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Sensitivity analysis based on complex variables in FEM for linear structures

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Abstract. One of the efficient and useful tools to achieve the optimal design of structures is employing the sensitivity analysis in the finite element model. In the numerical optimization process, often the semi-analytical method is used for estimation of derivatives of the objective function with respect to design variables. Numerical methods for calculation of sensitivities are susceptible to the step size in design parameters perturbation and this is one of the great disadvantages of these methods. This article uses complex variables method to calculate the sensitivity analysis and combine it with discrete sensitivity analysis. Finally, it provides a new method to obtain the sensitivity analysis for linear structures. The use of complex variables method for sensitivity analysis has several advantages compared to other numerical methods. Implementing the finite element to calculate first derivatives of sensitivity using this method has no complexity and only requires the change in finite element meshing in the imaginary axis. This means that the real value of coordinates does not change. Second, this method has the lower dependency on the step size. In this research, the process of sensitivity analysis calculation using a finite element model based on complex variables is explained for linear problems, and some examples that have known analytical solution are solved. Results obtained by using the presented method in comparison with exact solution and also finite difference method indicate the excellent efficiency of the proposed method, and it can predict the sustainable and accurate results with the several different step sizes, despite low dependence on step size.

Keywords: complex variables method (CVM); discrete sensitivity method (DSM); linear structures; semi-analytical method

1. Introduction

Sensitivity is a calculation of the derivative of the dependent variable with respect to another in a problem. Application of sensitivity quantity is when the designer is looking for an optimal design for a problem using gradient reduction methods, and in practice, it determines the degree of importance of objective function change of the problem respect to design variables change (Choi 2005, van Keulen *et al*. 2005). There are many efficient algorithms such as SQP method needing calculation of derivatives of objective functions and constraints respect to design parameters for

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September.
van Keulen, F. and De Boer, H. (1998), "Rigorous improvement of semi-analytical design sensitivities by exact differentiation of rigid body motions", *Int. J. Numer. Methods Eng.*, **42**(1), 71-91.
van Keulen, F., Haftka, H.M. and Kim, N.H. (2005), "Review of options for structural design sensitivity analysis, part 1: Linear systems", *Comput. Method Appl. Mech. Eng.*, **194**(30-33), 3213-3234.
Vatsa, V.N. (2000), "Computation of sensitivity derivatives of Navier-Stokes equations using complex variables", *Adv. Eng. Software*, **31**(8), 655-659.
Voorhees, A., Millwater, H. and Bagley, R. (2011), "Complex variable methods for shape sensitivity of finite element models", *Finite Elem. Anal. Des.*, **47**(10), 1146-1156.
Voorhees, A., Millwater, H., Bagley, R. and Golden, P. (2012), "Fatigue sensitivity analysis using complex variable methods", *J. Fatigue*, **40**, 61-73.

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