Nonproportional Damping Identification for Offshore Structures from Modal Testing Data

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ABSTRACT

Proportional damping as a special type of viscous damping, which expresses the damping matrix as a linear combination of the mass and stiffness matrices. While for complex structures, such as offshore structures, there are cases in which nonproportional damping is needed to simulate the dynamics of the system with sufficient accuracy. This paper is to identify the nonproportional damping matrix employing modal testing data. One approach taken here is a general damping matrix decomposition technique, which can consider the situation that different parts of the structure have different damping; and another is that the proposed identification method only require several complex modes will be included in the numerical studies. Numerical studies have been conducted for a jacket-type offshore structure based on synthetic data generated from finite-element model. The results suggest that: 1) measured damping ratio or ratios is/are matched perfectly; global damping matrix can be estimated accurately with several higher order measured modes, even when only lower order complex modes are measured such as the first two or three, a reasonable damping matrix can be obtained.

KEY WORDS: nonproportional damping; general damping matrix; lower order; complex mode; damping ratio.

INTRODUCTION

Linear, vibrating systems always have some type of a damping mechanism that dissipates energy. This form of damping may be viscous, structural damping or Coulomb damping. During free vibration, all structures exhibit some degree of energy loss. Traditionally, this energy loss is referred to as inherent damping. The most significant source of inherent damping is internal friction in the structural materials, connections, and nonstructural components (Lazan, 1968; Nashif et al., 1985; Kareem and Gurley, 1996). For simplification, proportional damping is often used to model the effect of damping in linear vibrational mechanical systems. However, in real structures such as platforms, nonproportional damping can arise readily because the majority of the damping is found to be concentrated at the joints between components of a structural assembly that does not result in a proportional distribution in damping (Ewins, 2000), progress in study of joint damping in metal plates has been detailed by Walker (2006); in many practical situations proportional damping model does not describe the dynamics of the structure with sufficient accuracy because of the complicated damping mechanisms that occur in practice (Ibrahim, 1983; Gawronski and Sawicki, 1997).

Nowadays, damping is still the dynamic characteristic that is the least understood and the most difficult to quantify. The lack of general methodology in identifying the system’s damping matrix can be partly due to the mathematical difficulties in modeling the dissipation energy in a vibrating structure. Damping matrix identification methods can be classified into two basic categories: (a) Damping identification from modal testing and analysis, and (b) direct damping identification from force response measurements. The proposed method in this paper falls in the first category and assumes that the mass and stiffness matrices are available.

Hasselman (1972) proposed a method measuring the off-diagonal elements of the modal damping matrix. In his method, the complex mode shapes are treated as a perturbation of the real mode shapes of the equivalent undamped system. Wolf (1984) emphasized on the identification of linear systems that exhibit nonproportional viscous damping. This method identifies the parameters that appear in the system’s transfer function without identifying the system’s physical parameters. Minas & Inman (1990) identified the damping matrix by combining modal testing and analysis. Though their method proved that the complete modal parameter data is not necessary for unique identification of the damping matrix, while higher order modes are needed in their second numerical study. Prells & Friswell (2000) investigated the difference between proportional and general viscous damping models. It has been shown that for non-defective models possessing a positive-definite mass matrix the difference between proportional and general viscous damping is equivalent to the difference between an orthonormal matrix and the identity matrix. This difference can serve as a measure of non-proportionality. Michael & Abhinav (2006) investigated the nature of damping matrix associated with multi degree of freedom simple shear building models. Their study showed that the incorrect formulation of damping matrix results in highly incorrect responses.

This paper identifies the nonproportional damping matrix employing modal test data by decomposing a proposed general element damping matrix. A 3-leg fixed offshore structure will be chosen for numerical studies. Considering only limited complex modes are available in field testing, damping matrix identification utilizing several lower order complex modes will be included in the numerical studies.