Adaptation of the UK national rotor rig for aeroelastic propeller testing in stalled conditions

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MENtOR & NESPA Projects

- Methods and Experiments for NOvel Rotorcraft (2019-2022). EPSRC funded
- The aim of MENtOR is to develop and validate methods and tools that will be used for the design and analysis of the next-generation rotorcraft.
- WP3 – University of Glasgow: Development and commissioning of a rotor rig capable of testing propellers in close to stall conditions. Driven by:
  - Re-emergence of propeller driven aircraft.
  - Relative lack of modern experimental databases of propeller stall/ stall flutter.
- NESPA project (Numerical and Experimental Study of Propeller Aeroelasticity), funded by Dowty Propellers

MENtOR
A UKVLN Project
Methods and Experiments for NOvel Rotorcraft

EPSRC
Engineering and Physical Research Council

NWTF

Rig requirements

- Possibility to test in stall/close to stall conditions.
- Mach scaled.
- Need to measure the mechanical strain on the blades.
- Need to properly fit inside the deHavilland wind tunnel at the University of Glasgow.

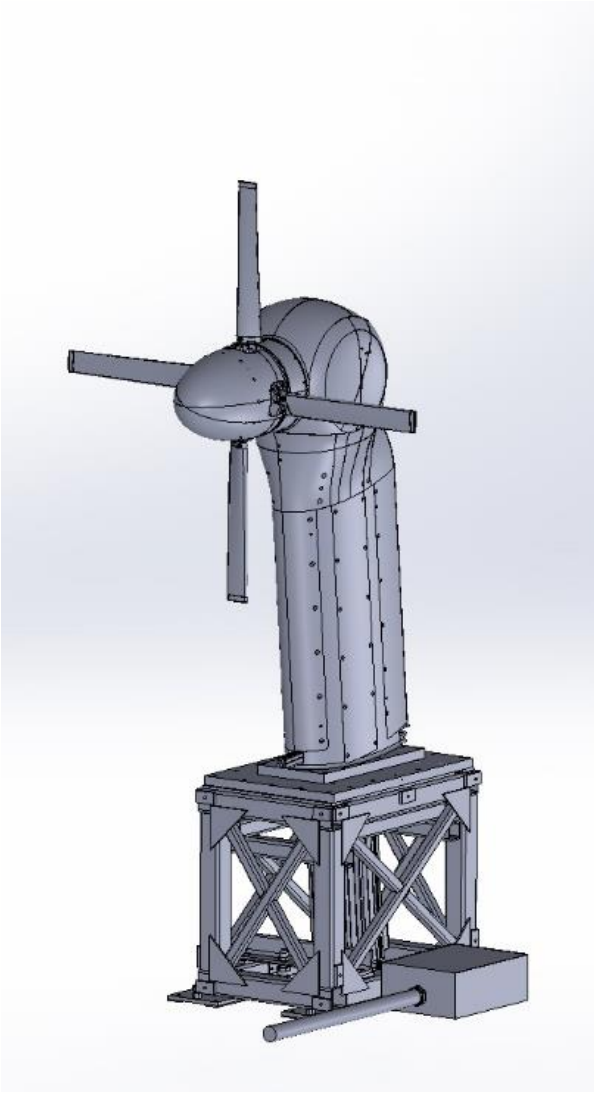
These implicate:

- Very high torque and power demand.
- Very high and unsteady loading on the rig.
- Necessity to bring data from the rotating to the stationary part of the rig.

The UK national rotor rig Facility.

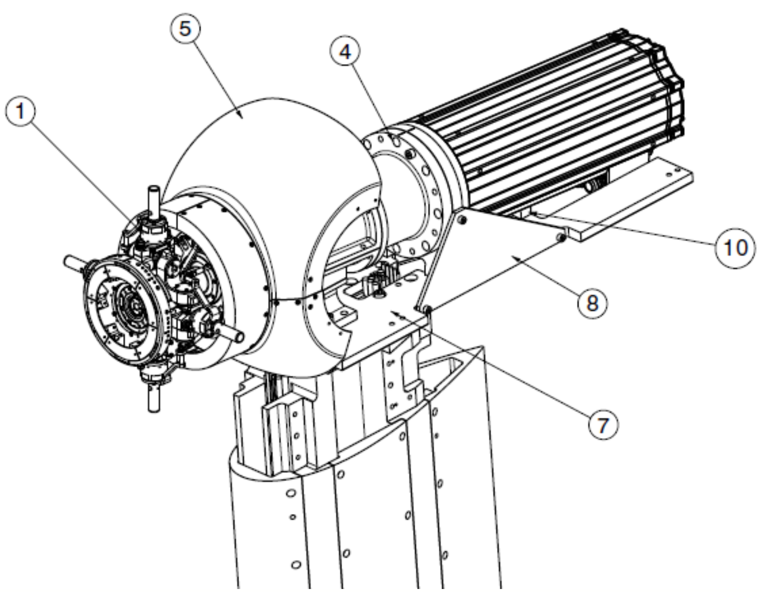
- Designed and manufactured by ARA.
- Gearbox on the top of the rig allowed the rotor to tilt to test airplane, conversion and helicopter mode.
- Rotor endowed with swashplate.
- D=1.4 m.
- Rotational speed up to 3500 RPM.
- Telemetry system.

