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Assessment of Thrust Vector Control as a Load Alleviation Measure in Preliminary Aircraft Design

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Introduction

- Improving aircraft efficiency is a key driver for future wing and aircraft concepts fulfilling Flight Path 2050s conditions [1]
- High-aspect wings improve aerodynamic efficiency but increase structural loads and wing mass while wing sizing is strongly driven by critical gust and maneuver loads defined in CS-25 [2]
- Established load alleviation concepts exist, but thrust vector control has received less attention in civil aircraft design
- This study investigates whether thrust vector control can alleviate wing loads and offset the mass penalty of an additional propulsion system

Aircraft Configuration

- A 270-passenger long-range aircraft with a high aspect ratio wing ($\Lambda = 12.381$) is used as baseline config (V0)
- Two modifications are investigated:
  V1: additional propeller engine at $\eta = 0.57$
  V2: additional propeller engine at $\eta = 1.0$
- The additional propellers provide continuous auxiliary thrust and are used for load alleviation during maneuvers by nacelle tilting
- Three thrust vectoring angles are analyzed: 10°, 30°, and 50°

Methods

- Aircraft design and structural sizing are evaluated using the PrADO preliminary aircraft design tool, with linear static analyses in Nastran [3]
- The assessment focused on critical maneuver load cases relevant to CS-25 certification which include maneuvers with positive and negative load factors
- Key evaluation metrics are: wing bending moment and torsional moment at load reference axis (see Figure 2) and overall weight impact

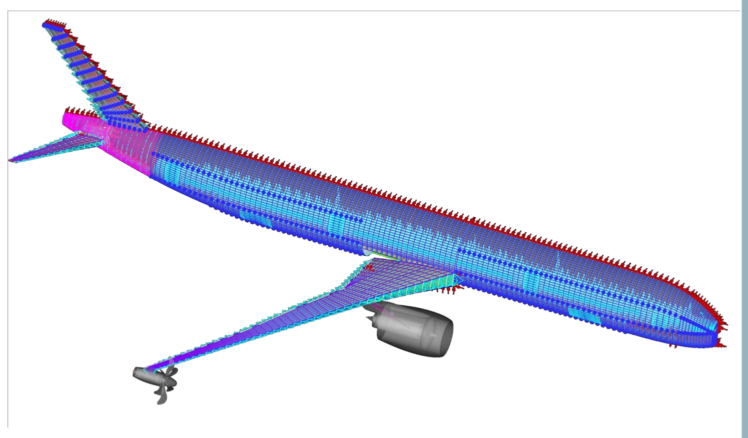

Figure 1: FE-model of V2 configuration

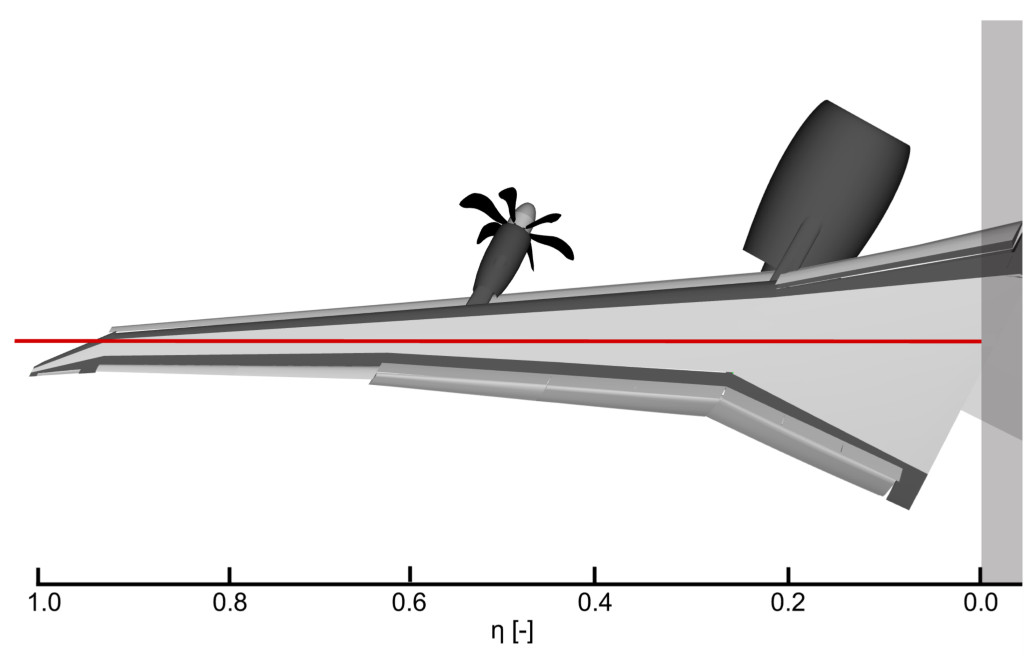

Figure 2: Load reference axis in the local wing coordinate system; exemplary for a V1 configuration wing

