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Robust multi-objective and multi-level optimization of complex mechanical structures

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ABSTRACT

This paper presents a new approach to robust multi-objective and multi-level optimization of the design of complex mechanical structures. The optimization is at two levels: system and elements. At system-level, the robust multi-objective problem has four cost functions: on the one hand the minimization of the global mass and displacement at a fixed point of the mechanical structure, and on the other hand the maximization of both the robustness and the displacement of the mass. At element-level the robust multi-objective problem has two cost functions: minimization of the element mass and maximization of its robustness. A robust condensation technique, based on an enriched Karhunen–Loève condensation, is used for complex structures which require a large finite element model. In contrast to existing formulations, this new approach takes into account uncertainties in the design parameters at system-level and element-level. It also allows for the task sharing which is commonly used in structural engineering.

1. Introduction

Nowadays, the design of complex structures (which require a large finite element model (FE model) such as aircraft, aerospace, etc., require the use of optimization methods. The size of the optimization problem depends on the number of variables and constraints required, especially for the design of structures with large interactions between their various components. Treating the problem in the conventional manner with all components considered simultaneously leads to excessive computer run times (CPU times). In order to control this growth in the size of the problem, a multi-level approach has to be used to decompose the problem (system-level) down into several sub-problems (element-level) taking into account the structural coupling effects. Such an approach enables us to use parallel computer processing, leading to a significant reduction in the computer run time and a decrease in the time needed the design cycle.

A multi-level approach is needed to decompose the entire system problem (system-level) into several sub-problems (element-level) taking into account the various coupling effects. The multi-level approach allows individual system components to be optimized, thus significantly reducing the time needed for the computation and the design cycle. Various concepts have been proposed [1–7] to decompose large optimization problems down into sub-problems. It should be noted that the design parameters of the global structure affect both the structure and sub-structures (density, Young modulus, etc.), while the design parameters of the sub-structures can be local dimensions (e.g. geometric dimensions: thickness, length, width). The constraints on the structure are global (e.g. structural displacement), while the constraints

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