Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

Design and Analysis of a Box-like Wing Configuration through Panel-Methods

Project work towards a thesis at LULEÅ UNIVERSITY OF TECHNOLOGY, LTU

Background

According to **Prandtl 1924**, the best wing system for minimum induced drag is the box-wing-like configuration followed closely by the C-wing configuration. The consideration implies identical lift distribution and total lift of both horizontal wings and a butterfly shaped lift distribution on the vertical tip wings. In this condition, the velocity induced by the free vortices is constant along horizontal wings and identically zero on the vertical side wings. The reduction in induced drag is dependent on the ratio of vertical tip height *h* and wing span *b*. With *h/b* about 10 % to 15 % a reduction of about 20 % to 30 % in induced drag can be noticed (**Frediani 2003**).

Due to time limitations in aircraft preliminary design, panel-method-based computer programs are preferably used for predicting the aerodynamics of the whole configuration. Those methods are capable of analyzing complex geometries by considering an inviscid, irrotational and linear flow. In a first step, it must be shown that the effect of the Prandtl's best wing systems is predicted with panel-methods such as the vortex-lattice method **Tornado** (**2007**) or the multi-lifting-line method **LIFTING-LINE** (**2009**). Analyses shall include lattice convergence studies. Results are to be verified by calculating each wing separately, comparing it with values found in literature and with values of the box-like wing configuration. Skin-friction drag and form drag are to be approximated through hand-book methods. Additionally, CFD (FLUENT) will be available for further detailed computations and analyses.

In a final step, parameter variations (*h/b*, wing area, wing sweep, etc.) shall be conducted to get an overview of the design space for later optimization runs. A selected (optimum) wing configuration shall be compared with a conventional aircraft wing in terms of aerodynamic coefficients and wing weight (bar model).

Task

- Literature research on box-wing like aircraft configurations, Prandtl's best wing systems and suggested panel-methods
- Geometry development of a basic box-wing configuration
- Analysis with Tornado and LIFTING LINE through lattice convergence studies
- Approximation of skin-friction drag and form drag through hand-book methods
- Verification and discussion of results and selection of the favoured panel-method used for further computations
- Parameter variations and analyses
- Comparison of the (optimum) result with a conventional aircraft wing in terms of aerodynamic coefficients and wing weight (bar model).
- Discussion of the results.

The report has to be written in English based on German or international standards on report writing.

Basic Literature

Frediani 2003 FREDIANI, A.; BALIS CREMA, L.; CHIOCCHIA, G.; et al.: Development of an Innovative Configuration for Transport Aircraft; A Project of five Italian Universities. In : AIDAA: *XVII Congresso Nazionale AIDAA* (Roma, 2003)

LIFTING-LINE 2009 LIFTING LINE - A multi-lifting-line method for design and check of nonplanar wing-configurations; URL: http://www.dlr.de/as/en/desktopdefault.aspx/tabid-188/379_read-625/ (2009-11-19)

Prandtl 1924 PRANDTL, Ludwig: *Induced Drag of Multiplanes* (Technische Berichte, Volume III, No. 7, pp. 309-315). NASA Technical Reports Server, URL: http://ntrs.nasa.gov/search.jsp (NACA-TN-182)

Tornado 2007 *Tornado – The Vortex Lattice Method*; URL: http://www.redhammer.se/tornado/TBG.html (2009-11-19); Published 2007-12-18