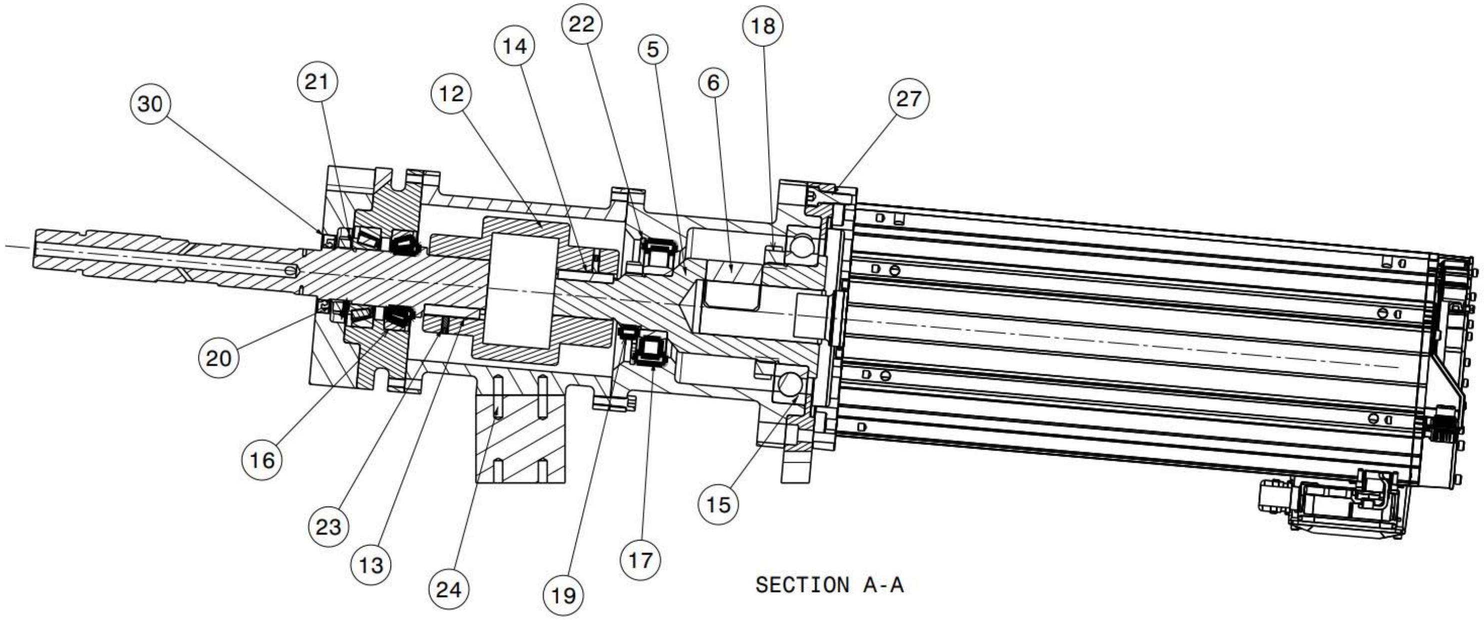
- Project concluded in 2016 before final commissioning phase.



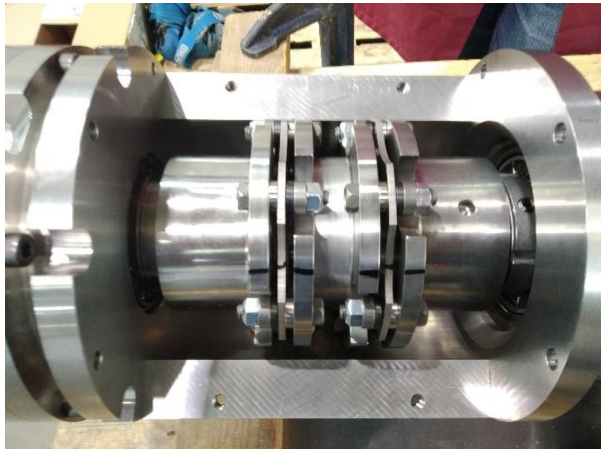
Rotor Rig adaptation

- A decision was made to revamp the UK National Rotor rig, that had not been further developed for several years.
- The focus shifted towards testing rotors in propeller mode, so a simplified, direct-drive design was developed to bypass the gearbox.



