Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: STRMAT

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Type: Oral
Status of corresponding author: Student
For student corresponding author: student member of one of the following: (none)

Title

Analysis of the structural behavior of wings with nonlinear components for passive load reduction

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Abstract

Weight reduction is an important way to develop more efficient aircraft. Load alleviation limits the load a wing has to carry thus enabling a lighter design of the wing and due to snowball effects a lighter aircraft. Passive load alleviation influences the load by deflections initiated by only the load itself, not needing additional sensors and actuators. This saves system complexity, weight and energy.
This paper shows results of a project which aims to extend the aeroelastic design space using strong nonlinearities such as buckling for load alleviation triggered above a critical load. The innovative and challenging concept is to design components with a significant structural nonlinearity coming into play at a defined load level, to trigger the deformation of the wing in a way to reduce aerodynamic load. Previous work concentrated on the structural behavior of single components. A wing box segment with a nonlinear progressive bending-torsion coupling was designed [1]. This segment twists the outer wing downward under high load. Previous work also considered two dimensional airfoil models with a nonlinear camber change due to a buckling stiffener with fluid-structure-interaction [2]. In dynamic gust encounters these airfoil models showed that the reaction speed of a structure has a significant influence on the gust load reduction capabilities compared to quasi-stationary maneuver loads [3]. The present paper integrates wing box segments with the developed design concept into a full three-dimensional wing finite element model, allowing for evaluation of the structural properties and nonlinear behavior of the full wing. The wing is analyzed under stationary and dynamic loading conditions regarding the additional wing twist due to the modified wing box segment, which reduces the effective angle of attack and thus lift in the outer wing area. The delay in reaction speed due to inertia is evaluated under the dynamic loading conditions. The result is a proposed wing design, which uses the modified wing box segments to improve the load alleviation behavior above a critical load compared to a conventional design.

References

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