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Fluid-Structure Interaction Study: Towards Active Flutter Control of a Composite Wing

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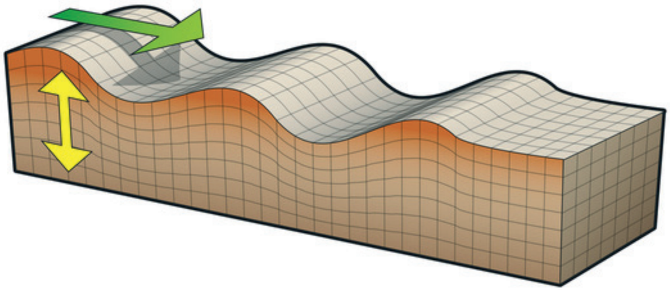
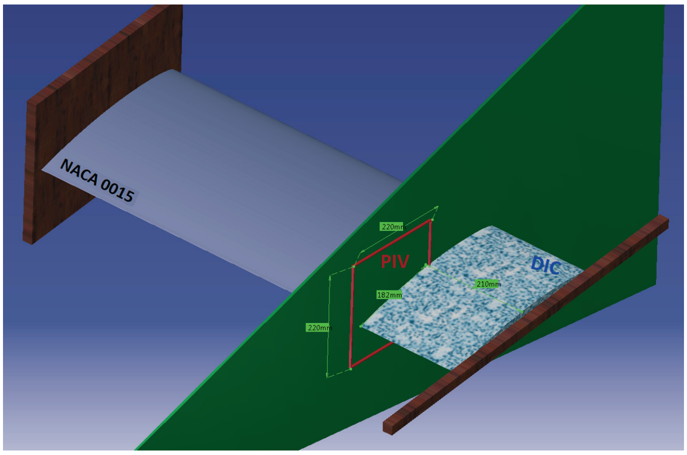
Introduction

In recent years, the study of aeroelasticity for a better understanding of fluid-structure interaction (FSI) phenomenon has been raised by the fast growing deployment of composite materials in aeronautical structures, as well as the need for more economical and innovative designs.

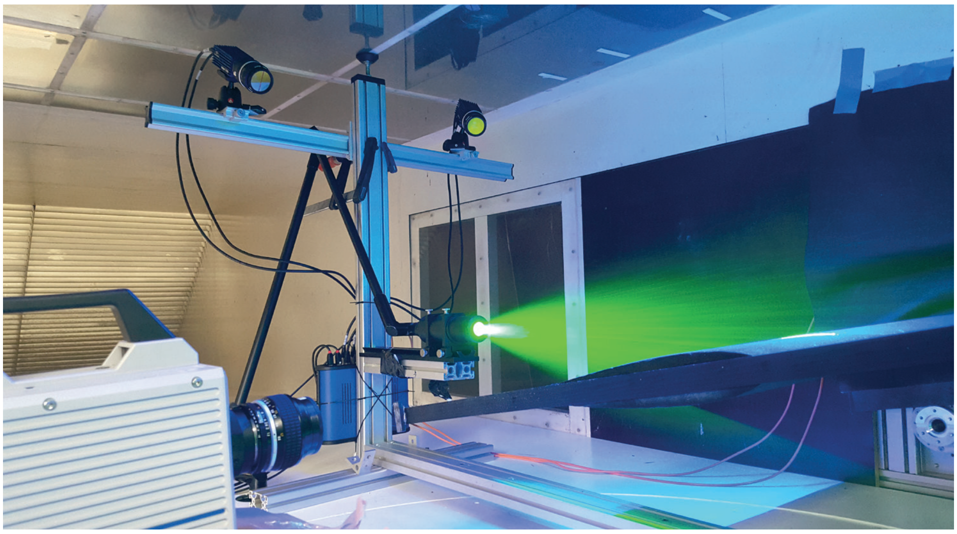


In this experimental investigation full-field, instantaneous data describing the fluid flow and structural response were gathered simultaneously. Digital Image Correlation (DIC) was utilized to describe the structural response and synchronized Particle Image Velocimetry (PIV) measurements were used to measure the fluid flow. This work is inspired by a PhD project that addresses the problem of active flutter control using actuation of a composite wing.

The test case under investigation was set up in an open circuit wind tunnel at the Fluid Mechanics laboratory of Vrije Universiteit Brussel. A Styrofoam wing (NACA0015, span 90 cm) was clamped at its root at the wall of the test section, and the free stream air velocity was 3.5 m/s. The free end of the wing had a load applied, which was then suddenly released to produce the disturbance that caused the wing tip to oscillate with an amplitude of up to 10 mm.



Experimental Setup



The 3D DIC system had two blue LEDs and two 5Mpix CCD cameras fitted with blue bandpass filters. The 2D PIV system comprised a 12 bit CMOS camera at 1024 x 1024 pixel resolution fitted with a green bandpass filter, and a 20 mJ Nd-YLF laser. The PIV system was operated at 750 Hz in single frame mode to capture time-resolved fluid motion, whilst the DIC system operated at 5 Hz. Both systems were triggered simultaneously and the DIC system was synchronized to phase-lock the PIV images.

