
<tr>
<th>designation</th>
<th>reference</th>
<th>quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLUE</td>
<td>ARALDITE AV 144-2</td>
<td>50 g</td>
</tr>
<tr>
<td>HARDENER</td>
<td>HARDENER HV 997</td>
<td>30 g</td>
</tr>
</tbody>
</table>

Use Case

This kit is designed to repair small damage caused by projections of various objects during use. It is used in the case of small impacts or chips on the blades DUC defined above and falls under the care and maintenance in good condition of the propeller.

In the case of heavy damage to propeller blades subjected to severe shock with the appearance of deep cracks, breaks or substantial cuts fiber, we recommend you contact the company DUC Propellers to diagnose specific damage to the propellers use UCR safely.

Precautions

GLUE: contains epoxy resins based on bis phenol A / F

HARDENER: contains Diethylenetriamine R

- Toxic to aquatic environments,
- Irritating to eyes and skin
- Wear suitable gloves and eye protection and face
- After contact with skin, wash immediately and thoroughly with soap and water,
- Collapse after use and store in a dry place (from +2 to +40 ° C).

Preparation and application

- Take a clean container and place a sufficient amount of glue to repair to make.
- Add the hardener respecting the determination following volumes:

<table>
<thead>
<tr>
<th></th>
<th>50 %</th>
<th>Use of own tools so as not to introduce glue or hardener in each vial kit.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLUE</td>
<td>50 %</td>
<td></td>
</tr>
<tr>
<td>HARDENER</td>
<td>50 %</td>
<td></td>
</tr>
</tbody>
</table>

- Mix glue and hardener in order to obtain a homogeneous mixture.
- Dull and degrease the surface of application.
- Apply the mixture on or cracks in abundance for the operation of finishing by sanding.

DRYING 24 hours at room temperature +20°C

- Sand the excess material until a smooth, well connected with the local profile of the blade.
- For a better esthetic result, apply a coat of polish.
11. Appendices

I. Technical folder of the propeller hub CARBONE FORGE®

2 tests reports about the DUC propeller hub:

1. Comparative test of the mechanical resistance between a ½ hub foundry in aluminum and a ½ hub carbon made with the CARBONE FORGE® technology.
2. Resistance test of the temperature: Measure of Tg.

1. COMPARISON OF THE CARBONE FORGE® HUB WITH THE ALUMINUM 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 an aeronautical pre-impregnated carbon fiber of class 180.

FORGED CARBON ½ HUB

ALUMINUM ½ HUB

Carbon’s reference: HEXCEL Hexply® M52/38%/UD150/CHS/460mm

Draping: Lay-up at 0°; +60°; -60°; 0°; +60°; -60°; 0°; … with 20 plies at the end

Aluminum 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

<table>
<thead>
<tr>
<th>Part n°</th>
<th>Aluminum (g)</th>
<th>Forged carbon (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>537</td>
<td>270</td>
</tr>
<tr>
<td>2</td>
<td>509</td>
<td>272</td>
</tr>
<tr>
<td>3</td>
<td>520</td>
<td>268</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>270</td>
</tr>
<tr>
<td>5</td>
<td>528</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>525</td>
<td></td>
</tr>
</tbody>
</table>

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 kinds of loading have been tried. Up to now, we have examined 2 main cases:

1st case:

Tension (up to about 15 kN), then compression (up to about 70 kN) of the hub along its symmetry axis
2\textsuperscript{nd} 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 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.
RESULTS

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

1st case:

ALUMINUM PARTS

<table>
<thead>
<tr>
<th>Part n°</th>
<th>Weight (g)</th>
<th>Tension stiffness (N/mm)</th>
<th>Specific tension stiffness (N/mm/g)</th>
<th>Compression stiffness (N/mm)</th>
<th>Specific compression stiffness (N/mm/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>509</td>
<td>29400</td>
<td>58</td>
<td>55500</td>
<td>109</td>
</tr>
<tr>
<td>3</td>
<td>520</td>
<td>28600</td>
<td>55</td>
<td>49000</td>
<td>94</td>
</tr>
<tr>
<td>6</td>
<td>525</td>
<td>27800</td>
<td>53</td>
<td>58800</td>
<td>112</td>
</tr>
</tbody>
</table>

