

MODELING AND ANALYSIS OF STRUCTURAL LOADS OF A FLEXIBLE TRANSONIC AIRCRAFT USING STRIP-THEORY FLIGHT DYNAMICS

Lars-Hendrik Lemke*, Frank Thielecke

*Hamburg University of Technology, Institute of Aircraft Systems Engineering
Nesspriel 5, 21129 Hamburg
Germany

ABSTRACT

Structural load alleviation functions (LAF) are a key technology to enable very efficient high aspect ratio wings on commercial aircraft. This is due to the inevitably higher flexibility of these slender wings, leading to increased structural loads during manoeuvres and gust encounters. However, active LAF based on fast actuated trailing edge control surfaces introduce additional system weight, which scales with bandwidth and deflection rate requirements [1]. Therefore, the realizable load alleviation factor has to be carefully weighed against its adverse impact on system weight and complexity through viable performance requirements. For large commercial aircraft, a first performance target can be defined from the certification specifications CS-25 Appendix K [2]: When a reliable reduction of the structural loads can be granted, the safety factor between the limit load and ultimate load can be reduced from 1.5 to 1.0. From this, a maximum load reduction of 33% of the critical load case can be defined as a LAF performance target, as depicted in Figure 1. However, the alleviation targets for all other load cases must also be defined in this context to get a representative set of requirements of the full-envelope. Therefore, all relevant load cases must be calculated, leading to a large number of test cases. To this end, a simplified flight physics model is employed, calculating structural loads reasonably fast, including the effects of structural dynamics for various mass cases and 3-dimensional transonic aerodynamics.

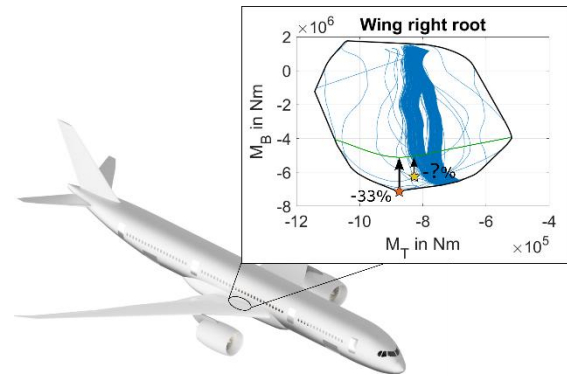


Figure 1: Qualitative depiction of the LAF target in the load envelope of the wing root

In this paper, meaningful load alleviation requirements for a commercial aircraft with a high aspect ratio wing are developed, using a long-range research reference configuration with an aspect ratio of approx. 12.5. The main components of the aeroelastic model used for flight mechanical simulations and structural load calculations are described. This includes a modal formulation of the structural dynamics with interpolable characteristics for all combinations of payload and fuel fillings and a coupled strip aerodynamics model, derived from CFD-CSM coupled flexible polar data and lifting line calculations. Due to the torsional elasticity of the wing and its strong bending torsion coupling, three-dimensional lift effects are relevant, especially for the local lift calculation at the wing tip. A formulation to cover those 3D-effects in the strip model using local induced angles of attack is presented. This flight mechanical model is analysed using a test environment covering all relevant manoeuvre and gust conditions of the CS-25 to define a meaningful set of performance requirements for the whole LAF envelope. This enables an efficient LAF design, fully leveraging the certifiable benefits with regard to current standards, without introducing unnecessary system weight. The procedure and the general findings provide a reference to contextualize load alleviation gains with respect to system efforts and certification limits.

- [1] K. Krall, L.-H. Lemke, F. Thielecke, J. Müller und C. Breitenstein, „Systems for Fast Actuated Droop Noses and Flap-Tabs for Dynamic Load Control,“ in *Deutscher Luft- und Raumfahrtkongress 2023*, 2024.
- [2] European Union Aviation Safety Agency, Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes CS-25 Amendment 28, 2023.