EXTENDED STABILITY AND STABILITY BOUNDARY REDUCTION ANALYSIS OF FLEXIBLE AIRCRAFT WITH FOLDING WINGTIPS

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ABSTRACT

One important factor when it comes to induced drag reduction and therefore improved efficiency is increasing the wing aspect-ratio, which usually leads to higher wingspans. To meet airport gate limitations, the most limiting factor when it comes to increasing the wingspan, the wingtips can be made foldable. That adds extra weight to the tip of the wing, raising the question of more possible applications. Different research studies suggest that folding wingtips with hinge lines not parallel to the flow could be used to reduce gust loads, which would lead to reduced structural weight and lighter aircraft with increased efficiency [1].

Most studies so far have assessed the capabilities of folding wingtips assuming rigid wings or not considering the full flight and/or wingtip dynamics [2], [3], [4]. Therefore, the effects of the interaction of the folding wingtip dynamics, the aircraft flexibility and the flight mechanics while considering the geometric nonlinearities introduced by the hinge have not been studied yet.

In a prior work the nonlinear equations of motions of a flexible aircraft with rigid folding wingtips were derived using Lagrange's equation. To describe the angle of attack as a function of fold angle and wing elastic displacement a geometrically exact formulation has been used. The equations of motion were extended to consider the full kinetic energy expression of the system and then implemented as nonlinear flight mechanical model in MATLAB/Simulink using the data of the GUSTAFO-1 aircraft. GUSTAFO-1 is an A320-like aircraft with a wing aspect ratio of 14.7 that was developed within the LuFo VI-2 project GUSTAFO and is based on the Common Research Model (CRSM). First results showed that the folding wingtip has an influence on the stability boundary and flight characteristics of an aircraft [5].

As the influence of different aircraft and folding wingtip parameters on the stability boundary and flight characteristics have not yet been methodically analysed, the objective of the present work is to methodically analyse these effects. Therefore, the effects of changing different folding wingtip parameters such as, hinge line angle, hinge stiffness and damping, folding wingtip mass and centre of gravity position, on the aircraft overall stability are analysed in the time and frequency domain to obtain the general trends. Results will also be compared to a configuration with stiff hinge.

Figure 1 shows on the left side how the pole positions of the GUSTAFO-1 aircraft for two different folding wingtip masses of 133 kg and 250 kg change with Mach-number. The influence of the folding wingtip mass on the pole position of the aeroelastic and flight mechanical modes can be observed. Increasing the wingtip mass, for example, leads the first mode (M1) to become unstable at a lower Mach-number, therefore decreasing the stability boundary. The right side of Figure 1 shows the eigenvector distribution plots and the influence of selected states on the modes. An important influence of fold angles θ and modal

amplitudes η on the flight mechanical and folding wingtip modes (FWT modes) can be observed, demonstrating the strong coupling among the dynamical states as the wing flexibility increases. The interaction is stronger for higher folding wingtip mass. Figure 2 shows the aircraft deformation during cruise for a very low (in blue) and a very high (in green) hinge stiffness.

The final paper will present the results of the study on the influence of different aircraft and folding wingtip parameters on the stability boundary and flight characteristics of the GUSTAFO-1 aircraft. Specific results as well as the general trends will be shown.

