The impact of vortical flow on the free rolling motion of a delta wing aircraft

M.T. Arthur
QinetiQ ltd.,
Cody Technology Park,
Ively Road,
Farnborough, Hampshire,
GU14 0LX

mtarthur@QinetiQ.com

Abstract

Since 1986 there has been a collaborative programme of research on computational methods for aerodynamics, initially under the auspices of the Independent European Programme Group and more recently under the auspices of the Western European Armaments Group (IEPG TA15, WEAG TA15 and WEAG THALES JP12.15). The specific concern of the programme is vortical flows associated with military aircraft configurations. In the early days of the programme, computational methods for calculating steady, inviscid flows were used to obtain results for comparison with wind-tunnel data for a variety of configurations exhibiting vortical flows. Inadequacies in the computational methods and the limitations of the experimental data were readily identified. Computational grids with topologies better suited to the flow were generated and methods for obtaining solutions of the Reynolds-averaged Navier-Stokes equations were used to obtain significantly better agreement with experiment. Improved turbulence models were developed or adopted and mesh adaptation schemes were explored as the limitations of available computer power became apparent. Flows with and without vortex breakdown were investigated and an improved understanding of the breakdown process and its computation were gained. Progress continued to be made. As the computational modelling improved and increased computing power became available, the emphasis within the programme shifted decisively towards unsteady vortical flows. Forced pitching and rolling motions were investigated and the effects on, and of, vortex breakdown were studied. New wind-tunnel tests were undertaken to provide the high quality experimental data needed.

A key element in the success of the programme has been the very strong working relationship that has developed between the partners and, as a crucial part of that, the close collaboration between the computational and experimental researchers. Interesting test cases have been identified and appropriate measurements made in particular parts of the flow field through very close co-operation.

A key ingredient in the U.K. contribution to the programme in recent years has been provided in the form of computational results obtained by Woodgate, Allan, Badcock and Richards in the Department of Aerospace Engineering at the University of Glasgow using the PMB3D code they have developed. PMB3D may be used to compute solutions of the steady or unsteady, Euler or Reynolds-averaged Navier-Stokes equations. The work has shown PMB3D to be a fast code capable of producing results as good as any available in Europe.

The paper will concentrate on recent work undertaken within the WEAG THALES JP12.15 programme concerned with the transonic, vortical flow over a 65^{o} sweep, cropped

delta wing-fuselage configuration in free-to-roll motions. The geometry, computational grid and one-degree-of-freedom vehicle equation of motion will be described. The difficulty of performing suitable experiments and of taking appropriate measurements will be discussed. Results showing both linear and non-linear behaviour will be presented, making clear the importance of understanding such flows for the designers of air vehicles and their control systems. Furthermore, the use of computational methods to simulate free flight will be discussed and the highly significant differences from wind-tunnel results will be presented. The test cases presented new challenges to both the experimentalists and the computationalists. In such circumstances, differences between computed and experimental results must be expected so that comparison between the experimental results and results obtained with a single code are of little value. The collaborative programme has enabled meaningful validation to be undertaken to the benefit of all computationalists and experimentalists. In the paper, results from the Glasgow University code PMB3D will be presented and compared with the results from three other CFD codes and with the experimental data.

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