THE EFFECT OF WINGBOX ELASTIC DEFORMATION ON THE MORPHING SHAPES OF THE TRANSLATION INDUCED CAMBER CONCEPT

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ABSTRACT

One of the technologies aiming at lowering the aviation environmental emissions through the reduction of aerodynamic drag is airfoil trailing edge camber morphing. It permits the smoother change in the camber of an airfoil compared to the conventional hinged and slotted flaps. Thus, it reduces the intensity of the bluff-body vortex, which is formed in hinged flaps at high deflection angles (10º-15º) [1]. One realization of camber morphing amongst others is the fishbone concept, showing drag reduction in 2D subsonic experiments between 16% to 50% [1] or 20% to 25% [2]. Another realization is the Translation Induced Camber (TRIC) morphing developed at TU Delft [3, 4]. TRIC demonstrated a delay in the boundary layer transition point of up to 15% of the chord between different morphing angles during the subsonic wind tunnel experiments of SmartX wing, hence, showing the potential to reduce friction drag [5].

However, the above wind tunnel studies assumed that the wingbox, to which the morphing surfaces are attached, was rigid. The same assumption holds for bench tests that aimed to measure the achieved shapes of morphing concepts such as honeycomb structure [6] and multi-block rotating ribs [7]. These studies ignored the effect of the out of plane deformation of the wingbox across the span, which will effectively be transferred to the morphing region itself.

Given the high flexibility and the resulting out of plane deformations observed in modern high aspect ratio wings [8], the wingbox segment where the morphing trailing edge is attached might undergo large deformations and affect the design of the morphing surface itself. Hence, it is necessary to examine the effect of the aeroelastic deformation of the wingbox in the design of the trailing edge morphing systems. The combined and usually competing curvatures of the wingbox in the spanwise direction and of the morphing trailing edge in the chordwise direction can change the stiffness of the morphing skin. Therefore, they can affect the actuation loads and eventually change the achieved shapes. Moreover, in the morphing concepts that include sliding skins such as TRIC, the friction between the moving parts may also increase due to the higher shear forces and bending moments. Consequently, the achieved morphing shapes, as well as the actuation force requirements, of a surface attached to a flexible wingbox may differ from those attached to a rigid wingbox.

The latest application of the TRIC concept is the trailing edge of the strut of a Strut-Braced Wing (SBW) configuration [9]. The thickness of the morphing trailing edge has been tailored [10] and the analysis shows 1% to 3% drag reduction at the combined wing and strut level [9].

This work continues the maturation of the TRIC application on the morphing strut by simulating and quantifying the effect of the elastic strutbox on the morphing trailing edge shapes. In order to achieve this, the most critical region of the strut in terms of out of plane bending curvature has been identified using a SBW aircraft aeroelastic numerical model. Then, a detailed FEM model of this region of the strut has been constructed, including the leading

edge, the strutbox and the morphing trailing edge. Representative bending moments have been applied to its boundaries in order to achieve the curvature levels obtained from the full SBW aeroelastic model. Figure 1 illustrates the detailed FEM under bending moments leading to a curvature similar to what expected under the flight conditions that the morphing shapes has been designed.

The final paper will include the sliding skin simulation in the FEM model and will compare the morphing trailing edge shapes between the rigid and the flexible wingbox conditions. In summary, this paper will numerically examine and quantify the effect of the deformation of the flexible carrying structures on the TRIC morphing shapes.

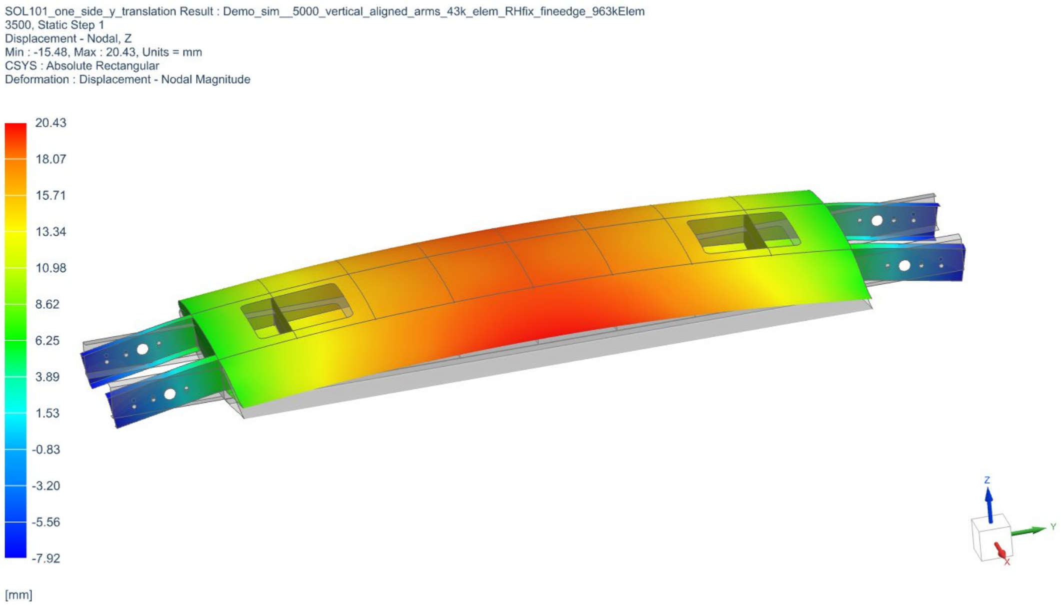

Figure 1: Spanwise deformation of the strut under representative loads

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