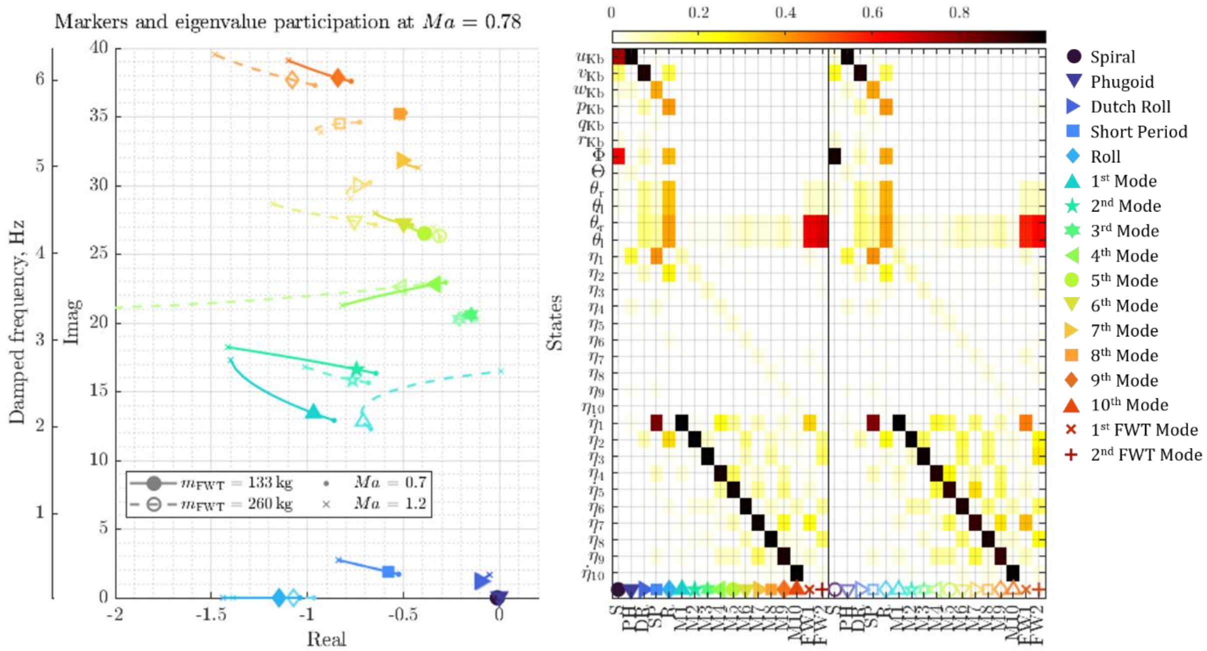

Figure 1: Pole positions and eigenvector distribution plots of GUSTAFO-1 for different Mach-numbers for m_{FWT} *= 133* kg *(darker solid lines and filled markers) and* m_{FWT} *= 250* kg *(lighter dotted lines and unfilled markers).*

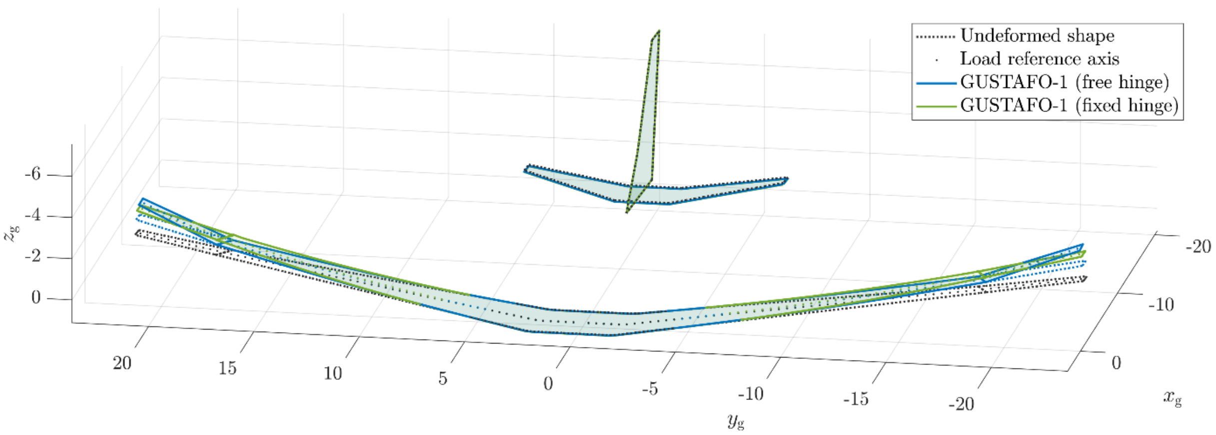

Figure 2: Flight shape of GUSTAFO-1 during cruise with low (blue) and high (green) hinge stiffness compared to undeformed aircraft (black, dashed)

References

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