Glasgow Experimental Database

1 INTRODUCTION

This document describes the database gathered at University of Glasgow. The experimental work was aimed to investigate the rotor flow in the vicinity of an obstacle and in particular it consisted of a set of tests reproducing hovering flight conditions at different positions with respect to a cubic obstacle with side dimension equal to the rotor diameter. Two different rotor rigs were used and load measurements from the rotor, pressure measurements on the obstacle faces and velocity measurements of the air flow have been gathered in this study.

2 ROTOR RIGS AND TEST CONDITIONS

The main features of the rotor rigs with the corresponding obstacles are reported in Table 14. The type of experimental investigation performed on each of the two rigs is also reported.

Characteristics	Rotor Rig 1 (Large)	Rig 2 (Small)
Cubic obstacle size	1 m	0.3 m
Rotor Diameter	1 m	0.3 m
Number of blades	4	2
Blade chord	53 mm	31.7 mm
Solidity	0.135	0.134
Rotor rotational frequency	1200 rpm	4000 rpm
Reynolds number at blade tip	220000	132000
Mach number at blade tip	0.18	0.18
Type of experimental investigation	Loads, LDA	Stereo-PIV, Pressure, flow visualisation

Table 1 - Rotor Rigs Features

The data that will be presented in this document will follow the conventions of Figure 1. Two different reference systems are defined: the global reference system (X;Y;Z) which defines the position of the rotor hub centre with respect to the obstacle and the rotor reference system (x;y; z), which corresponds to the load-cell axes. The origin of the absolute (X;Y;Z) coordinate system is fixed and it is placed on the floor, at the obstacle mid-span (as in Figure 1).

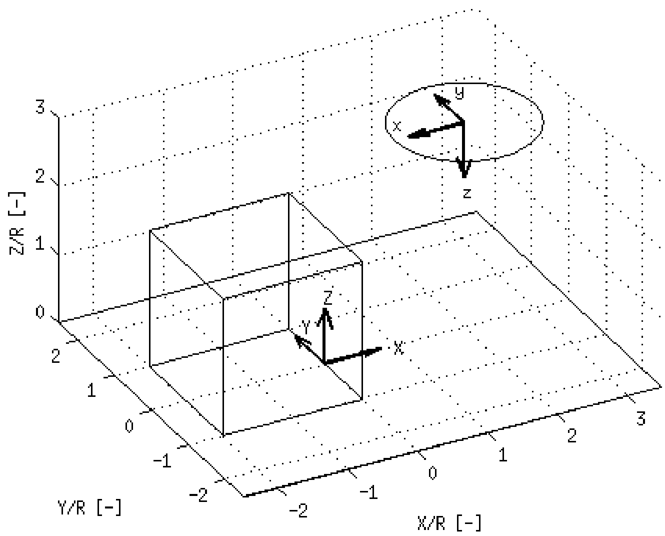

Figure 1 - Reference Systems

The database consists in a set of tests reproducing hovering flight conditions at different positions with respect to the obstacle. The position of the rotor centre in each of these test is represented in Figure 2 and Figure 3. Two different planes were investigated: the symmetry plane (Y/R=0) and a plane coincident the the lateral face of the obstacle (Y/R=1). The LDA and PIV data were acquired in a selection of the test points.

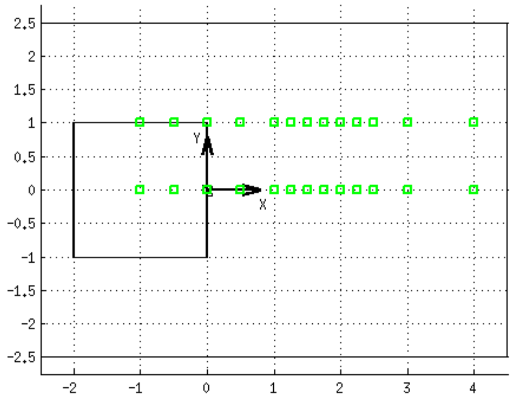

Figure 2 – Test Points, Birdseye view

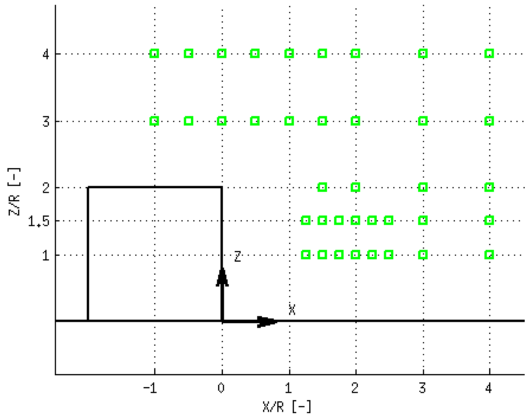

Figure 3 - Test Points, Lateral view

3 AVAILABLE DATA

3.1 Loads Measurements

The loads data are available in the subdirectory **"Loads"**. Two files are present:

- "Loads_Symmetryplane.dat", which includes the data acquired when the rotor is placed in the symmetry plane (Y/R=0).
- "Loads_outSymmetryplane.dat", which includes the data acquired when the rotor is placed out of the symmetry plane (Y/R=1).

