Two-level design optimization of aircraft structures under stress, buckling and aeroelasticity constraints

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The complexity of aircraft design is due to increased interaction between the different individual disciplines determining the performance of the aircraft. The general problem of multidisciplinary design optimization (MDO) is extraordinarily complex. It is due to highly large number of design variables and constraints proceeding from the different disciplines. MDO requires repetitive generation of models and analysis as design variables vary. The process can be very time-consuming. Therefore, in practice it is necessary to simplify the design problem and to form the MDO framework that automates the process.

In this paper we are restricted by one of the typical problems concerning the determination of structural parameters for weight minimization with taken into account the variety of strength, buckling and aeroelasticity requirements. Practical optimization problems can have from hundreds to thousands design variables and thousands of highly nonlinear and implicit constraints from various disciplines. We have a multidisciplinary aero-structural optimization problem where stress, aeroelasticity and buckling constraints should be taken into consideration together. The best way to solve such complex problem is to consider all these constraints and design variables simultaneously in one design optimization process. However, there is no possibility at present time to do this due to very large dimension of the optimization task.

To solve this problem it is proposed to use different level models in multidisciplinary design optimization procedures. The paper describes a developed approach of multilevel optimization which include both calculation of design constraints in different level models and two-level optimization scheme. In this approach the optimization problem can be reformulated as a series of smaller subproblems for separated subsystems of structure. To coordinate coupling between the subsystems a coordination problem is added. Each subproblem having own goal function and constraints is solved independently at the first level. The coordination problem is solved at the second level.

In the paper the two-level approach to structural optimization with stress/aeroelasticity and panel buckling constraints is demonstrated in details. The design constraints are written for a stiffened panel which can be modeled by equivalent rectangular stiffened plate. Different methods are used to calculate critical stresses for global buckling of panel, local buckling of skin between stringers and local buckling of stringer elements. The approximate equations of interaction of different load components are used to compute critical load parameter of buckling. Main relationships for the constraints are given.

The design optimization of supersonic airplane wing is presented to demonstrate the application of the proposed two-level method. Such important structural wing parameters as optimal panel sizes, number of stringers in panels and ribs steps are determined.