Application of Interventing Variables in a Bilinear Approach for Fuzzy Structural Analysis

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ABSTRACT

An important and unavoidable issue in modern structural engineering is the correct manipulation and quantification of uncertainties for the aim of achieving robust and reliable designs. This vagueness and imprecise information of the variables is contained in loads over the system, material properties, cyclical behaviour, etc. Nowadays, methods based on interval analysis and fuzzy logic have claimed attention [1]. Within these methods, each uncertain parameter is characterized through membership functions. Then, the technique called fuzzy structural analysis is employed to build the membership functions of the response of interest (displacement, stresses, etc.). The principal problem in performing this technique resides in the almost impossible way of finding an analytical solution for the variability in this response. Hence, a discrete method known as α-level optimization has been developed [2], where a series of interval analysis are performed. However, the application of such procedure involve the solution of different optimization problems, with it consequently high computational cost (due to the necessity of repeatedly solving the linear system) and possible existence of non-convex problems. In order to avoid this issue, Taylor series expansion of the response can be constructed [3]. In this approximation, one single structural analysis is required in order to calculate the solution for the expansion point and derivatives with respect to fuzzy parameters. Nevertheless, results applying Taylor series expansions are not extremely accurate, especially in problems with high levels of uncertainties.

In this contribution a new approach within the frame of fuzzy structural analysis is presented. The interest is to obtain the variability in form of membership functions of the displacement in linear static structures where the uncertainties are presented in both structural properties and loading. This approximation is built from a first order Taylor series expansion [3], incorporating intervening variables to capture the non-linear relationship existing between displacement and structural parameters and direct variables to include the effect of loading. Thus, a high quality approximation for the response of interest is obtained performing a single structural analysis. For the structural parameters, power-type intervening variables are used, involving a real constant that fits the actual non-linear relationship. For the proper choice of the latter one, different methods are compared in the search for an accurate and automatic procedure [4]. As an application and in order to highlight the benefits of the presented work, different structures modelled by the finite element method are considered, comparing the obtained results with existing methods and the exact solution, obtained through direct optimization.

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