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Optical diagnostics for flow control on small wings

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14. ABSTRACT

The original proposal and purpose of this special grant were to replace a laser that had suddenly become unfixable. A new, dual-head Nd:YAG laser has been purchased, installed, and heavily-used in essential work. Two most recent investigations concern the flow over a complex wing-body-tail geometry, and the flow over a simple, standard NACA 0012 airfoil at moderate Re, when the flow properties are found to be responsible for very surprising force balance data, including negative lift at positive angle of attack. These are quite extensive studies and sample data only are given in this report. Full details will be published and given in formal reports. The laser has done exactly what we had planned, and extensive PIV-based investigations that would have taken months can now be done in one week.

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Optical Diagnostics for Flow Control on Small Wings

FA9550-15-1-0255

PI: Geoffrey R Spedding

Start: 7/1/2015

End: 6/30/2016

Abstract

The original proposal and purpose of this special grant were to replace a laser that had suddenly become unfixable. A new, dual-head Nd:YAG laser has been purchased, installed, and heavily-used in essential work. Two most recent investigations concern the flow over a complex wing-body-tail geometry, and the flow over a simple, standard NACA 0012 airfoil at moderate Re, when the flow properties are found to be responsible for very surprising force balance data, including negative lift at positive angle of attack. These are quite extensive studies and sample data only are given in this report. Full details will be published and given in formal reports. The laser has done exactly what we had planned, and extensive PIV-based investigations that would have taken months can now be done in one week.

Accomplishments

1. Laser purchase and installation

The Quantel laser has been installed and was operational immediately. Thanks to the greatly improved beam stability and to the high intensity (as compared with our previous laser, which had nominally similar specifications), the productivity and reliability of PIV-based measurements is greatly improved.

Two examples are given below. One makes use of the high reliability to make complete transects with no recalibration in a complex wing-body-tail geometry, and the second uses the fine spatial resolution to further our understanding of transitional Reynolds number flows over wings, as discussed in the proposal.

2. Wing-Body-Tail study

It has been proposed that a novel wing-body-tail combination would produce a complete aircraft of significantly greater aerodynamic efficiency than current common configurations. Strong statements require strong evidence and so we have been testing configurations for a number of years in the Dryden Wind Tunnel. The new laser system has allowed a much greater efficiency in PIV-based wake surveys that are quantitative, and from which drag can be estimated. Two sets of data are shown in Figs 1,2. Each single point comes from 100 independent vector fields, repeated over 6 experiments. The uncertainties are calculated from estimates of the variance over all experiments.

The variation of $w(y)$ is reduced over the fuselage for specific angles of a trailing edge flap, which we term a Kutta Edge, because it fixes the location of the rear stagnation point. Trimming the aircraft in this way increases lift and reduces induced drag. Perhaps not coincidentally, the shape resembles somewhat that of a seabird.

This research is not currently supported by AFOSR, but if we have an opportunity to properly explain why the mechanism works (as opposed to simply that it does), we may apply for funding in future, pending sufficient initial progress on the more practical aspects.