FORGED CARBON PARTS

<table>
<thead>
<tr>
<th>Part n°</th>
<th>weight (g)</th>
<th>Tension stiffness (N/mm)</th>
<th>Specific tension stiffness (N/mm/g)</th>
<th>Compression stiffness (N/mm)</th>
<th>Specific compression stiffness (N/mm/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>268</td>
<td>28600</td>
<td>107</td>
<td>50000</td>
<td>186</td>
</tr>
<tr>
<td>4</td>
<td>270</td>
<td>23330</td>
<td>86</td>
<td>52600</td>
<td>195</td>
</tr>
</tbody>
</table>

We can notice that the overall tension stiffness of the parts is comparable with those obtained with aluminum alloys. However, considering the lower weight of carbon parts, specific performances are much higher.
2nd case:

### ALUMINUM PARTS

<table>
<thead>
<tr>
<th>Part n°</th>
<th>Weight (g)</th>
<th>Tension stiffness (N/mm)</th>
<th>Specific tension stiffness (N/mm/g)</th>
<th>Failure load (kN)</th>
<th>Specific failure load (N/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>537</td>
<td>7410</td>
<td>13.8</td>
<td>&gt;43.9</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>528</td>
<td>7410</td>
<td>14</td>
<td>37.4</td>
<td>71</td>
</tr>
</tbody>
</table>

### FORGED CARBON PARTS

<table>
<thead>
<tr>
<th>Part n°</th>
<th>Weight (g)</th>
<th>Tension stiffness (N/mm)</th>
<th>Specific tension stiffness (N/mm/g)</th>
<th>Failure load (kN)</th>
<th>Specific failure load (N/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>270</td>
<td>9610</td>
<td>35.6</td>
<td>40.5</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>272</td>
<td>8000</td>
<td>29.4</td>
<td>38.9</td>
<td>143</td>
</tr>
</tbody>
</table>

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.

### Conclusion

We have seen that this process enables 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).
2. TEMPERATURE RESISTANCE – DUC HUB CARBON

The tests of temperature resistance were carried out on a sample of DUC propeller half hub manufactured with the Forged Carbon process in HEXCEL COMPOSITES laboratory.

Pre-impregnated carbon fibers: Reference: Hexply® M52/38%/UD150/CHS/460mm

Results:

The results of tests of Tg were carried out on DSC and DMA apparatuses. (see the curves)

![DMA curve]

Tg = 103.93°C

![DSC curve]

Tg = 107.14°C
II. Technical folder of the blade SWIRL STANDARD and INCONEL

1. Resistance of the SWIRL blade in STANDARD and INCONEL versions
2. Fatigue test of the DUC blade

1. RESISTANCE OF THE SWIRL BLADE CALCULATIONS AND TEST RESULTS

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF THE SWIRL BLADE ACCORDING THE ENGINE AND THE VERSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SWIRL FOR ROTAX ENGINE</strong></td>
</tr>
<tr>
<td>Length of the SWIRL blade (mm)</td>
</tr>
<tr>
<td>Weight of the SWIRL blade (kg)</td>
</tr>
<tr>
<td>Position of the center of gravity – cote AB (mm)</td>
</tr>
<tr>
<td>Radius of the center of gravity (mm)</td>
</tr>
<tr>
<td><strong>SWIRL FOR JABIRU 2200 ENGINE</strong></td>
</tr>
<tr>
<td>Length of the SWIRL blade (mm)</td>
</tr>
<tr>
<td>Weight of the SWIRL blade (kg)</td>
</tr>
<tr>
<td>Position of the center of gravity – cote AB (mm)</td>
</tr>
<tr>
<td>Radius of the center of gravity (mm)</td>
</tr>
<tr>
<td><strong>SWIRL FOR JABIRU 3300 ENGINE</strong></td>
</tr>
<tr>
<td>Length of the SWIRL blade (mm)</td>
</tr>
<tr>
<td>Weight of the SWIRL blade (kg)</td>
</tr>
<tr>
<td>Position of the center of gravity – cote AB (mm)</td>
</tr>
<tr>
<td>Radius of the center of gravity (mm)</td>
</tr>
</tbody>
</table>

**TYPE OF ENGINE**

The studies were carried out on 3 types of 4 times engines and on one type of 2 times engine.

