Preliminary design of morphing flaperon using optimization by genetic algorithm

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Airfoil morphing is the ability to change the cross-sectional profile of an aerodynamic surface, which may substitute traditional control surfaces and high-lift devices that use rotational, translational or combined movement. Some concepts change the shape of an airfoil along its full chord length, while others only morph a part of an airfoil. The morphing of the smaller part of an airfoil is generally a substitution of leading or trailing edge devices on a regular wing structure. The advantage of this approach can be seen in simpler design and keeping the standard wing structure which may help short-term applicability. In both cases, morphing presents contrary structural requirements. Stiffness is required to maintain a specified shape, whereas compliance is necessary to reduce the actuation force of morphing elements. Therefore, airfoil morphing design is always a multidisciplinary problem including aerodynamic, kinematic, structural, material design etc. and leads to a complex optimization problem. This article presents an approach to morphing flaperon design.

For the morphing flaperon design in this article, the concept of the integrated hinge with load-bearing upper skin was used, similar to the original solution by Kensche [1], in combination with the laminar airfoil inspired by Kubrynski [2] The section of the upper skin is a morphing skin that bends up and down for flaperon deflection. At the lower skin, the surface is discontinued and covered with tape or possibly an elongating skin in the future. A hinge for an actuation lever is located at the lower skin. A hinge pin is guided in a straight rail. The arrangement is in the figure 1.

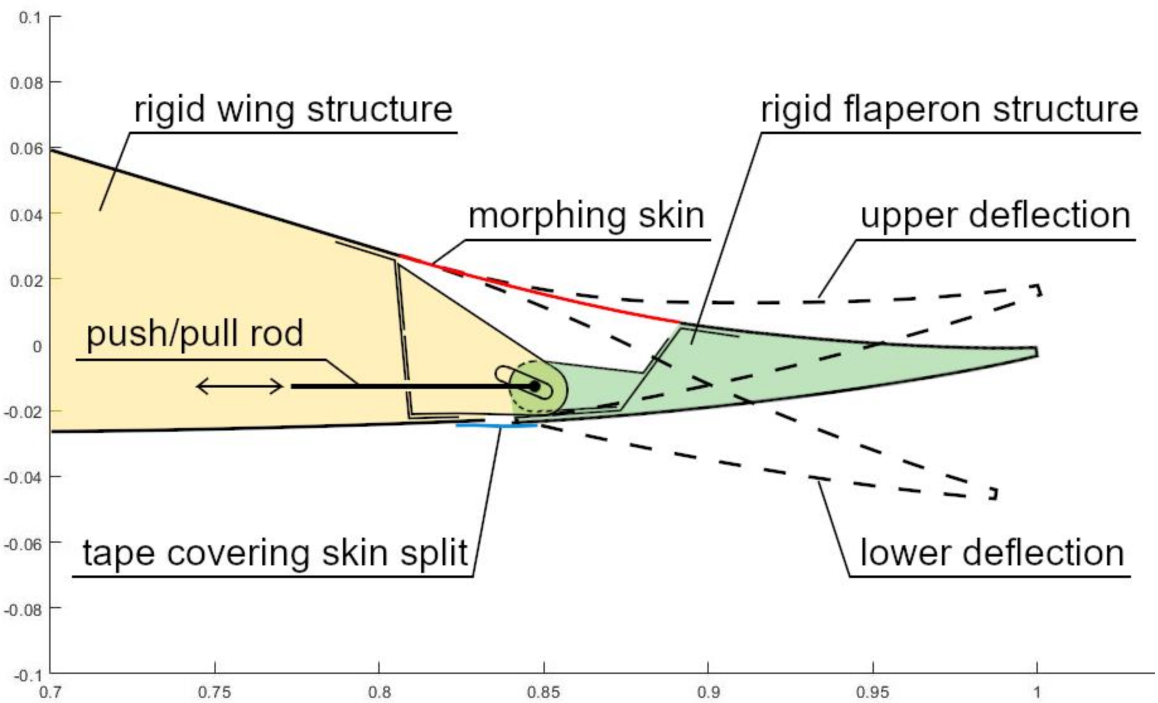

Figure 1 Morphing flaperon arrangement with load-bearing skin

The control force of the morphing flaperon comprises aerodynamic force (aerodynamic hinge moment equivalent) and actuation force. To reduce the actuation force, the bending stiffness of the morphing skin has to be reduced or an arm of the momentary couple increased. However, the latter is restricted by an internal airfoil envelope that must be respected. The reduction of the morphing skin bending stiffness is limited by buckling under the compressive load that occurs in case of lower flaperon deflection. As can be seen, the structural design is a multidisciplinary optimization problem, which can be solved using the genetic algorithm.
The design workflow of the morphing flaperon starts with a definition of parametric geometry. The main geometry features form the first group of optimization parameters. These are supplemented with parametric material data of the composite morphing skin. The geometrical shapes to be achieved through morphing motion are based on the previous results of the aerodynamic optimization [3] of the flapped laminar airfoil. This reduces the complexity while respecting the aerodynamic shape but focusing on structural design. The objective function for optimization incorporates the reserve factor, target geometry fulfilment and actuation force. To produce the single objective value a weighing is used, but it is accompanied by constraints. The constraints hierarchize the order in which the objective values are minimized and also limit them to viable ranges. Therefore, the dependence of the optimization output on the selection of weighing factors is reduced.
The described problem was solved using a genetic algorithm from MATLAB function which calls structural FEM calculation to determine an individual's properties for evaluation and selection. The presented problem formulation proved feasible. The algorithm can find a morphing geometry for the material properties to satisfy the target shape and reduce the control force. The use of additional conditions to amend and modulate the standard weighing of objectives proved effective. In future research the workflow and problem formulation will be adapted for the full range of flaperon motion, different material data input and multiple failure modes. The morphing skin will necessitate the fatigue analysis as well. This will be the next step in morphing flaperon design with emphasis on short-term applicability.

References

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