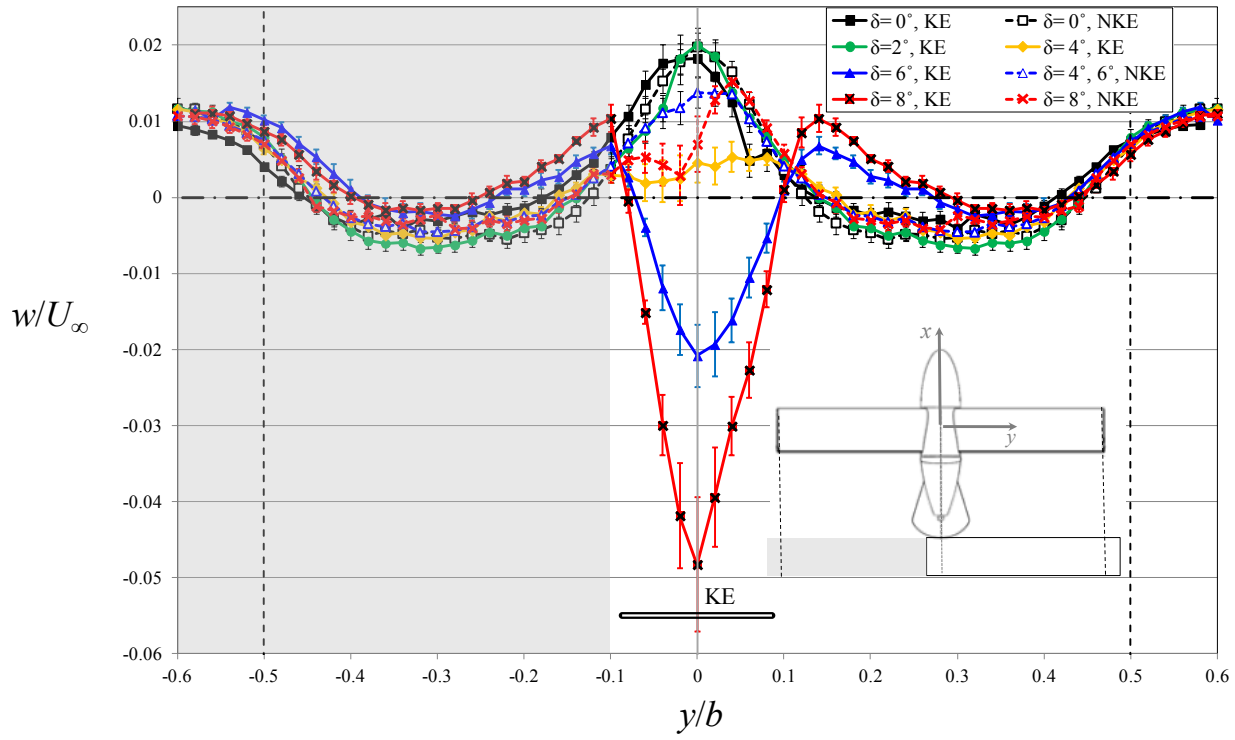

Fig. 1 The spanwise downwash distribution for lowest total drag, θ = -3°

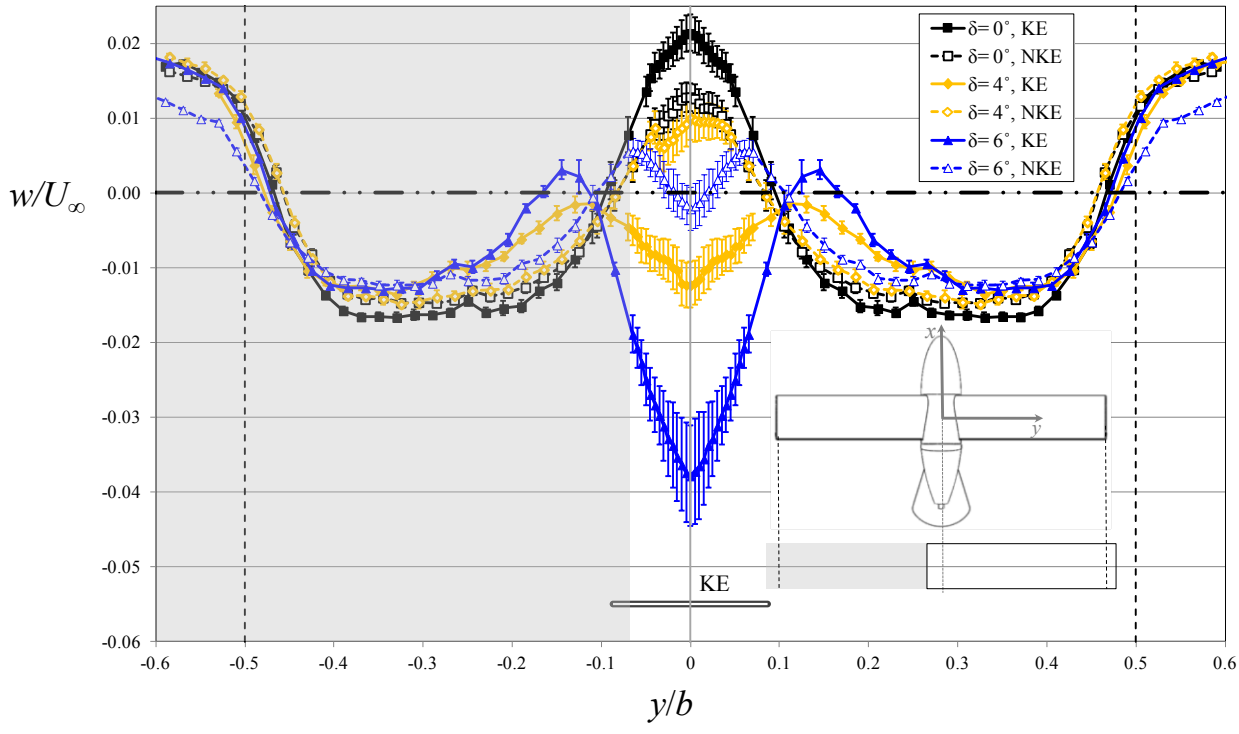

Fig. 2 The spanwise downwash distribution for highest L/D, θ = 0°

3. Moderate Re wings

Under previous AFOSR support, we have conducted many studies on acoustically forced transitions in marginally stable boundary layers. In principle, manipulation of such flows would allow 80% improvements in L/D, and we have proposed to fold some of these techniques into a flow control scheme, where the flow controller is optimised and not just tested empirically.

Pending funding of this work, we have continued to probe sometimes surprising aerodynamic characteristics of