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Two-level Conceptual Design of Morphing Wings

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This paper introduces a novel approach to the conceptual design of morphing aircraft by means of a two-level design approach. The first level consists of a morphing wing model specific to the concept that is investigated. This is used to identify the types of morphing in the concept and generate the corresponding morphing constraints for the second level. The second level is a generic morphing aeroelastic optimisation framework that is used to optimise the morphing parameters and find the optimal morphing configuration for the flight cases under consideration. The second level also returns the morphing energy requirements to overcome the forces induced by the external loads, which can be used to assess the feasibility of the concept and potentially identify new constraints for a second optimisation run. The design approach has been applied to the optimisation of both a twist morphing wing and shear morphing wing to illustrate the potential of the design approach. The results clearly show the potential of the morphing technologies and the added information this design approach can give in the conceptual design stage.

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.[1] 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. Extensive research has been performed on methods to incorporate the ability to morph as the flight state requires, into wings with are sufficiently stiff to cope with the requirements of increased payload and flight speed. Barbarino et al.[1] give a detailed overview of the current state of the art in morphing research and the concepts that have been developed over the years. An overview of morphing aircraft throughout history, including various morphing mechanisms, is given in figure 1.

In the 1980s, NASA launched two research programs dedicated to morphing structures with the Active Flexible Wing program[2] and its Mission Adaptive Wing program.[3] This research effort was followed by several research programs in the 1990s and 2000s in the USA, the Smart Materials and Structures Demonstration program,[4] the Aircraft Morphing program,[5,6] the Active Aeroelastic Wing program,[7] and the Morphing Aircraft Structures program.[8] 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

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