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VDM IN INVERSE PROBLEMS OF SAFETY ENGINEERING

Jan Holnicki-Szulc*, **Łukasz Jankowski***

Institute of Fundamental Technological Research (IPPT PAN)
ul. Pawińskiego 5b, 02-106 Warszawa, Poland
e-mail: {holnicki, ljank}@ippt.pan.pl

1 INTRODUCTION

The virtual distortion method (VDM) [1] is a quick reanalysis method developed in the Institute of Fundamental Technological Research (IPPT PAN). Earlier related work includes the research of professors Nowacki, Eshelby, Kröner, Argyris, Maier, Majid and Celik, and others; for references see [1, 2]. The term *virtual distrotion* has been coined in 1989 [3], and the concept of the influence matrix has been proposed, which is the distinguishing factor of the VDM that provides for its effectiveness. This contribution presents the background and formulation of the method and reviews its applications in safety engineering.

2 VDM AND STRUCTURAL REANALYSIS

Basically, the VDM is a technique for fast structural reanalysis [1, 4]: it yields the response of a modified structure by computing the effect of the modifications on the original response, without solving full structural equations. Various types of structural modifications are treatable in a unified manner, including modifications of structural stiffness, mass and damping, and various material nonlinearities like plastic yielding. The methodology has been applied for deterministic static and dynamic reanalysis [1], as well as for modeling of stochastic response of structures with uncertain parameters [5].

A simple formulation in time domain is obtained in the problem of computing the strain response $\varepsilon(t)$ of a truss element. Denote the (known) response of the unmodified element by $\varepsilon^{\mathrm{L}}(t)$, and let the (known) stiffness reduction ratio be $\mu := \tilde{E}/E$. Zero initial conditions are assumed. The modification is modeled with a time-dependent virtual distortion $\varepsilon^0(t)$. The element forces should be the same, that is $EA(\varepsilon(t) - \varepsilon^0(t)) = \tilde{E}A\varepsilon(t)$, which yields

$$\varepsilon^0(t) = (1-\mu)\varepsilon(t). \tag{1}$$

The original structure is linear, thus the response of the distorted element is

$$\varepsilon(t) = \varepsilon^{\mathrm{L}} + \int_0^t B(t-\tau)\varepsilon^0(\tau)\,\mathrm{d}\tau, \tag{2}$$

where $B(t)$ is the strain of the unmodified element subjected to an impulsive unit distortion (dynamic influence matrix, here 1×1). Substitution of the (2) into (1) yields the following integral equation. The response of the modified element is then obtained by (2).

$$\varepsilon^0(t) - (1-\mu)\int_0^t B(t-\tau)\varepsilon^0(\tau)\,\mathrm{d}\tau = (1-\mu)\varepsilon^{\mathrm{L}}, \tag{3}$$

3 APPLICATIONS IN SAFETY ENGINEERING

The VDM has been applied to solve a range of important real-world inverse problems in the field of safety engineering [6]. It includes several applications in structural health monitoring, such as identification of structural damages [7], monitoring of nodal joints [8], local monitoring at the substructural level [9], load identification [10] and to the design of impact-resistant, adaptive structures [11]. Moreover, general analogies have allowed the VDM to be successfully applied to monitoring of water leakages in piping systems [12], as well as to monitoring of electrical networks [13].

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