An experimental investigation on stall flutter over a vertically mounted rigid finite wing

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Abstract

As stall flutter has relevant engineering implications, such as in blades of wind turbine and HALE (high-altitude long-endurance aircraft). This work presents the experimental investigation of rigid wing setup in a closed-circuit wind tunnel having 2.1 *m* × 1.5 *m* test section. The experimental campaign reached stable and symmetrical LCO within the freestream range from 9 *m/s* up to 14 *m/s* ($1.69 \times 10^5 < Re < 2.63 \times 10^5$). Two techniques were used for position tracking: one mechatronic and one image-based. The latter used 'shake-the-box' method applied to a body, which has proven a successful approach as a non-intrusive tool.

1 Introduction

The experiments were carried out at the 7x5 Wind Tunnel; a closed-circuit facility with two test sections in serial. For this experiment, the setup was installed at the high-speed test section (2.1 *m* × 1.5 *m*). The wing is a NACA0012 cross-section model of aluminium (.e. structure) and carbon-fibre composite (e.g. skin) of 0.3*m* chordwise and a span length of 0.77 *m*. A servo motor with cylindrical shield is the base for the wing, which was connected to a 6-axis Delta IP65 load cell.

In the heaving axis, the system was attached to a pair of linear-guided carriages, and the nominal rest position is found after two identical, counterbalance springs were linked, providing a spring constant (k) of 400 *N/m*. In the pitching axis, one pair of identical rubber bands were used on each side, connecting the wing leading edge to the cylindrical base.

The image-based tracking solution involved Particle Tracking Velocimetry (PTV) with 'shake-the-box' methodology, where 5 Phantom V641 high-speed cameras recorded a scattered pattern of 8mm dots on the wing surface. Experimental setup is illustrated in Figure 1.

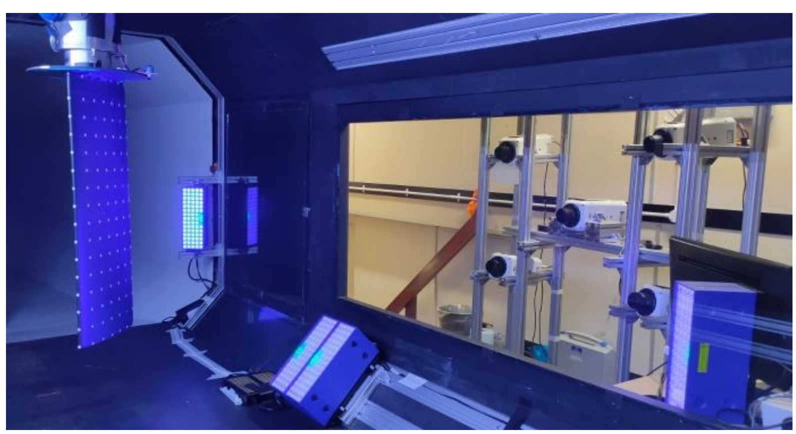

Figure 1: Wing system and 'shake-the-box' hardware setup for structural analysis.

2 Summary of Results

Both position tracking tools were performed simultaneously and lately compared in order to assess the quality of the image-based technique as a surface tracking tool. The later were processed in two steps: (i) obtaining the time-resolved position tracking with 'shake-the-box' methodology, then (ii) reconstruction of the wing surface and estimation of the angular and heaving history. Assuming the mechatronic position tracking results as baseline, the non-intrusive results are compared and presented in Figure 2.

A nominally harmonic dataset were found for each self-sustained LCO, which allowed analysis in phase-averaged format (Figure 3), where the properties are averaged as a function of the angle of attack cycle (i.e. pitching motion) discretised within 1° resolution.

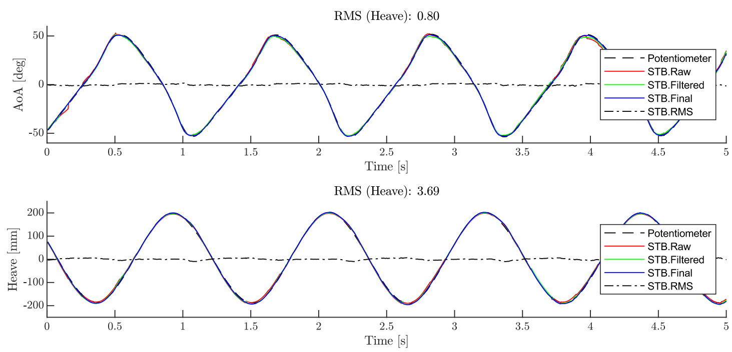

Figure 2: Position tracking validation: mechatronic- vs image-based systems.

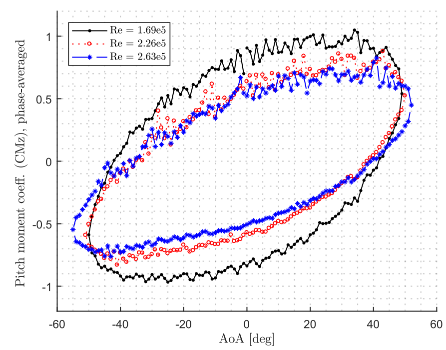

Figure 3: Phase-averaged LCO's.

3 Conclusions

The occurrence of a self-sustained LCO were found of the system with a NACA0012 rigid wing. An initial perturbation was required to trigger the phenomenon; however, the motion amplitudes were noticeably stable and reproducible for a same trigger input.The absolute minimum freestream able to sustain the motion was 8.5m/s with minor decay instabilities, and any freestream higher than 14 m/s would reach the physical end-stops. The 'Shake-the-Box' method applied as a body tracking solution has been successfully validated, allowing the use of this approach as a non-intrusive tool for further applications.

Acknowledgements

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