Numerical Study of Wall-Mounted Finite Span Wings

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Abstract

The extensive use of hydrofoils and airfoils in applications including domestic and military, air, water, and land vehicles, as well as air-conditioning and wind turbines, means that their design for minimally noisy and maximum aerodynamic performance, is not only an important issue for defence, but one with broader economic, health and environmental ramifications.

Wall-mounted finite span wing flows occur when a boundary layer developing on a surface encounters a hydrofoil or airfoil attached to that surface. Although fundamental to various engineering fields, there is a lack of insight into the underlying physics of these flows. Particularly important is the noise created by the complex flow structures associated with them.

The main objective of this work is to investigate the noise and associated flow structures of wall-mounted finite span wings and to develop noise prediction methods for these flows. A number of recent wall-mounted finite span wing experiments (Moreau et al., 2015; Moreau and Doolan, 2013) involving flat ended finite length wings attached to flat plates are simulated using three-dimensional Reynolds Averaged Navier Stokes (RANS) based methods, which provide greater insight into the complete flow structure than is available from the original experiments. The flow structures are observed and compared with experimental measurements. A flow topology model is developed to describe the observed tip vortex formation process for the zero angle of attack condition. Existing leading and trailing edge noise models that are suitable for predicting the noise from 2D airfoils are extended to be applicable for 3D airfoil applications, allowing spanwise variations in geometric and flow properties to be taken into account. Additionally, an isolated tip noise model is developed based on the size of the tip vortex obtained from RANS flow simulations. The developed noise models have been validated against experimental measurements and have been shown to agree well and thus provide a means for prediction of the noise produced by wall-mounted finite span wing flows. The increased understanding of the wall-mounted finite span wing flow structures and the increased capacity of the developed wall-mounted finite span wing flow noise modelling is expected to have applications in the design of airfoils and hydrofoils with improved aerodynamic and aeroacoustic performance.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree. I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968. The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works. I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted.

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