A framework for the aeroelastic analysis and design of generic morphing wings

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Werter et al.[1] introduced a novel approach to the conceptual design of morphing aircraft by means of a two-level design approach. This paper presents the extension of this model with an updated camber and span morphing model, a parasitic drag model, and a dynamic aeroelastic model. The first level consist of a morphing wing model specific to the concept that is investigated and is used as an input to the generic morphing aeroelastic optimisation framework in the second level. The second level returns the optimum morphing configuration and the energy required to overcome the external forces to reach this configuration. This information can be used to assess the feasibility of the design and, if required, the feasible design limits defined in the first level can be redefined. The framework has been applied to the optimisation of a UAV at three different flight conditions for minimum drag in a trimmed flight condition under aeroelastic and morphing constraints. The results show the trade-off between parasitic and induced drag depending on the flight speed and show that the framework presented can be used successfully for the design and optimisation of morphing wings.

I. Introduction

The main advantage of morphing wings is that the wing can be optimised for several different flight phases with conflicting requirements, by changing its shape when transitioning from one phase to another. The concept of morphing wings is not new and has been applied since the early ages of aviation. The Wright Flyer, the first heavier than air aircraft with an engine, enabled roll control by changing the twist of its wing using cables actuated directly by the pilot.[2] The increasing demand for extra payload and higher cruise speeds led to a demand for a stiffer wing structure, making it difficult to morph the wing depending on the mission profile. Current aircraft wings are therefore designed as a compromise for the missions they fly, performing sub-optimal at each individual flight state. Substantial research has been done on the aeroelastic modelling of these morphing aircraft using models of different levels of complexity[3,4,5,6,7,8] and on the optimisation of morphing aircraft by changing the wing sweep, span, chord distribution, and many other wing parameters[9,10] to assess the potential benefits of morphing aircraft.

In the 1980s, NASA launched two research programs dedicated to morphing structures with the Active Flexible Wing program[11] and its Mission Adaptive Wing program.[12] This research effort was followed by several research programs in the 1990s and 2000s in the USA, the Smart Materials and Structures Demonstration program,[13] the Aircraft Morphing program,[14,15] the Active Aeroelastic Wing program,[16] and the Morphing Aircraft Structures program.[17] Parallel to the research done in the USA, the European Union has also funded several research programs since 2002, including the Active Aeroelastic Aircraft Structures (3AS) project, the Aircraft Wing Advanced Technology Operations (AWIATOR) project, the New Aircraft Concepts Research (NACRE) project, the Smart Fixed Wing Aircraft (SFWA) project, the Smart Intelligent Aircraft Structures (SARISTU) project, the Novel Air Vehicle Configurations (NOVEMOR) project and the CHANGE project.

However there seems to be a lack of a transparent way to discretise a morphing aircraft for optimisation in a way that results in a sufficiently low number of design variables for quick sizing, while not constraining

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