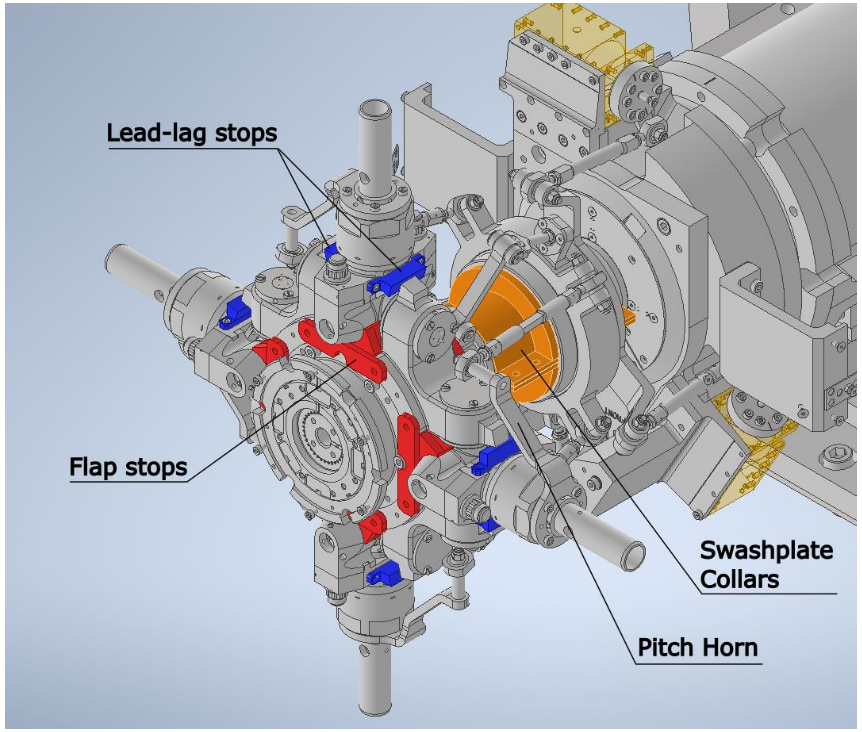


Rotor Rig adaptation



Rotor Rig adaptation

- Flap, lead/lag and pitch stops were designed to simulate propeller mode and test at fixed collective without cyclic pitch.
- Pitch adaptors to increase the collective pitch range.



New Blade Design

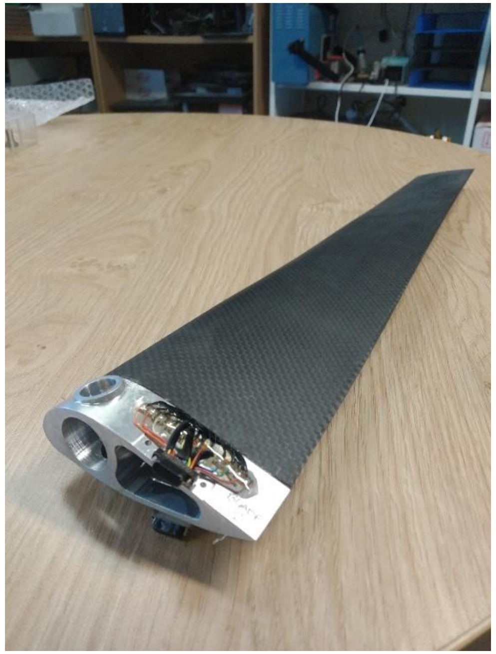
- CFD Loads estimation by CFD Lab @ UofG with the original set of blades.
- 4 blades, $\theta_c = 32°, \; M_{TIP} = 0.6, \; \Omega = 2780\ RPM, U_\infty = 40\ m/s$

