

STRUCTURAL OPTIMIZATION OF AN UAV LEADING EDGE WITH TOPOLOGY OPTIMIZATION

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1. INTRODUCTION

Unmanned aerial vehicle (UAV) are used for a wide range of missions, such as monitoring of forest fires or the observation of the climate. In the context of the EU project CHANGE (Combined morphing assessment software using flight envelope data and mission based morphing prototype wing development) the implementation of different morphing mechanisms to extend the endurance and range is investigated, based on a UAV with a span of 4 m. In this paper the design of one of these mechanisms - an adaptive wing leading edge - is presented. The deflection can be reached by use of a compliant mechanism in combination with a conventional linear actuator. Limited design space is certainly a challenge. The advantage of the compliant mechanism is the avoidance of fine mechanics, which always helps towards lightweight designs. A cost efficient manufacturing technique for such structures is additive layer manufacturing, where a compliant mechanism can be built in one step. In the presented approach, the skin of the leading edge is tailored in the first design step. After that, the topology of the inward mechanism is pre-dimensioned with an optimization routine.

2. SKIN TAILORING

The object of the skin tailoring is the distribution of the stiffness along the skin perimeter in a way, that the internal mechanism will be able to deform the skin into all desired shapes. The dimensioning process of the skin is similar to that used in the project SADE and is based on the papers of Kintscher et. al. [1, 2]. The target shapes are defined by aerodynamics. Together with feasible layups of orthotropic material and a load introduction point, they are the input to this algorithm. With the aid of a SIMPLEX algorithm the skin layup is generated with the objective to minimize the deviation between the outer skin contour and the required initial and target shape - considering the aerodynamic loads. The stiffness of the skin is later condensed to the load introduction point and will be considered in the optimization of the compliant mechanism. The resulting skin is an elastic system attached to the mechanism and has to be considered during the mechanism design process.

3. TOPOLOGY OPTIMIZATION OF THE COMPLIANT MECHANISM

In topology optimization a regular grid is defined, where the material distribution can be changed in each cell. The objective function is a mathematical description of the main objective and can consider many different targets such as stiffness or acoustic pressure. In case of the compliant mechanism for the leading edge the objective function is to minimize the distance between the the position of the load introduction point (stringer) and its target locations in both conditions: the initial and target shape position, which are the results in the skin tailoring. In this case, the target shape can be reached by using only one stringer.

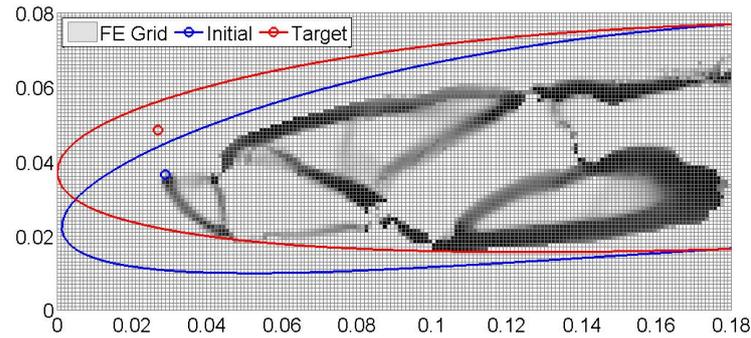


Figure 1. compliant mechanism for an UAV

The method to generate the topology is applied with the Solid Isotropic Material with Penalization (SIMP). It's described by Sigmund and Bendsoe [3, 4] and was implemented for the leading edge in a 2D grid. A result of the compliant mechanism is shown in figure 1, where white parts are defined as non-material cells and black parts are full-material cells. SIMP allows a continuous distribution between non and full material, which is reflected in gray regions in figure 1. The calculation of the object function and the sensitivities bases on a gradient search algorithm and is called Method of Moving Asymptotes (MMA). Appropriate boundary conditions of the optimization are defined and implemented. The first one is the consideration of the leading edge contour, where passive regions were defined and the optimization cannot change the material distribution. A second boundary condition is the limitation of the distributed volume in the optimization to reach a lightweight design.

4. CONCLUSION

With the aid of a topology optimization and a SIMPLEX algorithm, a framework for adaptive leading edge design was set up. The combination of both methods leads to a compliant mechanism, which is feasible. This structure will be the base for a mechanism to deflect the leading edge of an UAV. In case of the UAV it's a solution to avoid fine mechanics and realize the functionality of a morphing leading edge. For future work a post design for solid state hinges and the connection between mechanism and skin have to be performed. Also the FE analysis of the skin and the mechanism in one model will be done to prove the reduction of the stiffness in the topology optimization.

References

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