Damage identification and monitoring of bridges using measured natural frequencies

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Summary

This paper presents an approach for the structural damage identification using only the changes of measured natural frequencies. The structural damage is characterized by a local decrease of stiffness and assumed to be associated with a reduction of a contribution to the element stiffness matrix, equivalent to a scalar reduction of the material modulus. A computational procedure for the direct iteration technique based on the non-linear perturbation theory is proposed to identify structural damage. The presented damage identification method is applied to the footbridge over the Slunjcica River near Slunj to demonstrate the effectiveness of the proposed approach. Using a limited number of measured natural frequencies, reduction in the stiffness of up to 100% at multiple sites is detected.

Keywords: bridges; damage identification; monitoring; natural frequency measurements.

1. Introduction

The field of structural damage identification is very broad and encompasses both local and global methods. Current damage-detection methods are either visual or localized experimental methods, such as acoustic emission, ultrasonic and thermograph. Such methods tend to be used only when the approximate damage location is known *a priori* and the portion of the structure being inspected is readily accessible. For evaluation of complex structures, such as bridges, methods of vibration testing offer the opportunity for *global* damage detection techniques that examine changes in the vibration characteristics of the structure. These methods, however, do not produce quantitative damage information that can be used to design a repair or assess the safety of the damaged structure. These shortcomings can be overcome when vibration measurements are used with the system identification algorithms.

Since the changes in the stiffness of the structure, whether local or distributed, will cause changes in the modal parameters (notably natural frequencies, mode shapes, etc.), the location and the severity of damage in structure can be determined by changes in the modal characteristics. Furthermore, since the natural frequencies are rather easy to measure with a relatively high level of accuracy, the methods based on the measurements of natural frequencies are potentially attractive [1-5]. These characteristics can be obtained by measurements at one point of the structure and are independent of the location chosen.

The authors [4] proposed a novel perturbation-based approach using the exact relationship between the changes of structural parameters and the changes of modal parameters in order to avoid the insufficiency of the first-order sensitivity analysis. For damage detection, the first-order approximation may be inaccurate since a large change of structural parameters due to damage might need to be detected [1-3].

In this paper the direct iteration technique based on the non-linear perturbation theory is utilized to identify structural damage, when information about only natural frequencies for the damaged structure is available. The proposed numerical procedure was already used to identify damage in a

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