small wings. Here we show one major result, which is currently being written for publication. It concerns the force coefficients of the NACA 0012, one of whose main traditional advantages is the mass of existing data. However, the data rapidly diminishes in quantity and quality as Re decreases. At Re = 50k, there is a result at one angle of attack, in a very substantial numerical computation. We seek to (a) understand the basic physics of flight at these transitional conditions, and (b) provide definitive comparisons with the single available Direct Numerical Simulation.

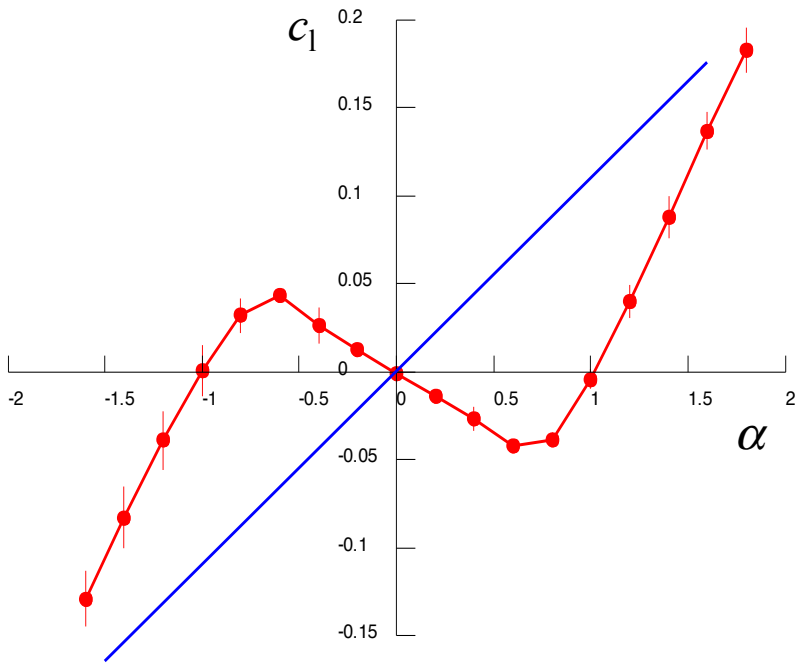

Fig. 3 Experimental determination of the surprising $c_l(\alpha)$ curve for the NACA 0012 at Re = 50k.