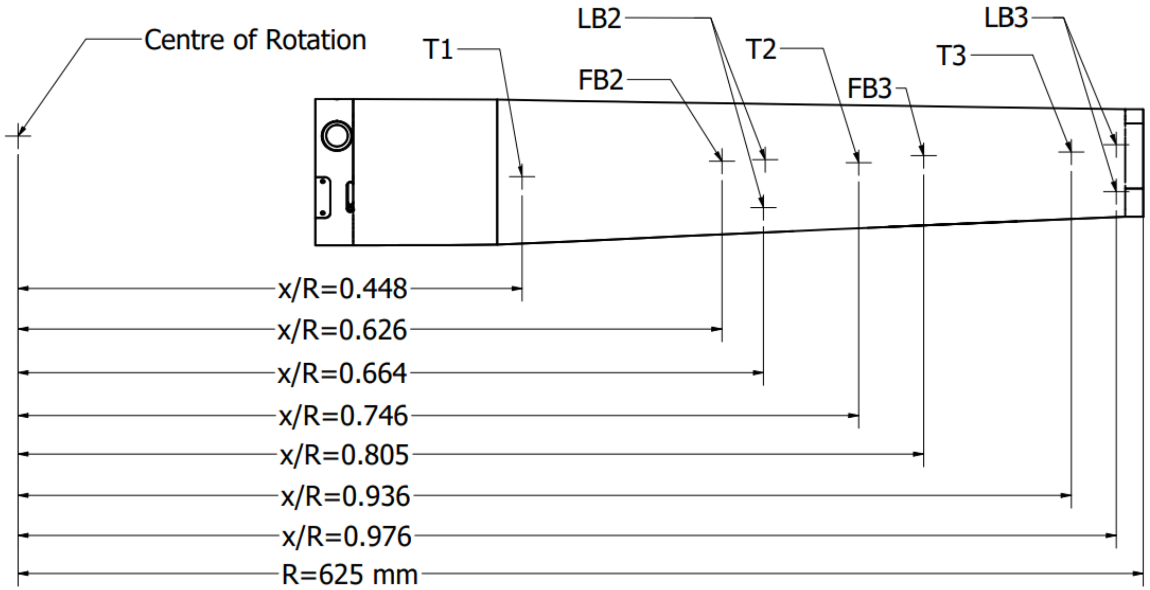
	CFD	Rig Limitations	
Thrust	1.754 kN	3.4 kN	☑
Torque	406.4 Nm	350 Nm	☒
Power	118.4 kW	77 kW (With Gearbox) 125 kW (Direct Drive)	☒ ☑

- Blade re-design to obtain earlier stall (at lower loads).
- Rotor diameter reduced to 1.25m (from 1.4m).
- Direct-drive allows to take full advantage of the rig capabilities.

New Blade Design

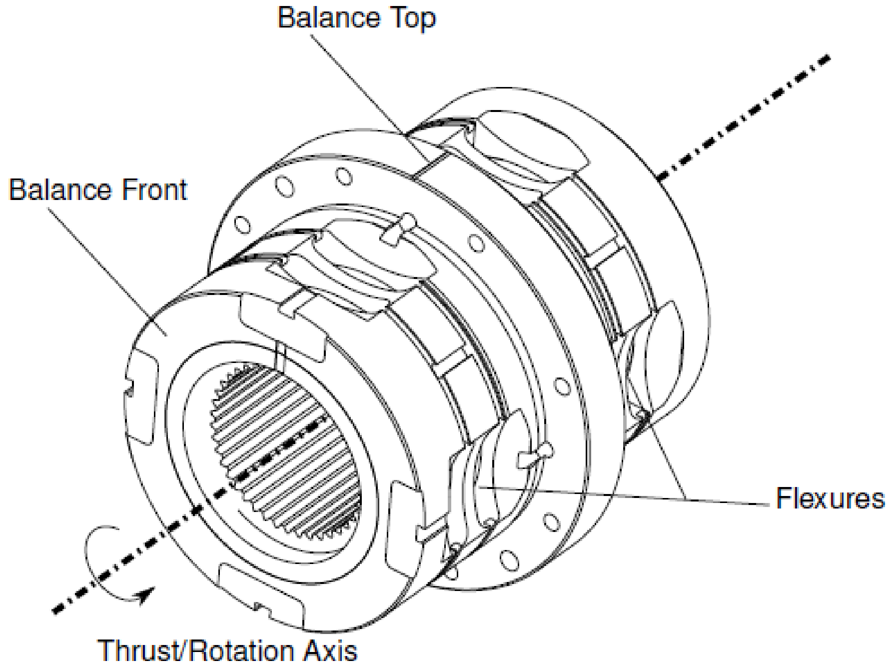
- 1.25m diameter, root chord 84.2mm, tip chord 60mm, 19.4° non-linear twist.
- Full bridges compensate for centrifugal and thermal effects.
- Instrumented with 7 fully bridged axial and shear bridges (4 actually working). Bonded on the inside of the internal surface of the blade.
  - 2 Flap Bending (FB).
  - 2 Lead-lag Bending (LB).
  - 3 Torsional Twist (TT).

