11th World Congress on Structural and Multidisciplinary Optimisation
07th -12th, June 2015, Sydney Australia

Load-Path Design and Control Using Topology Optimization

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Abstract

Many failures in load-carrying structures occur due to error in calculating load path. For example, the certification failure in Boeing 787 assembly was caused by error in estimating load distribution between upper and lower fasteners of the center wingbox. It was also reported that two thirds of missed steady state and dynamic loads cases in Boeing for last 30 years were caused by inadequate load analysis. Even if the external limit loads and design loads are well defined, it is difficult to analyze/evaluate accurate internal loads that are applied various joints of complex systems, which can cause overload and early joint failure.

Instead of trying to analyze internal load for a given joint configuration, the main objective of this paper is to design/control internal load path of load-carrying structures using a new topology optimization strategy. A new topology optimization formulation with a local control of interface load is formulated, to minimize the structural volume subject to constraints on the ratio of multiple internal interface loads (or joint loads). The sensitivity analysis on local interface load is performed using the adjoint method. Material penalization is done using the SIMP approach and MMA is used for optimization algorithm. Multiple case studies successfully demonstrated excellent control of local load path for advanced design of aircraft structural systems.