Multidisciplinary Level Set Topology Optimization of the Internal Structure of an Aircraft Wing

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Topology optimization determines the optimal layout of a structure within a design space. Low weight efficient structures are vital to aircraft performance making aerospace structures an important field for the application of topology optimization. Topology optimization has been used to achieve significant weight savings at the component design level. However optimizing the internal structural layout of an entire wing could lead to greater improvements. Furthermore we topology optimization cold be used to investigate potential internal structures for the revolutionary wing configurations of future generations of aircraft.

In this work, topology optimisation is applied to the aero-structural problem of aircraft wing design. This is a well-known multidisciplinary optimisation problem, previously tackled by element-based topology optimisation methods such as SIMP but for the first time using the level set approach. Changes to the internal structure of the wing impact its aerodynamic performance and in turn the loading of the wing. This aero-structural coupling needs to be considered during optimization.

In this investigation the internal structure of a 3D wing model is optimized using the level set method of topology optimization. The level set method uses a set of signed distance functions stored at the finite element nodes to define the location of the structural boundary. Local sensitivity values are used to update the signed distance function values, moving the structural boundary to create a more optimal structure.

The aerodynamic loading on the wing at a given flight condition are calculated by applying the Doublet Lattice Method (DLM) to a 2D model of the wing planform. The aerodynamic loads are then transferred to the top surface of a 3D finite element (FE) model of the wing. Inertia loads calculated from the structural distribution are also applied to the model. The FE model is then solved for linear statics and the optimization sensitivities are calculated. Once the structure has been updated the wing deformation is transferred to the DLM grid to update the aerodynamic loading for the new wing.

The results in which the wings were optimized to minimize overall compliance subject to a volume constraint have demonstrated the potential of the multidisciplinary optimization procedure using the level set method. We find that the optimum solution is significantly different from the solutions reported in the previous literature.