A generic aeroelastic morphing wing analysis framework

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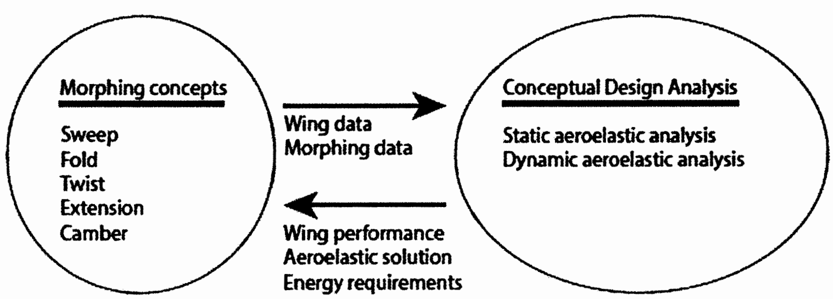
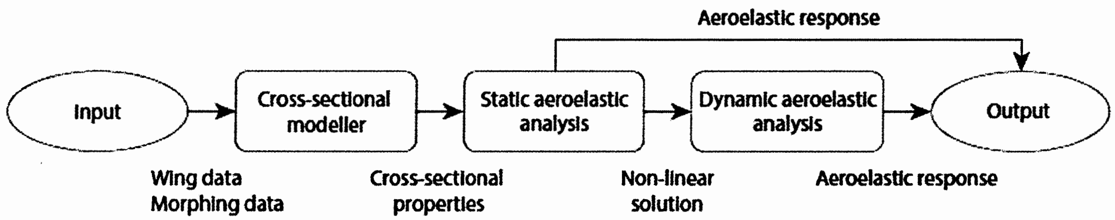
The main advantage of morphing wings is that the wing can be optimised for several different flight phases with conflicting requirements by changing its shape when going from one phase into another. Extensive research in the past decades has focused on the aeroelastic modelling of these morphing aircraft using models of different level of complexity [1–3] optimising morphing aircraft by changing the wing sweep, span, chord distribution, and many other wing parameters [4] and optimising the internal structure of the wing using topology optimization [5,6]. However, there seems to be a lack of a transparent way to discretise morphing aircraft for optimisation in a way that results in a sufficiently low amount of design variables for quick sizing, while not constraining the design space a priori. It was stated by Dr. Anna-Maria Rivas McGowan during a short course on morphing aircraft in Lisbon, Portugal, 2008 [7] that there is a need for a set of generic design tools for the conceptual design of morphing aircraft that are at the right level of fidelity, so that the design space can be explored efficiently even with a large number of design variables.



Two-level approach for morphing wing conceptual design

The research proposed here is based on the two-level conceptual design approach of morphing wings, as previously presented by the authors [8] and illustrated in the figure above. The first step of the design approach allows the user to specify morphing concept specific parameters that should be included in the design. These include morphing parameters (e.g. level of sweep or level of camber), geometry, structural and inertial properties, and operational flight envelope information. The wing is split into several spanwise segments, and for each segment the morphing design parameters can be set independently to obtain the required wing shape. Based on these parameters, the performance of the morphing wing is assessed in the second step of the design approach. The main advantage of this approach is that the analysis framework is generic and can easily be embedded in an optimisation process, while the first step can provide morphing concept specific constraints.



Layout of the morphing analysis framework.

The analysis framework consists of several modules, as indicated in the figure above. The first module is the cross-sectional modeller [9], which transforms the three-dimensional wing data into cross-sectional data for each wing segment, making it suitable for one-dimensional analysis. Next, in the static aeroelastic analysis, linear Timoshenko beam elements are coupled using a co-rotational framework in order to obtain a nonlinear structural solution. The aerodynamic model is based on a potential flow aerodynamic panel code to allow for the modelling of three-dimensional aerodynamic effects. The structural and aerodynamic models are closely coupled to obtain the aeroelastic model, which is solved using the Newton Raphson iteration method. In order to obtain the dynamic aeroelastic model, the structural model is linearised around the static aeroelastic equilibrium solution and coupled to an unsteady aerodynamic model based on the doublet panel method. Finally, if an initial and final morphed configuration are specified, the analysis framework can provide an estimate of the required morphing energy to overcome the aerodynamic forces by computing the work done over the morphing manoeuvre. In this way, the analysis framework allows for the assessment of morphing concepts by providing morphing energy requirements, aeroelastic stability information, and overall wing performance data.

To summarise, this research proposes a framework for the analysis of conceptual designs of morphing wings. The two-level approach allows for easy implementation in an optimisation process, while concept specific limitations can be considered. The analysis provides an estimate of the required morphing energy, aeroelastic stability and overall performance of the wing, which can be used for the assessment of morphing concepts.

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