Investigation of the Orthogonal Blade-Vortex Interaction

1st Interim Report

by

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Preliminary results from a PIV study of the orthogonal blade-vortex interaction are presented. The tests have focussed upon phenomena occurring over the lower and upper surfaces of the blade. An analysis of the BVI over the upper surface has revealed an inflow to the vortex core, which contrasts with the radial outflow previously observed over the lower surface.

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Abstract

Preliminary results from a PIV study of the orthogonal blade-vortex interaction are presented. The tests have focussed upon phenomena occurring over the lower and upper surfaces of the blade. An analysis of the BVI over the upper surface has revealed an inflow to the vortex core, which contrasts with the radial outflow previously observed over the lower surface.

1. Experimental Study

The initial investigation and preliminary data obtained for the orthogonal blade-vortex interaction has allowed familiarisation with the Particle Image Velocimetry technique, as well as an assessment of the analysis method and new experimental apparatus designed for data acquisition.

1.1 Tests Performed

Through the implementation of a new optical arrangement, the dual PIV system may now be used with the laser lightsheets displaced from one another within the flow to allow for simultaneous measurement of upper and lower surface positions, and hence direct comparison of obtained data. Preliminary data for the trailing edge region has been obtained, for both lower and upper surface locations. Future work will be based upon the use of the dual PIV system, and direct comparison of the behaviour of the vortex on the upper and lower blade surfaces. By tracking the progression of the split vortex on either side of the blade from the leading to trailing edge, a representation of the interaction from the initial severing of the vortex core to the rejoining of the two halves at the trailing edge position will be constructed.

1.2 Development of the Analysis Methodology

For the assessment of the out-of-plane component present within the flow, calculation of the divergence within the region of interest has proven to be a viable method of determination, allowing an assessment of the acceleration in the axial flow direction. This calculation is based upon the mass flow within the two dimensional plane under observation. Through the use of this technique, a more accurate representation of the axial flow behaviour may be obtained, since it is determined through the inspection of the whole flow, rather than a subjective view of the region of interest within the flow, which has been employed in previous analysis, and can be inaccurate and misleading.

Through the implementation of this analysis method, it has been ascertained that the flow present on the lower surface of the blade is decelerating towards the blade surface. This may be represented by a 'splashing' effect due to the impingement of the axial flow onto the blade. Analysis of the regions of vorticity and relative vortex core size at positions away from the blade also point to the existence of the vortex 'shock', as observed through previous experimentation and computational modelling, with the bulging of the vortex core near to the blade surface evident.

1.3 Preliminary Analysis

Initial observations made from the data acquired for the upper blade surface have indicated that axial flow, as would be expected, is accelerating away from the blade

surface (figure 1). Correspondingly, the radial component of the vortex appears to be of the form of a 'sink' (figure 2), as opposed to the 'source' flow observed on the lower surface. This sink/vortex flow would be indicative of the thinning of the vortex core on the upper surface, which has again been of note in previous studies. In order to examine this more fully, the upper surface will need to be interrogated for positions away from the blade surface in order to obtain the pattern of variations, if any, in the core radius.

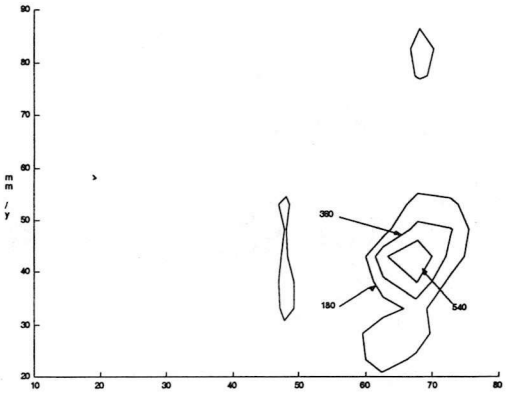

Figure 1: Divergence contours (1/sec) associated with upper surface interaction Blade leading edge situated at –55.3mm

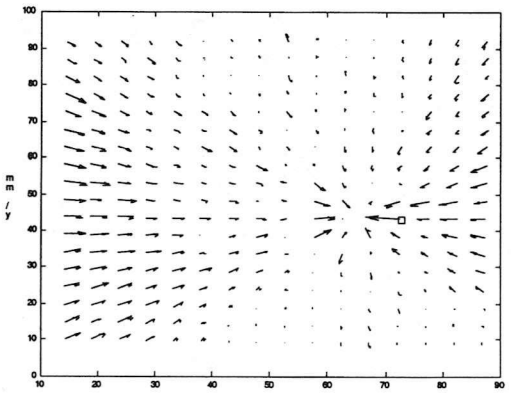

Figure 2: Radial Inflow associated with figure 1 Maximum Velocity 5.2 m/s

1.4 Conferences & Publications

An abstract for the Royal Aeronautical Society Aerodynamics Research Conference has been accepted for presentation in April 2001, at the RAeS HQ in London. There will be a rotorcraft session at this meeting. The conference paper may lead to a publication in the Aeronautical Journal.

2. Research plans for remainder of contract period

The current priority is to complete the experimental programme. The experimental rig for the boundary layer interaction is under construction, and this will soon be ready for testing. It is anticipated that these tests will take place in December/ January. Much confidence has been gained with the operation of the two PIV systems for simultaneous interrogation of the upper and lower surfaces. The tests with the light sheets close to the blade surface are the most difficult and are almost complete. Experiments upon the vortex joining still need to be carried out, and these should take place in January. Data analysis is to run concurrently with the experimental programme. Fortunately the analysis codes have been speeded up, so the raw analysis is not so burdensome.

Abstracts are due for submission in February for the International PIV workshop in Gottingen in September. It is essential that this meeting is attended, so the abstract preparation will form part of the effort in January/ February. It is clear from the literature searches that there is not much data on orthogonal BVI available world-wide. For the latter part of the research programme we will focus upon detailed data analysis for publication. At present it seems reasonable that there will be a visit to the USA to report the findings in June or July.

3. Administrative actions (staffing)

The significant administrative action during the period was the appointment of the research student to the contract. It was decided to offer the post to Ms Juliana Early, who graduated with a second class (upper) degree in Aeronautical Engineering from the Department of Aerospace Engineering, University of Glasgow in July 2000. For her final year project she performed some experimental work in the current area, and her experience and aptitude for experimental work was deemed suitable. Furthermore she had expressed an interest in pursuing research work well before she graduated. Ms Early is employed full-time on the contract and she is responsible for the day-to-day running of the project.

Technician support for the project is provided by a wind tunnel technician, Mr. D. Perrins. He assists with any adjustments to the mechanical operation of the test facilities, i.e. the wind tunnel and the rotor rig.

Appendices

A. Financial statement

A breakdown of the funds so far used is as follows. The exchange rate of £1=$1.3987 was valid on 24th November 2000.

Equipment	£1598	
Studentship	£2566	
Consumables	£932	
Technician salary	£248	
Total	£5344	$7475
Balance remaining		**$23767 = £16992**

B. Important property acquired during present report period

The significant equipment item acquired was a desktop personal computer for running the experiment and data analysis. This has accounted for entire equipment expenditure so far and is a one-off item.

The significant consumables item was a MATLAB licence. Again this is a one-off expenditure.