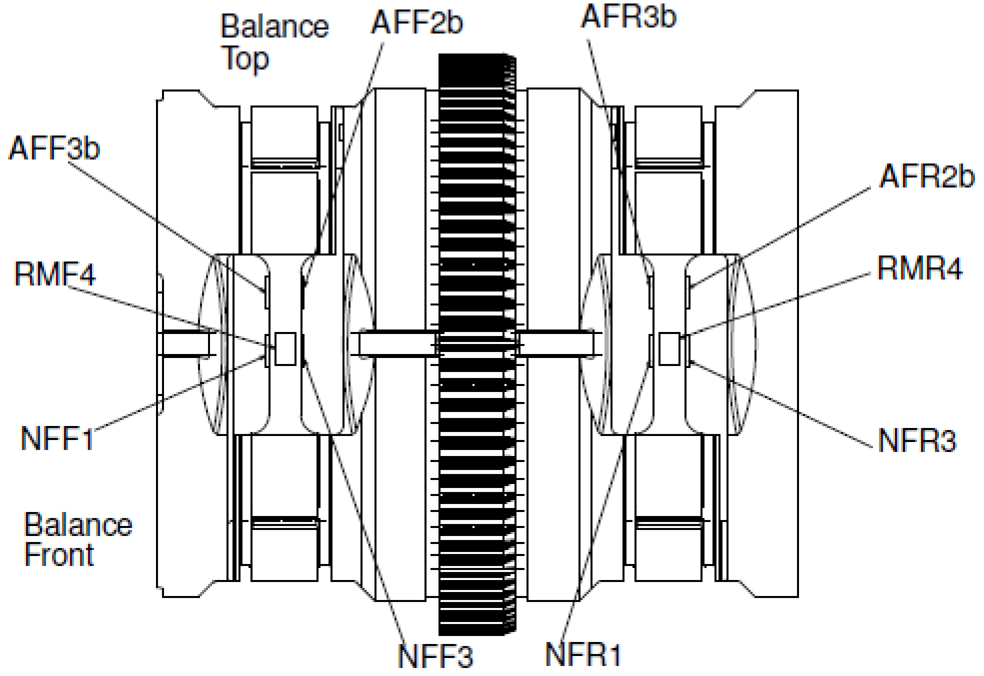




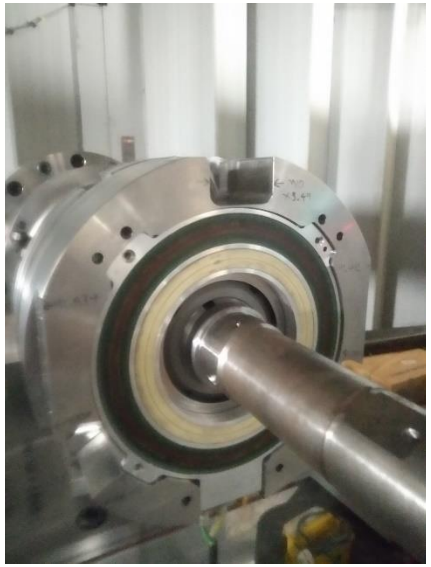
Rotating Shaft Balance

- Designed and manufactured by ARA.
- 6 components load-cell, installed at the end of the main shaft.
- Up to 3.4kN thrust, 350 Nm torque, 250 Nm out-of-plane moments.
- 8 bridges measured to resolve the 6 components.

