Nonlinear aeroelasticity of Strut-Braced High Aspect Ratio Wings

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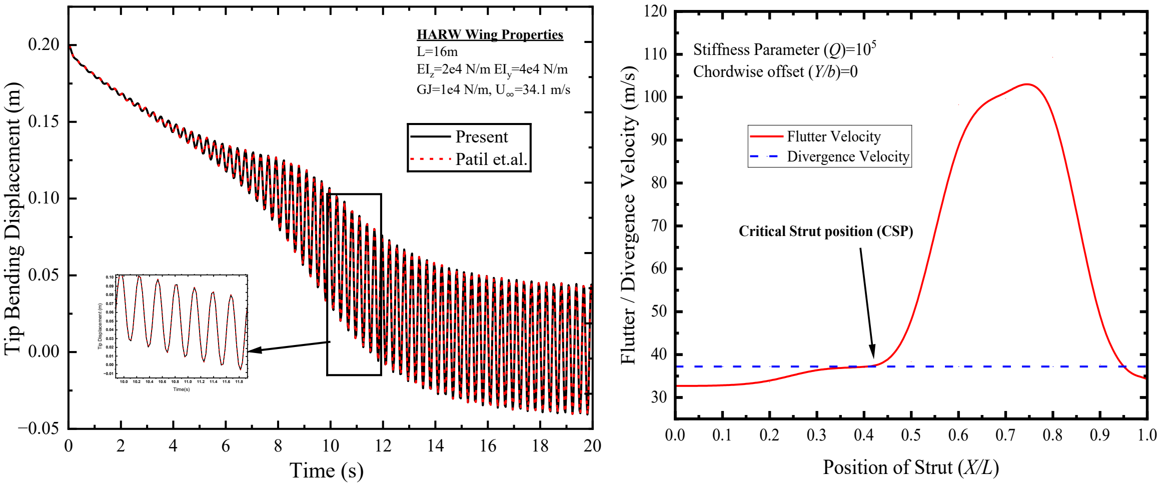
High Aspect Ratio Wings (HARW) represent a cornerstone in the pursuit of fuel-efficient, long-endurance aircraft designs, particularly for applications in unmanned aerial vehicles (UAVs), regional transports, and emerging sustainable aviation technologies [1]. It is well known that aerodynamic-induced drag is reduced by increasing the aspect ratio of the wing, thereby resulting in more economical flight operations [1]. However, owing to these aerodynamic advantages, there are structural design constraints such as higher stress concentration on the wing root, and higher structural flexibility which causes the wing to be more prone to larger deflections, which in turn affect the overall aeroelastic behaviour. To eliminate these downsides, Strut-Braced High Aspect Ratio Wings (SB-HARW) were proposed (see Fig.1(a)) which may be proved to be more advantageous than the traditional wings [2].

(a) (b)

Figure 1: (a) SB-HARW of an unconventional Aircraft [4] (b) Simplified Model of SB-HARW

However, the nonlinear aeroelastic behaviour of SB-HARW is still not understood very well, which needs to be investigated further for a more reliable and safer design. Traditional analyses have predominantly focused on instability margins, yet the post-flutter regime remains underexplored [2]. This paper presents a comprehensive nonlinear aeroelastic investigation into the post-flutter behaviour of Strut-Braced High Aspect Ratio Wings (SB-HARW), emphasizing the role of structural bracing in mitigating or exacerbating these phenomena. The wing structural dynamics model is simulated using a third-order nonlinear beam theory, while the strut is modelled as a nonlinear spring attached to a point which has offsets in the different directions relative to the wing elastic axis as shown in Fig.1(b). combined with a nonlinear strut model. This model includes the geometric nonlinearities, inertial effects, and bracing configurations. To simulate the aerodynamics of the system, an unsteady aerodynamic model is used. Fig. 2(a) shows the validation of the developed code for post-flutter behaviour of a HARW without strut, and a very good agreement is observed. Moreover, in Fig. 2(b) shows the effect of strut spanwise location on the flutter behaviour of a SB-HARW. This clearly indicated that the strut can greatly influence the onset of flutter and most probably the post-flutter behaviour of SB-HARW.



(a) (b)

Figure 2: (a) Validation of time-response of HARW with reference [3] (b) Simplified Model of SB-HARW

The full paper will aim to characterize the post-flutter response of SB-HARW under varying aerodynamic loads, quantifying the influence of key bracing parameters such as spanwise location, chordwise offset and strut stiffness. The findings will advance the state-of-the-art in SB-HARW aeroelastic design by filling the gap in the literature on post-flutter analysis of such systems.

References

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