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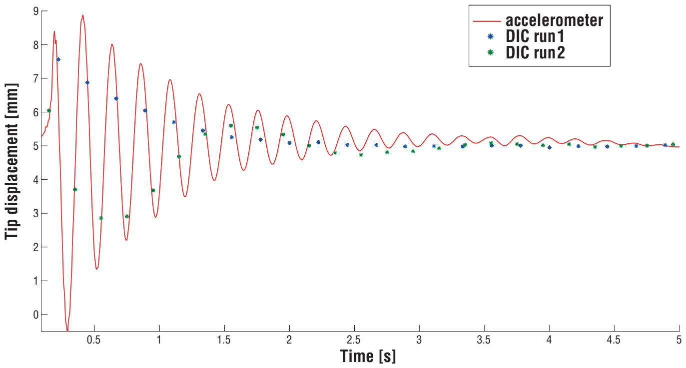
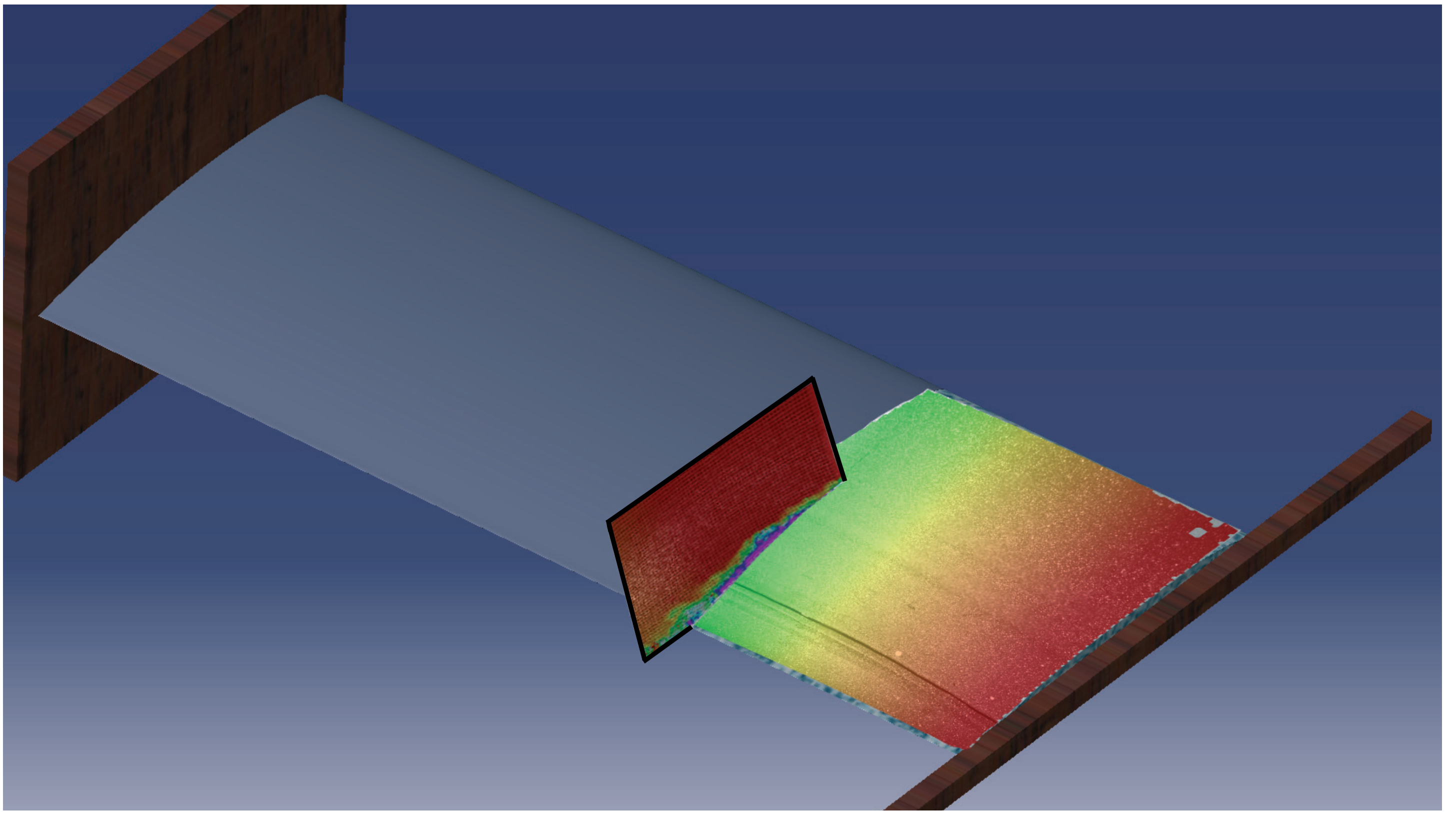
Results

The DaVis software (StrainMaster and FlowMaster modules) was used to process the DIC and PIV data sets. The DIC results provided a 3D reconstruction of the wing surface and the displacement of the wing with respect to the initial position. It should be noted that the reference position is taken as the clamped wing tip position before release. The PIV analysis was performed using multi-grid interrogation and adaptive interrogation window techniques.

The plot on the right shows the wing tip and simultaneously acquired accelerometer data. The image below shows the calculated displacement map (DIC) superimposed on the wing surface together with the perpendicular plane of fluid velocity (PIV) data.





The measurements presented herein have shown the potential of using 3D DIC and high-speed 2D PIV in the description of aerolastic dynamic response of a wing. The opportunities conferred in this area of research by the use of full-field imaging techniques can prove an invaluable asset for any experimental investigation of aeroelasticity.

For further details see '*Experiments on the active aeroelastic test bench (AATB) for the identification of unsteady aerodynamics*' by J. Ertveldt et al. (IFASD 2015).

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