

Master thesis and internship[BR]- Master's thesis : Aeroelastic analysis of a slender wing : wind tunnel tests and modelling[BR]- Integration internship

Auteur : Pirnay, Maxime

Promoteur(s) : Andrianne, Thomas

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Aeroelastic analysis of a slender wing : wind tunnel tests and modelling

Pirnay Maxime

Supervisors : T.Andrianne , X.Amandolèse
Master in Aerospace Engineering, University of Liège
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Abstract

The development of lightweight and flexible wing structures in modern aerospace applications raises critical challenges in the prediction and control of aeroelastic instabilities, particularly flutter. In this context, this thesis addresses the modelling and experimental validation of flutter phenomena in slender, flexible wing structures. The study combines the development of a reduced-order aeroelastic model with wind tunnel testing to investigate the stability of high aspect-ratio configurations.

The numerical model is constructed using a Rayleigh-Ritz decomposition of the structural dynamics, coupled with two aerodynamic representations: a quasi-steady approximation and an unsteady formulation based on Theodorsen's theory. The approach allows for capturing bending-torsion coupling and tip-mass effects using a low-order formulation. A parametric study is conducted to investigate the influence of design variables, including tip mass, tip torsional inertia, chordwise location of the mass and other design choices, on the minimum flutter speed.

Two experimental campaigns were carried out to support and validate the numerical model. A first wing configuration, developed at the Institut Aérotechnique (IAT), was tested to identify modal characteristics and assess aerodynamic coefficients through incidence measurements. These measurements revealed a significant influence of inter-section gaps and three-dimensional effects on the aerodynamic slopes. The second wing, designed at the University of Liège, was tested under increasing flow speeds to observe flutter onset. In both cases, dynamic responses were recorded using accelerometers and/or laser sensor. Modal parameters were extracted using identification techniques including Stochastic Subspace Identification (SSI) and PolyMAX.

The comparison between experimental and numerical results confirms the model's ability to predict frequency evolution, damping trends, and aeroelastic instabilities. In particular, the observed flutter regime for the Liège wing is qualitatively well captured by the unsteady aerodynamic formulation. Furthermore, the influence of parameter uncertainties was investigated through sensitivity analyses.

Keywords : flutter, modal analysis, PolyMAX, Stochastic subspace identification, wind tunnel, slender wing.

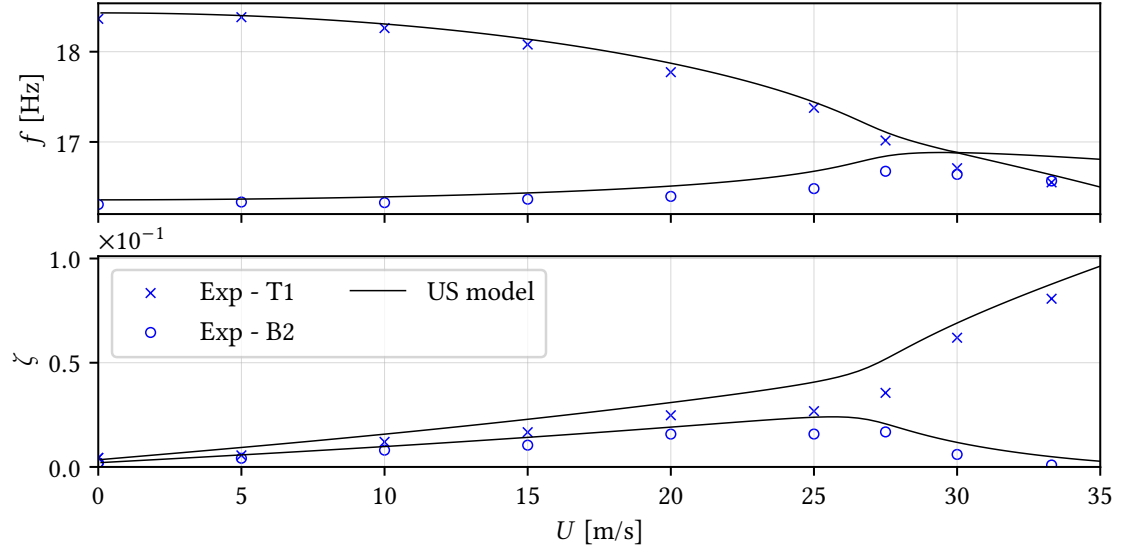


Figure 1: Evolution of natural frequencies and damping ratios as a function of freestream velocity for IAT configuration. Results obtained numerically with unsteady Theodorsen model (US) are superimposed to experimental results, extracted with SSI method.

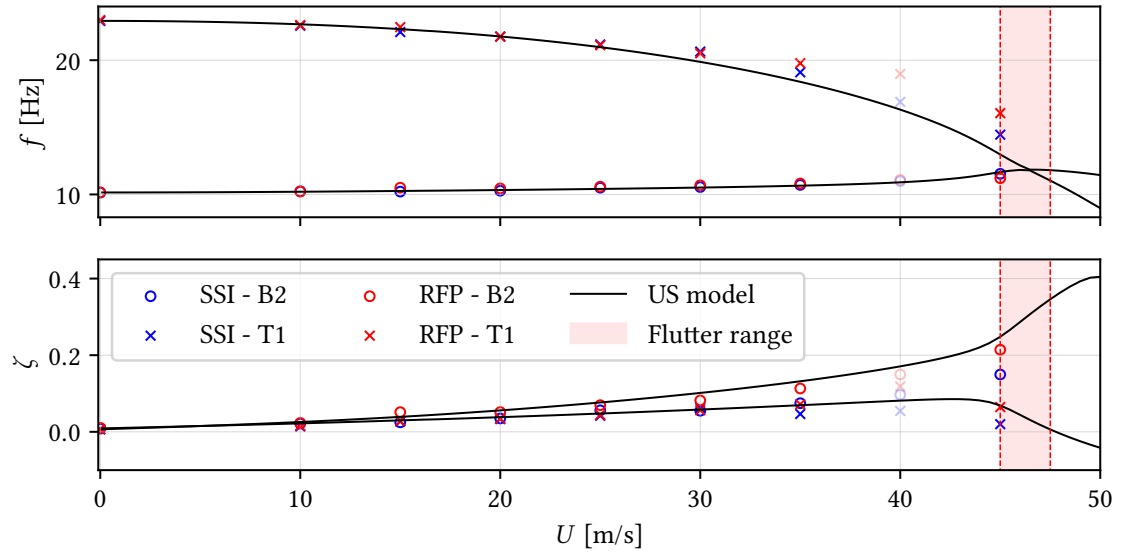


Figure 2: Evolution of natural frequencies and damping ratios as a function of freestream velocity for ULiège configuration. Results extracted using SSI and RFP method. Red regions illustrate the range of velocity in which flutter occurred. Results obtained numerically with unsteady Theodorsen model (US) are superimposed to experimental results.