The result is extraordinary. The wing develops negative lift at positive angles of attack. The result is very repeatable (note error bars in curve of Fig. 3). Now the question remains: why?

For the first time, we have obtained accurate and reliable flow field information for this condition. The data below are preliminary.

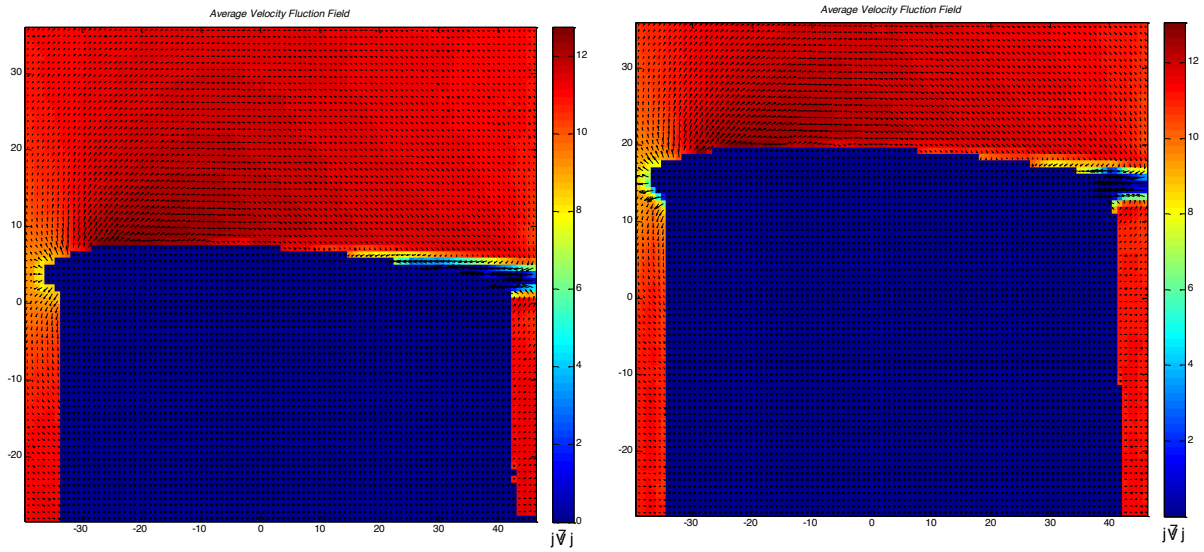

Fig. 4 The upper and lower boundary layers for $\alpha = 0.5$ deg.

The reason for the negative lift at α = 0.5 deg is that the bottom layer boundary layer separates later than the top one. At small α, it is the trailing edge separation that determines the aerodynamics, and not the presence or absence of laminar separation bubbles. The data in Fig. 4 are a very small part of an ongoing investigation.

4. Conclusions

We have purchased the Evergreen 200 PIV laser system, made by Quantel. The system is performing exactly as planned and is in very regular use. It will be an essential component in any future AFOSR funded project, the first of which is due to begin September 2016.

1.

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Optical diagnostics for flow over small wings

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FA9550-15-1-0255

Principal Investigator Name

The full name of the principal investigator on the grant or contract.

Geoffrey R Spedding

Program Manager

The AFOSR Program Manager currently assigned to the award

Doug Smith

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Reporting Period End Date

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Abstract

The original proposal and purpose of this special grant were to replace a laser that had suddenly become unfixable. A new, dual-head Nd:YAG laser has been purchased, installed, and heavily-used in essential work. Two most recent investigations concern the flow over a complex wing-body-tail geometry, and the flow over a simple, standard NACA 0012 airfoil at moderate Re, when the flow properties are found to be responsible for very surprising force balance data, including negative lift at positive angle of attack. These are quite extensive studies and sample data only are given in this report. Full details will be published and given in formal reports. The laser has done exactly what we had planned, and extensive PIV-based investigations that would have taken months can now be done in one week.

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Research Objectives

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Funding Summary by Cost Category (by FY, $K)

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