Chapter 62
Dynamic Behaviour and Crack Detection of a Multi Cracked Rotating Shaft using Adaptive Neuro-Fuzzy-Inference System:
Vibration Analysis of Multi Cracked Rotating Shaft

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ABSTRACT

The presence of crack changes the physical characteristics of a structure which in turn alter its dynamic response characteristics. So it is important to understand dynamics of cracked structures. Crack depth and location are the main parameters influencing the vibration characteristics of the rotating shaft. In the present study, a technique based on the measurement of change of natural frequencies has been employed to detect the multiple cracks in rotating shaft. The model of shaft was generated using Finite Element Method. In Finite Element Analysis, the natural frequency of the shaft was calculated by modal analysis using the software ANSYS. The Numerical data were obtained from FEA, then used to train through Adaptive Neuro-Fuzzy-Inference System. Then simulations were carried out to test the performance and accuracy of the trained networks. The simulation results show that the proposed ANFIS estimate the locations and depth of cracks precisely.

1. INTRODUCTION

All metal members that are subjected to vibration and cyclic stresses in more or less localized areas, cracks may occur. Since cracks cannot be easily seen with the naked eyes, the non-destructive testing methods like ultrasonic testing, X-ray, etc. can be used to detect them. However, these methods are costly and time-consuming for complex or large structures. For this reason, the vibration-based structural health

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monitoring methods, especially those based on the change of modal parameters (frequencies, shape and damping), have been explored for detecting cracks. These vibration-based techniques have been applied to a variety of engineering structures, such as beams, trusses, rotors, etc.

In the past most of the research work has been done on a structure with a single transverse surface crack. When more than one crack appears in a structure, the dynamic response becomes more complex depending upon the relative positions and depths of these cracks. For the first time, Dimaragonas et al. (1983) suggested an analytical method for the computation of dynamic response of a cracked Euler-Bernoulli beam by modeling the cracked region as a local flexibility resulted from fracture mechanics. Christides et al. (1984) developed a continuous theory for vibration of a uniform Euler-Bernoulli beam containing one or more pairs of symmetric cracks. A differential equation of motion and corresponding boundary conditions are given in this paper using the Hu-Washizu variational principle. Darpe et al. (2003) detected that various combinations of position and depth can lead to the identical changes in the natural frequencies. Ostachowicz et al. (1991) analysed the effect of positions and depths of two cracks on the natural frequency of cantilever beams. Shen et al. (1990) have analysed a pair of symmetric cracks at mid-span and focused their attention on the effect of these cracks on the mode shapes. Ruotolo et al. (1996) studied the effect of crack depth and location on the eigenfrequencies of a double cracked beam. Al-Said (2008) developed a mathematical model describing the lateral vibration of a stepped cracked beam carrying concentrated masses and obtained a global effect of cracks to the system. The advantage of the proposed algorithm is to identify the crack by monitoring a single natural frequency of the system. Ranjan et al. (2012) studied experimentally the variation in vibration characteristics of multi cracked rotating shaft using piezoelectric sensor. And they observed from the numerical results that, there were appreciable changes in vibration characteristics of the rotating shaft with and without cracks which can be utilized for multi cracks identification of structures. Sekhar (1999) carried out a parametric study of two transverse open cracks in a rotor and studied the effect of various crack parameters on the eigen-frequencies and stability speeds of rotors. He used finite element model of a rotor bearing system for flexural vibrations and carried out a study on two aligned open cracks. Dong et al. (2009) introduced finite element (FE) model, which is based on a transfer matrix analysis and local flexibility theorem to obtained crack identification of a static (non-rotating) rotor with an open crack. Han et al. (2003) the continuous wavelet transform of the measured wave signals was used to detect the damage location. In this method the magnetostrictive effect was employed for a non-contact measurement of stress waves in rotating shafts. Masoud et al. (1998) suggest a mathematical model to study the effect of crack depth on the transverse vibration characteristics of a pre-stressed-fixed cracked beam. They studied the effect of interaction between the crack depth, and axial load on the beam natural frequencies. An experimental verification was carried out for the obtained theoretical results. Chati et al. (1997) studied the dynamic characteristics of a cantilever beam having a transverse edge crack by using modal analysis. In the field of non-destructive evaluation (NDE), neural networks are a very useful tool for analyzing and filtering different variety of measured quantities and signals. Kang et al. (1998) used a neural network approach to determining fatigue crack configuration. Etemad et al. (2009) proposed indirect method of diagnosing a shaft using neural networks. They obtained natural frequencies by means of a finite element method. Then those Numerical data were used to train three two-layer feed-forward back-propagation neural networks. He et al. (2001) proposed a genetic algorithm based method for shaft crack detection. Dharmaraju et al. (2004) developed a general identification algorithm to estimate crack flexibility coefficients and crack depth based on the beam force–response information. They used a Euler–Bernoulli beam element in the finite element modeling, and the crack has been modeled by a local compliance matrix, which has four