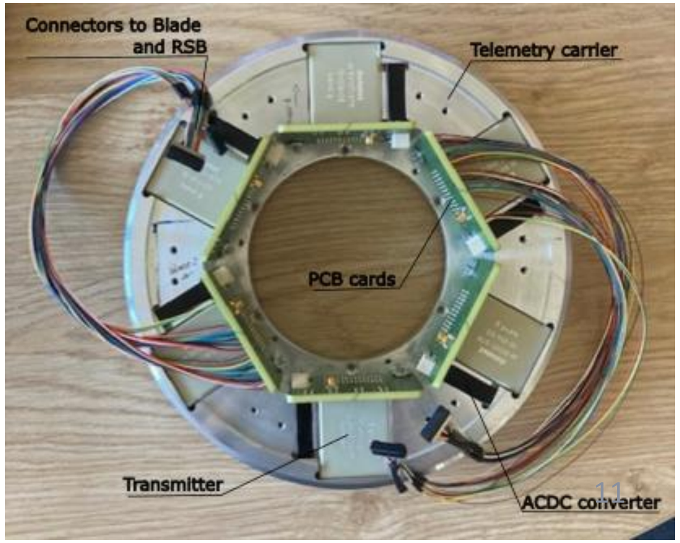




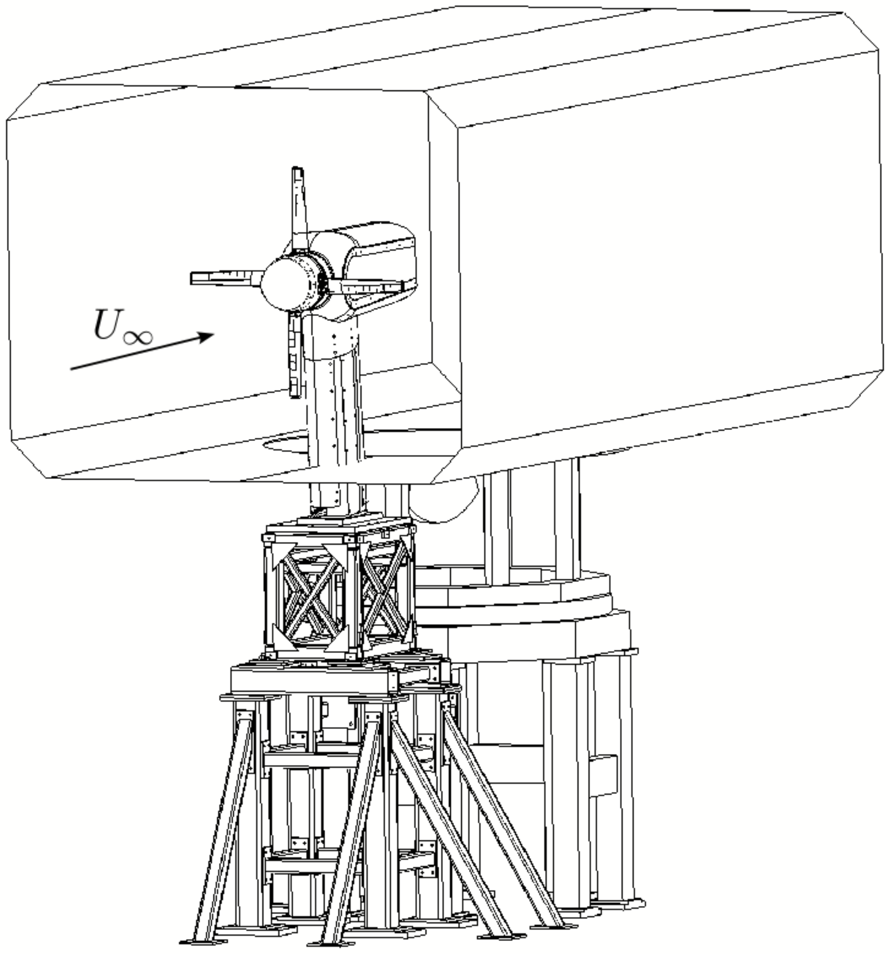
Telemetry System




- Provided by Datatel Gmbh (Germany).
- 60 channels available.
- Power is provided to the rotating part of the rig by means of an inductive ring.
- Transmission antenna co-located with the inductive ring.
- Contact free transmission of measured data from the transmitter to the receiver (3mm gap).
- Transmitter carrier installed within the spinner.