4 times engines:
- **ROTAX 912** with rotation/reducer 2,27
- **ROTAX 912S** with rotation/reducer 2,48
- **JABIRU** without reducer

2 times engines:
- **ROTAX 582** with rotation/reducer B 2,58
- **ROTAX 582** with rotation/reducer C 2,62
- **ROTAX 582** with rotation/reducer C 3
- **ROTAX 582** with rotation/reducer C 3,47
- **ROTAX 582** with rotation/reducer C 4
CALCULATION OF THE CENTRIFUGAL FORCE

We applied the following formula: \[ F = \frac{M \times V^2}{R} \]
with
- \( F \): Centrifugal force (N)
- \( M \): blade’s weight (Kg)
- \( V \): linear speed (m/s)
- \( R \): Radius of the center of gravity (m)

The theoretical value of the maximum centrifugal force is increased by using a safety factor of 1.5.
The theoretical maximum centrifugal force is determined by applying a safety factor of 1.5 at the speed of motor rotation (RPM).

STATIC TENSILE TEST

In addition of the tensile test of blade described below, another static tensile test is carried out on the assembly of one blade on the composite propeller hub. The goal of this test is the evaluation of the embedding performances between the blade foot and the 2 half hubs.
The static tensile test with the blade in the axis uses the same device as the offset tests with 32°.

- Static pulling with the blade in the axis: Delaminating at 58000 N
- Estimate of the static pulling with the blade in the axis: Calculated break point at 96000 N

It was impossible to obtain a complete rupture of the blade because of the tears around the attaching bolts of the system of traction.
To estimate a value of rupture in the axis, we exerted an eccentric static traction of 32°. The rupture occurred on the level of the shoulder of blade’s foot. We can consider that the rupture of the blade in the axis represents approximately the double of the rupture’s value with 32° because with this position, only half of the blade’s foot is in contact with the assembly.
The two tests with 32° were also carried out to observe the behavior of the blade subjected to combined pulling. These statements do not show to in any case reality being given that the centrifugal force is inevitably in the axis.

- Static pulling with the blade with 32° of the axis: Break point at 48000 N
- Static pulling with the blade assembled in the hub with 32° of the axis: Break point at 48000 N
**Picture 1:** Blade alone at 32°

**Picture 2:** Blade at 32° in its hub

---

DH_SW_NM_01_A-SWIRL-Instruction_Manual.docx  
15/12/2009  
24/26
### CENTRIFUGAL FORCE OF THE SWIRL BLADE STANDARD

