Wing Topology Optimization with Self-Weight Loading

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1. Abstract

We have been developing a topology optimization tool to be integrated in a MDO framework for wing conceptual design as a pre-conditioner of the initial design and, eventually, replace the current structural analysis module. In the present version of the MDO framework, the wing structure configuration is restricted to conventional layouts comprising spars, ribs, stringers and skin. Moreover, optimization is reduced to sizing and placing the initial design elements without the ability to add or remove elements. Therefore, the problem outcome is dependent of the initial design and user experience. We intend to use topology optimization as a pre-processor tool to aid the definition of the initial structure. However, our final goal is to fully integrate the topology optimization tool in the MDO framework instead of using the actual structural analysis module. Topology optimization not only optimizes the structure but it also shapes and transforms it. For that reason, the initial design dependency and the conventional layout restriction are eliminated.

We have already applied the topology optimization tool to the wing's interior volume or individual elements (spar or rib) in order to minimize the wing's overall compliance, while loading the skin with aerodynamic pressure distribution. We use an alternative version of the well known finite element based method SIMP, where the finite element minimum stiffness is independent of the penalization factor, combined with the globally convergent version of the MMA optimization algorithm. To deal with numerical instabilities, such as checkerboard pattern and mesh dependency, we have implemented the sensitivity filter and three morphological based density filters.

In this paper we address the problem of introducing self-weight loads. One would expect this problem to be a direct extension of the minimum compliance topology optimization problem with fixed external loads. However, there are particular difficulties that must be addressed when density dependent loads are applied. When any kind of body load is applied to the design space the compliance function can be either monotonous or non-monotonous regarding the design variables. This issue can be solved by using a non-monotonous approximation as the globally convergent MMA. Another difficulty is the parasitic effect for low densities when using the power law. To mitigate this instability, we purposed a novel solution. Though, the method presented is developed to be used only in the optimization of wing structures or structures with similar load. In this case, it not only solves the problem but it also increases the solution discreteness.

To validate and test the new method we minimized the compliance of a cantilevered beam subjected to the self-weight load. Besides the body load, we also apply a fixed external load at the free tip. The problem is solved for different directions of the external load and ratios between body and external load. Results show us that when the external load acts in the opposite direction of the body load, the solution becomes more discrete. Same conclusion can be taken from the compliance minimization example applied to a wing volume loaded with aerodynamic pressure and self-weight.

Finally, we intend to optimize a flying wing where the aerodynamic and self-weight loads have a similar magnitude.

2. Keywords: Multidisciplinary Optimization, Topology Optimization, Self-Weight Load, Wing Design.