Chapter 22
Metamodel-Based Optimum Design Examples of Structures

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ABSTRACT

In order to achieve greater fuel efficiency and energy conservation, the reduction of weight and enhancement of the performance of structures has been sought. In general, there are two approaches to reducing structural weight. One of which is to use materials that are lighter than steel and the other is to redesign the structure. However, conventional structural optimization methods using gradient-based algorithm directly have difficulties in defining complex shape design variables and preventing mesh distortions. To overcome these difficulties a metamodel-based optimization method is introduced in order to replace the true response by an approximate one. This research presents four case studies of structural design using a metamodel-based approximation model for weight reduction or performance enhancement.

INTRODUCTION

The latest structural components are lighter than their past counterparts, and provide higher fuel efficiency and performance. In particular, structural optimization methods have been applied to the structural design of automobiles, railroad vehicles, aircraft, etc., because of the demands for the development of eco-friendly machinery (Lee & Kang, 2007; Song et al., 2009). Several structural optimization methods are included in many commercial softwares (MSC.Software, 2004; VR & D, 2000), and are frequently adopted for weight reduction or performance enhancement. Because structural design optimization includes a number of degrees of freedom in finite element analysis, it is important to reduce computation time.

The best way to obtain the optimum design of a structural component is to adopt the classical structural optimization method built-in to the commercial software, such as NASTRAN (MSC. Software, 2004) and GENESIS (VR & D, 2000).

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This approach suggests that it is efficient to make mapped meshes. But mesh qualities worsen when design variables are modified; and furthermore, it is not easy to perform sensitivity analysis in the case of nonlinear FE analysis. To overcome the disadvantage of classical methods built-in to NASTRAN and GENESIS, recent researches have utilized a metamodel-based optimization method. Metamodel-based optimization methods are suitable for problems of structural design requiring much computation time, difficult computational sensitivity problems, or problems having a noisy response function (Lee & Kang, 2006, 2007; Song et al., 2009; Lee, 2010). Examples of metamodel methods are approximation methods, including the response surface model, neural network, radial basis method, and kriging. In this research, several examples of metamodel-based optimization using kriging are investigated. Research by Sacks shows that the DACE modeling method (Sacks et al., 1989; Guinta & Watson, 1998), known as one of the kriging interpolation methods, is considered to be a statistically reliable and consistent method for approximating deterministic computer experiments. It is known that the kriging interpolation method provides accurate predictions of highly nonlinear responses.

The overall structural design process using the kriging metamodel is as follows: First, the DOE (Design Of Experiments) is carried out to define the design samples. As a sampling method, Latin hypercube design, orthogonal array, maximum entropy method, and so forth can be utilized. Second, FE analysis is performed with a number of sample points. Third, surrogate models of related responses are built. Thus, the responses of interest are replaced by kriging models. As a final step, an optimum design is calculated, by considering formulation. It is easy to solve the approximated formulation since the responses requiring much computation time are replaced by simple mathematical equations. Thus, it is not important to select an algorithm to solve the formulation in this step. The overall design process suggested in this research is shown as Figure 1.

The examples of application of the metamodel-based optimization considered in this study are automotive door design (Lee & Kang, 2007), disk brake design (Song & Lee, 2009), control arm design (Song et al., 2009), and robust design method (Lee, 2010).

KRIGING INTERPOLATION METHOD

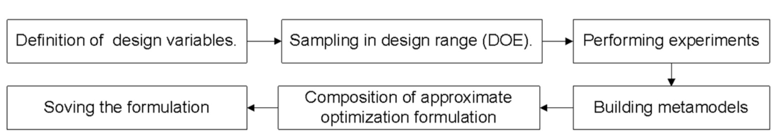
The Kriging interpolation method is well explained in the references (Sacks et al., 1989; Guinta & Watson, 1998). In the kriging model, the global approximation model is represented as

$$y(\mathbf{x})=g(\mathbf{x})+z(\mathbf{x}) \tag{1}$$

where, $\mathbf{x}$ is the vector for design variables, $g(\mathbf{x})$ is a known function of $\mathbf{x}$, and $z(\mathbf{x})$ is the realization of a stochastic process with mean zero, variance σ^2, following the Gaussian distribution. When $g(\mathbf{x})$ is treated as the constant β, Equation (1) is rewritten as

$$y(\mathbf{x})=\beta+z(\mathbf{x}) \tag{2}$$

Figure 1. Design process overview



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