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Detecting cracks in pipes filled with fluid from changes in natural frequencies

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ABSTRACT

This paper deals with the identification of a single open crack in a straight pipe containing fluid under pressure by frequency measurements. The crack is assumed to be a transverse partial cut of the pipe wall thickness with straight front and it is simulated by an equivalent elastic spring. It is shown that the measurement of the damage-induced shifts in a pair of natural frequencies of the bending vibration can be used to formulate and solve the diagnostic problem. In particular, it is shown that the change in the first two frequencies in a simply supported uniform pipe is sufficient to localize a small crack, except for a symmetrical position, and to determine the damage severity. Closed-form expressions are provided for damage location and severity. An extension of the method to simply supported uniform pipe with two cracks of equal severity is also presented. The analysis is based on an explicit expression of the frequency sensitivity to damage and allows to consider pipes under general set of boundary conditions. Analytical results agree well with the numerical tests.

1. Introduction

Non-destructive testing techniques enjoy growing focus among the engineering community. Many conventional diagnostic methods, such as those based on visual inspection, thermal or ultrasonic analysis, X-ray methods and others, are local by nature. To be effective these require direct accessibility of the region to be inspected and a good preliminary knowledge of the position of the defective area. Vibration-based techniques are a potentially effective diagnostic tool, see, for example, [14,24] and the book [23]. These can operate on a global scale and do not require a priori information on the damaged area. Vibration methods based on natural frequency data are one of the most convenient diagnostic methods, because changes in natural frequencies can be measured easily from just one accessible part of the component. Also such measurements are fast, easy and cheap. However, it is well known that measurements involve small changes in frequencies to be able to detect small cracks. Then, the results of identification strictly depend on the inaccuracy of the analytical model used to interpret experiments and on measurement errors [6,22]. In spite of this difficulty, encouraging results have been obtained in the last three decades and an extensive literature on crack detection in rods and beams based on natural frequency data is now days available, see, for example, [1–5,7–10,15–17,20,21,28,29,31–33].

Crack identification in pipes filled with fluid from frequency measurements is of special concern in this paper. The possibility of detecting localized damages in such components has been investigated only recently. The first investigation has been developed by Murigendrappa et al. [26]. The authors represented an open crack in a straight hollow pipe in bending vibration as a rotational elastic hinge inserted at the damaged cross-section. The stiffness K of the

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