The Out of Ground Effect (OGE) condition in absence of the obstacle is the following:

$$c_{T,OGE} = 7.36 \cdot 10^{-3}, \quad c_{Q,OGE} = 8.75 \cdot 10^{-4}, \qquad FM_{OGE} = 0.51$$

The data format, which is the same for the two files, is the following:

- X/R [-] Z/R [-] : Position of the rotor centre, in fractions of the rotor radius.
- cT [-] cQ [-] FM [-] : Thrust coefficient $c_T = \frac{T}{\rho V_{TIP}^2 A}$, Torque coefficient $c_Q = \frac{Q}{\rho V_{TIP}^2 AR}$, Figure of Merit.
- cMx [-] cMy [-] : x and y moment coefficient $c_M = \frac{M}{\rho V_{TIP}^2 AR}$.
- T [k] P_abs [Pa] rho [kg/m^3]. Air data: temperature, absolute pressure, density.

A previously stated, the position of the rotor centre is defined in the absolute reference system (X,Y,Z), whereas the moment coefficient is expressed in the rotor reference system (x,y,z). According to this convention, a positive cMy corresponds to nose-up pitching moment , if we imagine the helicopter facing the obstacle.

3.2 LDA Measurements

LDA measurements along the rotor x and y axes (see the Reference system of Figure 1), 4 cm (4%D) above the rotor plane, were performed in order to understand how the interacting flow field affected the rotor performance. The LDA measurements were carried out in a subset of the measurement points of Figure 3, i.e. those at Z/R = 1.5, 2, 3, due to the maximum and minimum height achievable by the traversing system.

The following files are available in the LDA subfolder:

- **LDA_Xsweep_symmplane.dat** : LDA measurements along the x direction, when the rotor is placed in the symmetry plane (Y/R=0)
- **LDA_Xsweep_outsymmplane.dat:** LDA measurements along the x direction, when the rotor is placed out of the symmetry plane (Y/R=1)
- **LDA_Xsweep_ref.dat:** LDA along the x direction, in absence of the obstacle
- **LDA_Ysweep_symmplane.dat dat** : LDA measurements along the y direction, when the rotor is placed in the symmetry plane (Y/R=0)
- **LDA_Ysweep_outsymmplane.dat:** LDA measurements along the y direction, when the rotor is placed out of the symmetry plane (Y/R=1)
- **LDA_Ysweep_ref.dat** LDA along the y direction, in absence of the obstacle.

The data format is the following:

" x [mm] y [mm] z [mm] v [m/s]",

where x, y, z are the coordinates of the measurement points, according to the rotor reference system. The velocity is expressed in the latter reference system too, so that a positive induced velocity points downwards. There is one column for each of the tests, identified by the header (i.e. Z/R=3, X/R=1).

3.3 PIV Measurements

Averaged Stereo-PIV measurements are available in the sub-folder PIV. The measurement plane is coincident with the problem symmetry plane, and focuses on the region between the obstacle and the rotor. PIV measurements were carried out using the small rotor rig in a subset of the tests, namely those at X/R= 1,3/2, 2 and Z/R= 1,3/2, 2. The data format is the following :

X [mm], Z [mm], u [m/s], w[m/s] ,v_outplane [m/s], mag2D [m/s],

- X and Z represents the position of the measurement point in the absolute reference system (X,Y,Z)
- u [m/s], w[m/s] are the in-plane velocity components
- v_outplane [m/s] is the out-of plane-velocity component. A positive velocity points towards the negative Y axis.
- mag2D [m/s] is the in-plane velocity magnitude, namely $\sqrt{u^2 + w^2}$

4 References

The database is described in the paper presented at the 72nd AHS forum:

Zagaglia, D., Giuni, M., Green, R.B., "Rotor-Obstacle Aerodynamic Interaction in Hovering Flight: An Experimental Survey," presented at the AHS 72nd Annual Forum, West Palm Beach, (FL) USA, 17-19 May 2016;