<table>
<thead>
<tr>
<th>Type of engine</th>
<th>Max. speed (Tr/min)</th>
<th>Speed with factor of increase 1.5 (Tr/min)</th>
<th>Reducer</th>
<th>speed after the reducer (Tr/min)</th>
<th>Radius of the gravity's center</th>
<th>linear speed (m/s)</th>
<th>Blade's weight (kg)</th>
<th>Centrifugal force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4 TIMES ENGINES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 912</td>
<td>6000</td>
<td>9000</td>
<td>2.27</td>
<td>3965</td>
<td>275</td>
<td>114.1</td>
<td>0.840</td>
<td>39780</td>
</tr>
<tr>
<td>ROTAX 912S</td>
<td>6000</td>
<td>9000</td>
<td>2.48</td>
<td>3629</td>
<td>275</td>
<td>104.5</td>
<td>0.840</td>
<td>33328</td>
</tr>
<tr>
<td>JABIRU 2200</td>
<td>3300</td>
<td>4950</td>
<td>1</td>
<td>4950</td>
<td>252</td>
<td>130.6</td>
<td>0.820</td>
<td>55468</td>
</tr>
<tr>
<td>JABIRU 3300</td>
<td>3300</td>
<td>4950</td>
<td>1</td>
<td>4950</td>
<td>248</td>
<td>128.5</td>
<td>0.810</td>
<td>53922</td>
</tr>
<tr>
<td><strong>2 TIMES ENGINES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>2.58</td>
<td>3953</td>
<td>275</td>
<td>113.8</td>
<td>0.840</td>
<td>39554</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>2.62</td>
<td>3893</td>
<td>275</td>
<td>112.1</td>
<td>0.840</td>
<td>38355</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>3</td>
<td>3400</td>
<td>275</td>
<td>97.9</td>
<td>0.840</td>
<td>29254</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>3.47</td>
<td>2939</td>
<td>275</td>
<td>84.6</td>
<td>0.840</td>
<td>21866</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>4</td>
<td>2550</td>
<td>275</td>
<td>73.4</td>
<td>0.840</td>
<td>16455</td>
</tr>
</tbody>
</table>

### CENTRIFUGAL FORCE OF THE SWIRL BLADE INCONEL

<table>
<thead>
<tr>
<th>Type de moteur</th>
<th>Régime max. (Tr/min)</th>
<th>Régime avec coef. de majoration 1.5 (Tr/min)</th>
<th>Réducteur</th>
<th>Régime après réduction (Tr/min)</th>
<th>Rayon centre de gravité pale</th>
<th>Vitesse linéaire (m/s)</th>
<th>Masse pale (kg)</th>
<th>Force centrifuge (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOTEUR 4 TEMPS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 912</td>
<td>6000</td>
<td>9000</td>
<td>2.27</td>
<td>3965</td>
<td>284</td>
<td>117.9</td>
<td>0.870</td>
<td>42549</td>
</tr>
<tr>
<td>ROTAX 912S</td>
<td>6000</td>
<td>9000</td>
<td>2.48</td>
<td>3629</td>
<td>284</td>
<td>107.9</td>
<td>0.870</td>
<td>35648</td>
</tr>
<tr>
<td>JABIRU 2200</td>
<td>3300</td>
<td>4950</td>
<td>1</td>
<td>4950</td>
<td>261</td>
<td>135.2</td>
<td>0.840</td>
<td>58850</td>
</tr>
<tr>
<td>JABIRU 3300</td>
<td>3300</td>
<td>4950</td>
<td>1</td>
<td>4950</td>
<td>256</td>
<td>132.6</td>
<td>0.825</td>
<td>56692</td>
</tr>
<tr>
<td><strong>MOTEUR 2 TEMPS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>2.58</td>
<td>3953</td>
<td>284</td>
<td>117.5</td>
<td>0.870</td>
<td>42307</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>2.62</td>
<td>3893</td>
<td>284</td>
<td>115.7</td>
<td>0.870</td>
<td>41025</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>3</td>
<td>3400</td>
<td>284</td>
<td>101.1</td>
<td>0.870</td>
<td>31290</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>3.47</td>
<td>2939</td>
<td>284</td>
<td>87.4</td>
<td>0.870</td>
<td>23388</td>
</tr>
<tr>
<td>ROTAX 582</td>
<td>6800</td>
<td>10200</td>
<td>4</td>
<td>2550</td>
<td>284</td>
<td>75.8</td>
<td>0.870</td>
<td>17601</td>
</tr>
</tbody>
</table>
2. FATIGUE TEST OF THE DUC BLADES

This test is the subject of a study of the static tensile strength (tests outlined above) blades with UCR suffered the stresses on a bench swing.

DUC blades have suffered this bending test for 30 hours or 2,340,000 cycles of oscillation of 70mm.

Following these requests, these blades have been tested in static tensile described above and the results showed no change in tensile strength.