Design and Assessment of a Mid-size Business Jet with Natural Laminar Flow Wing

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Abstract:

The business jet market is a relatively small but highly competitive arena. Every manufacturer is continuously working on aircraft performance and systems to offer maximum customer comfort with the best flying capabilities. On the other hand, present improvements of modern business jets are mostly related to improvements of systems for passenger comfort and safety, avionics, and flight control systems. At the moment, the airframe configuration has been well-developed and rarely has unconventional configurations that may take the aircraft performance to a new level. Potential reasons for such behaviour include design and manufacturing complexities and costs that may not pay off the performance benefits and introduce significant business risks. Since the beginning of the 1960s, two certified business jets featured unconventional airframes compared to their competitor in their class. HFB 320 HansaJet and Honda HA-420 Hondajet. Both aircraft tried to improve their characteristics by introducing an unconventional configuration design.

A preliminary analysis of 21 Mid-size, Super Mid-size, and large business jets currently available at the market using regression learning showed that two main important parameters that influence the business jet acquisition price (and so their potential demand) are the speed and range. Although the speed has a dominant effect, the range influence is also large, as shown in Figure 1. Consequently, a potential increase in range at a similar value of Direct Operating Costs (DOC) may be the feature that can draw customer attention and make a new aircraft competitive in the market.

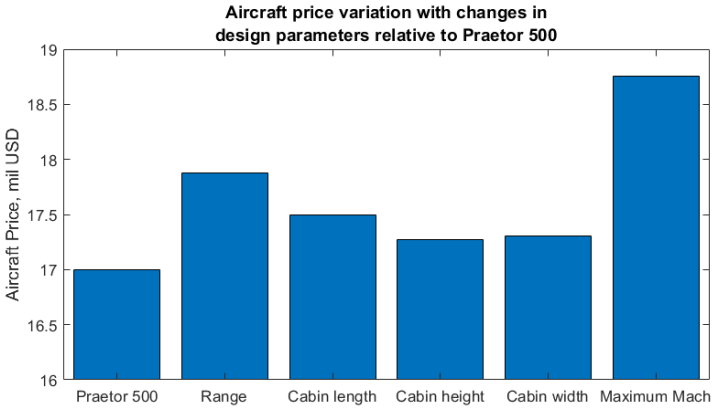

Figure 1. Sensitivity of the sample mid-size jet similar to the Praetor 500 to selected aircraft configuration parameters.

With advances in modern composite materials and manufacturing techniques, the design of unconventional configurations is becoming more available. To design an aircraft with a range extension at a similar DOC, a more fuel-efficient airframe is required. Studies in [1] demonstrated that a forward-swept wing could feature Natural Laminar Flow (NLF) with sufficient mid-chord sweep to avoid significant compressibility drag. Moreover, results demonstrated that aeroelastic tailoring might reduce adverse effects of aeroelastic divergence without wing weight gains.

The present research focuses on the design and assessment of a mid-size business jet featuring NLF. The assessment was divided into three major steps. First, initial sizing, trade studies using SUAVE aircraft design environment was used to estimate the potential increase in range with the introduction of NLF. Then, a low-fidelity Multi-disciplinary Design Optimization was performed to improve the initial design. Finally, to reduce uncertainties in the current design, an aerodynamic shape optimization using medium-fidelity Q3D [2] and high-fidelity ADflow [3] software and a composite wing design using Finite Element Analysis were performed.

The configuration of the business jet having a similar cabin as the Praetor 500 is shown in Figure 2. Preliminary results after the wing aspect ratio, taper ratio, percent laminar flow, and wing weight deviation showed a potential increase in range by 7-10% compared to the Praetor 500 depending on achieved laminarization and weight penalties.

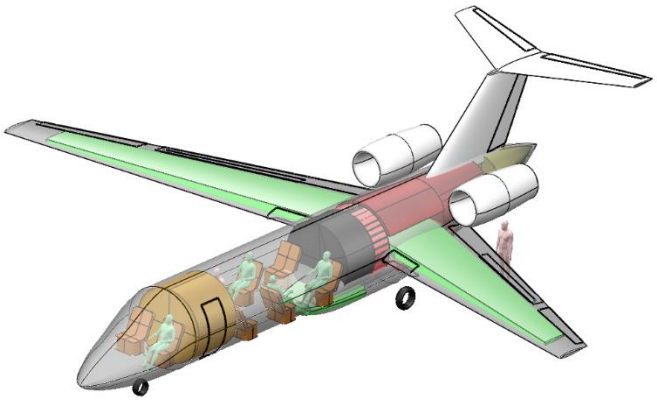

Figure 2. Forward-swept NLF business jet layout.

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