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NeoCASS: An integrated tool for structural sizing, aeroelastic analysis and MDO at conceptual design level

Luca Cavagna, Sergio Ricci *, Lorenzo Travaglini

Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano, Italy

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A B S T R A C T

This paper presents a design framework called NeoCASS (Next generation Conceptual Aero-Structural Sizing Suite), developed at the Department of Aerospace Engineering of Politecnico di Milano in the frame of SimSAC (Simulating Aircraft Stability And Control Characteristics for Use in Conceptual Design) project, funded by EU in the context of 6th Framework Program. It enables the creation of efficient low-order, medium fidelity models particularly suitable for structural sizing, aeroelastic analysis and optimization at the conceptual design level.

The whole methodology is based on the integration of geometry construction, aerodynamic and structural analysis codes that combine depictive, computational, analytical, and semi-empirical methods, validated in an aircraft design environment.

The work here presented aims at including the airframe and its effect from the very beginning of the conceptual design. This aspect is usually not considered in this early phase. In most cases, very simplified formulas and datasheets are adopted, which implies a low level of detail and a poor accuracy. Through NeoCASS, a preliminar distribution of stiffness and inertias can be determined, given the initial layout. The adoption of empirical formulas is reduced to the minimum in favor of simple numerical methods. This allows to consider the aeroelastic behavior and performances, as well, improving the accuracy of the design tools during the iterative steps and lowering the development costs and reducing the time to market.

The result achieved is a design tool based on computational methods for the aero-structural analysis and Multi-Disciplinary Optimization (MDO) of aircraft layouts at the conceptual design stage. A complete case study regarding the TransoniCRuiser aircraft, including validation of the results obtained using industrial standard tools like MSC/NASTRAN and a CFD (Computational Fluid Dynamics) code, is reported. As it will be shown, it is possible to improve the degree of fidelity of the conceptual design process by including tailored numerical tools, overcoming the lacks of statistical methods. The result is a method minimally dependent on datasheets, featuring a good compromise between accuracy and costs.

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* Corresponding author.
E-mail address: sergio.ricci@polimi.it (S. Ricci).

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1. Introduction

Most of the life-cycle cost of an aircraft is incurred during the conceptual design phase and therefore, the earlier an appropriate conceptual configuration can be found, the more economical the whole design process will be, avoiding costly later redesign and corrections. Contemporary commercial aircraft conceptual design tools make extensive use of handbook methods based on semi-empirical theory and data. In particular, during the conceptual design phase, statistical-based approaches are adopted for structural weight estimation, like those reported in Refs. [1,2]. Nevertheless, it appears as rather unreliable to adopt statistical-based approaches where knowledge is not sufficiently available, e.g. unconventional configurations and new technologies such as Joined Wings [3,4] and Blended Wing Body aircraft [5]. The use of statistics for the structural weight estimation implies that almost all airframe information are practically absent till the preliminary design phase. Due to this choice, it is almost impossible to include aeroelastic requirements that in fact are considered later during the design loop.

As a matter of fact, new transport aircraft are very flexible and aeroelastic effects must be tackled right from the beginning of the design phase, avoiding expensive redesign during preliminary design phase and weight penalties needed to satisfy aeroelastic requirements not previously taken into account. Recently, new software systems specifically tailored for aircraft conceptual design have been proposed (see Ref. [6]). They are composed by specific modules encompassing different aspects and requirements, such as those coming from environmental impact. However, the capabilities of considering more realistic structural models are still missing. In some cases, statistical-based approaches for the prediction of the structural weight are simply overcome by a single loading parameter, like the root wing bending moment. Specific methods based on semi-analytical approaches have then been developed to have a realistic overview of the airframe [7,8]. However, in many cases they are specific modules not included into a more general aircraft conceptual design framework, where aircraft performances and stability and control can be evaluated for example.

The need for aeroelastic analysis capability within SimSAC project has led to the development of a completely new specialized module called NeoCASS (Next Generation Conceptual Aero-Structural Sizing Suite) to perform structural sizing, aeroelastic analysis and optimization within the conceptual design process.

The following pages give a detailed description of NeoCASS and each of its modules.

2. Layout of NeoCASS

NeoCASS (*Next generation Conceptual Aero Structural Sizing*) is a suite of modules that combines state of the art computational, analytical and semi-empirical methods to tackle all the aspects of the aero-structural analysis of a design layout at conceptual design stage. It gives a global understanding of the problem at hand without neglecting any aspect of it: weight estimation, initial structural sizing, aerodynamic performances, structural and aeroelastic analysis from low to high speed regimes, divergence, flutter analysis and determination of trimmed condition and stability derivatives both for the rigid and deformable aircraft.

NeoCASS includes two main modules, named GUESS (*Generic Unknowns Estimator in Structural Sizing*) and SMARTCAD (*Simplified Models for Aeroelasticity in Conceptual Aircraft Design*), respectively. A connection to a third module, called W&B (*Weight and Balance*), shared by other programs available in SimSAC, is also available.

Fig. 1 outlines the different pieces involved. AcBuilder is used to define the general external and internal layout of the aircraft interactively and easily, thanks to a user-friendly graphical interface. Some examples are given in Fig. 2.

When the CFD solver Edge developed by FOI is used for higher fidelity simulations, vibration modes are given by SMARTCAD to carry out Fluid and Structure Interaction (FSI) simulations, such as static or dynamic coupled response, using the built-in functionalities. Also, the aero database for the Flight Control System (FCS) software can be enhanced with the effects of flexibility on stability derivatives through correction coefficients for the rigid values. In order to start the aeroelastic analysis, the semi-analytical module GUESS, based on a modified version of the AFaWWE code (*Analytical Fuselage and Wing Weight Estimation*) [9], is run to produce a first-try stiffness distribution. The sizing is performed in a fully stressed design condition. Formulas from experimental surveys are adopted to include instability limits related to compressed panels and stiffeners (see Section 3). See Ref. [10] for further information. During this first sizing phase, no aeroelastic effect is considered. After the initial structural sizing is completed and the first stiffness distribution is determined,

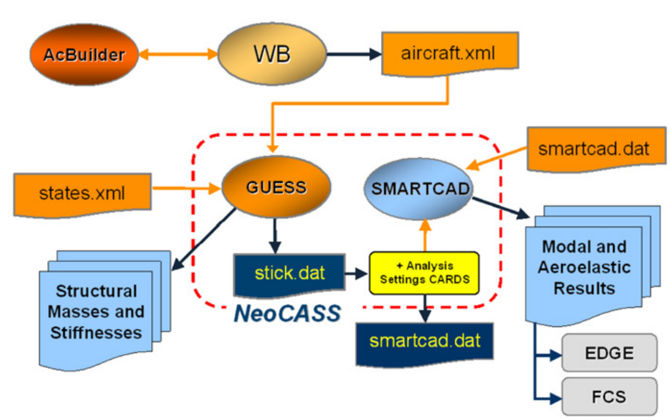

Fig. 1. NeoCASS layout.

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