Results

- Adding secondary propeller engines with thrust vector control reduce wing bending loads in both modified configurations V1 and V2
- For V1 local **reductions in wing root bending moment of up to 14%** are achieved
- However, V1 also causes a **strong increase in torsional effects** due to the large offset between propeller and load reference axis (thrust vector causing immense "pitch-down" moment)
- In the inner wing region $\eta < 0.2$, the torsional moment even changes sign for positive-load maneuvers
- For V2 the bending relief is stronger, with **root bending moment reductions exceeding more than 20%** for several load cases at 50° tilt
- Compared with V1, V2 shows lower torsional penalties, since the propeller has a smaller offset from the load reference axis
- Including LA in preliminary design already **reduces MTOW by 3.1 t**; however, the **DOC remains 11.4% above** the baseline aircraft V0 due to the additional propulsion system and associated maintenance costs

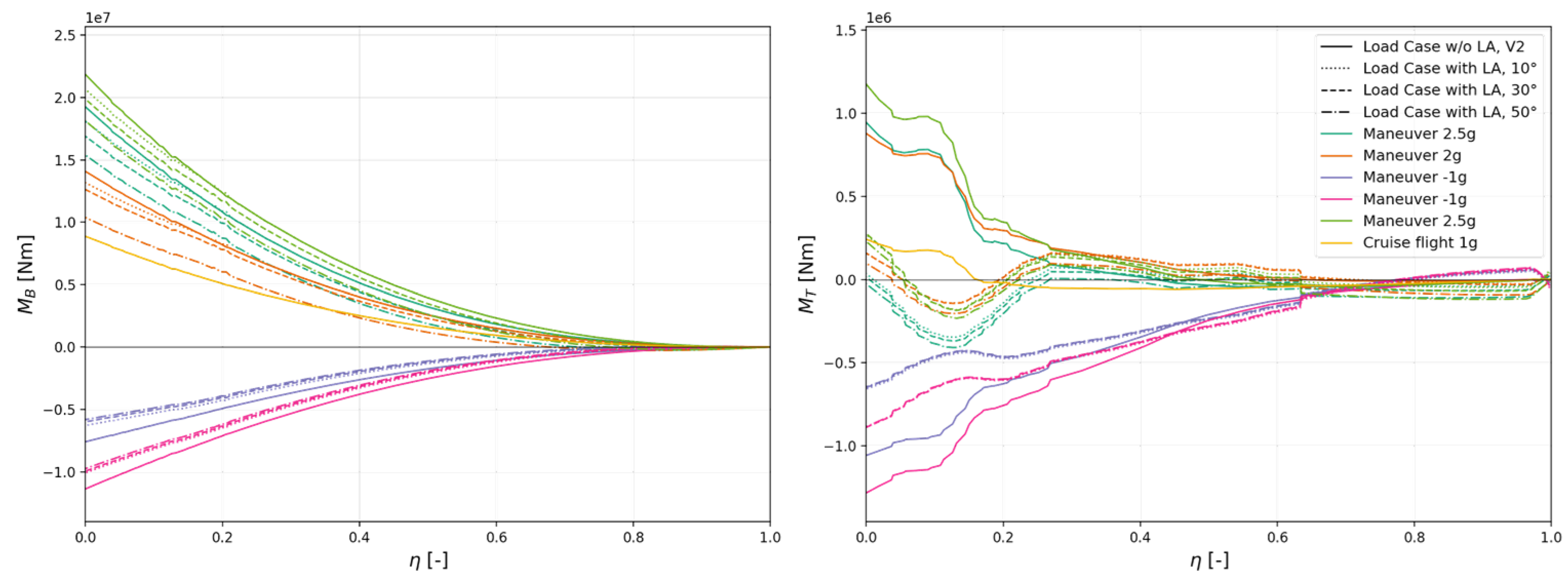

Figure 3: Bending moment MB (left) and torsional moment MT (right) for the configuration V2 with mid-spanwise propeller for the three tilt angles ξ in comparison to the non-tilted propeller

Conclusion

- The results show that thrust vector control can alleviate critical wing loads in preliminary aircraft design, but the effect strongly depends on engine placement due to torsional side effects
- For the configurations studied, the structural mass benefit was sufficient to compensate for the added propulsion-system mass, however DOC due to rising maintaining costs increases. This highlights the need for further system-level investigations

References

[1] European Commission, Commission, Directorate-General for Mobility, Transport, Directorate-General for Research, and Innovation. Flightpath 2050 – Europe's vision for aviation – Maintaining global leadership and serving society's needs. Publications Office, 2011.

[2] European Union Aviation Safety Agency. Certification specifications and acceptable means of compliance for large aeroplanes (cs-25). https://www.easa.europa.eu/en/document-library/certification-specifications/cs-25. Amendment 28, 15. Dezember 2023

[3] Wolfgang Heinze, Peter Horst, and TU Braunschweig. Preliminary design of a blended wing body configuration using the design tool prado. 2001.

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