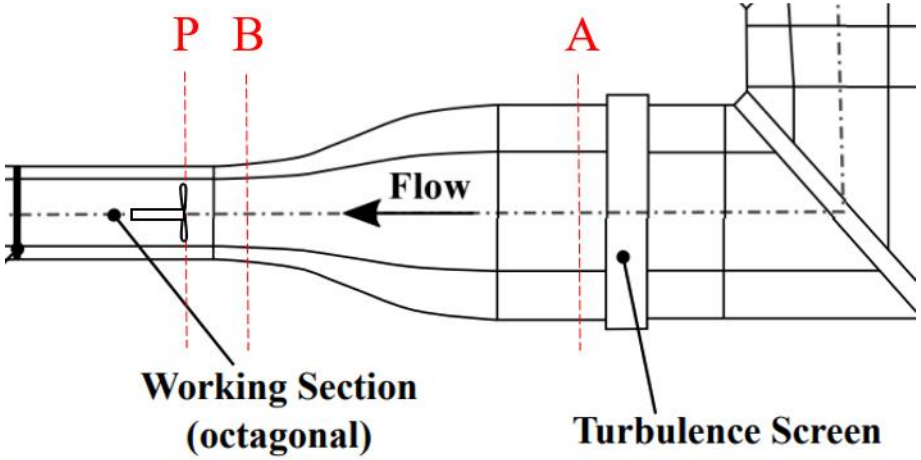
Installation in the DeHavilland WT

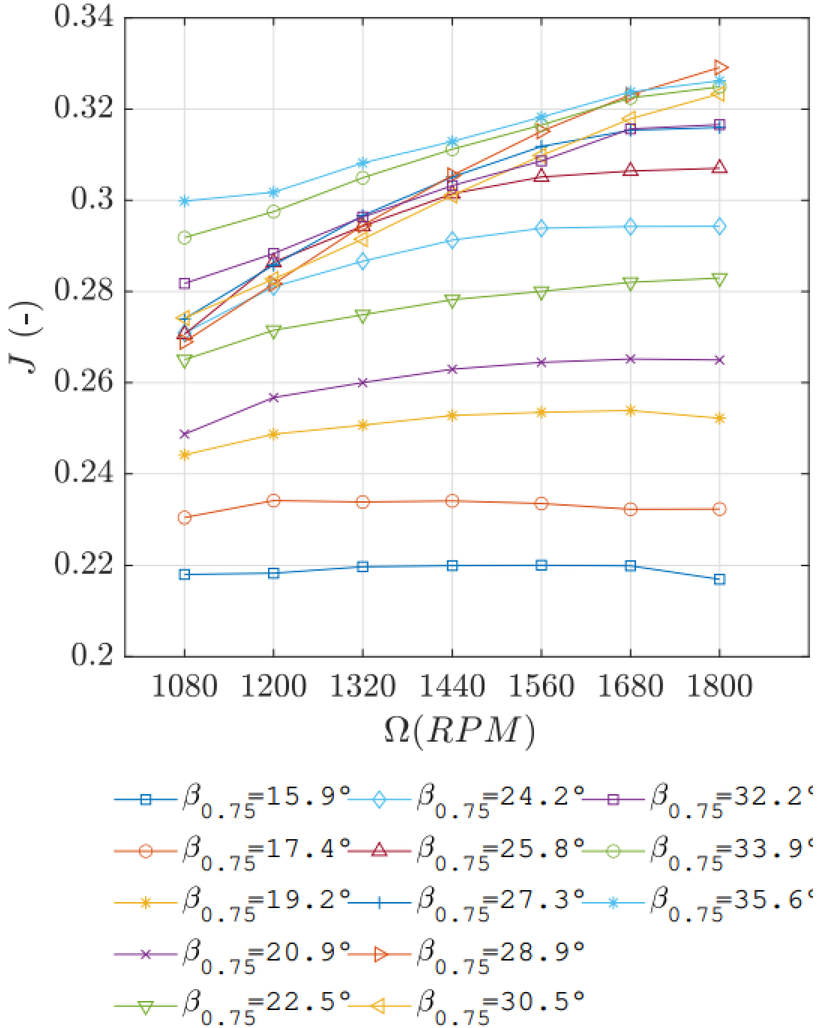


- Test section is 9x7 ft (2.7x2.1m).
- The rig is mounted on a supporting steel frame.
- The rotor spin axis is at the centre of the test section, ~3.5m from the ground.
- Very large mass (approx. 375 kg), top-heavy.

- Need to understand the dynamic properties of the rig, in order to know which frequencies not to operate at and accelerate through during spin-up and spin-down.
- Modal test campaign carried out with the help of the University of Bristol (A. Tatar, J.Wu, B. Titorus, D. Rezgui)

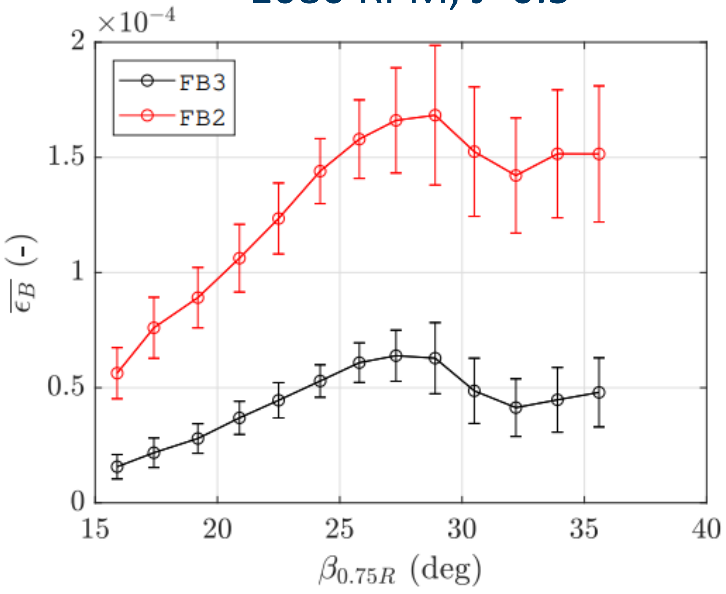
WT reference speed and calibration.

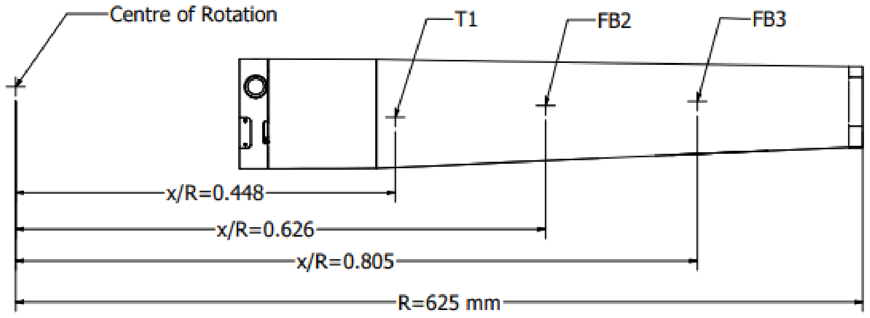


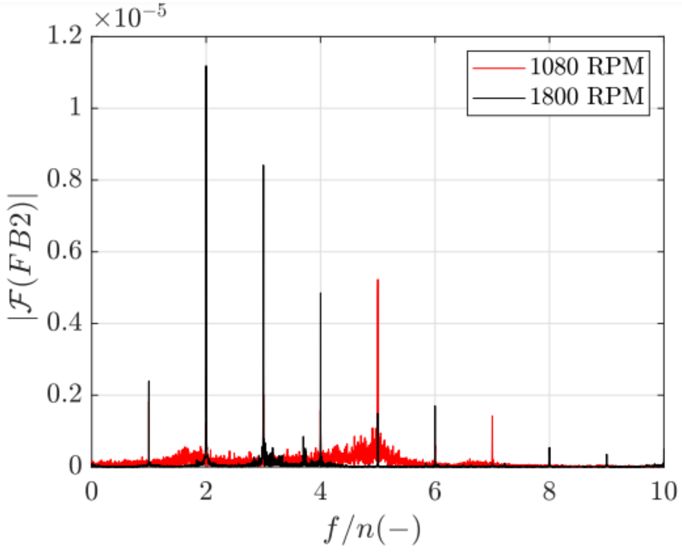


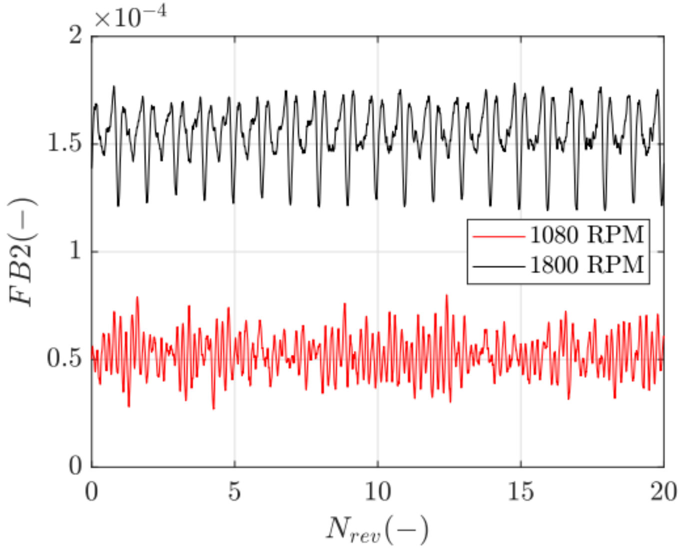
Sample Results

1080 RPM, J=0.5









$\beta_{0.75R} = 30.5°$

J=0.5

Thank you for your attention.

Any questions?