NEW TRENDS OF SHAFT CRACK IDENTIFICATION IN A ROTOR SYSTEM

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An important rotor fault, which can lead to catastrophic failure if undetected, is fatigue cracks in the shaft. Vibration behaviour of cracked structures, in particular cracked rotors has received considerable attention in the last three decades [1,2]. The problem of damage and crack identification in structural components has acquired important role in recent years. It has been seen that new model-based fault diagnosis techniques are being developed rapidly in order to meet the demand for increasingly intelligent condition monitoring systems for the maintenance of modern industrial process. For diagnosing the state of a machine usually signal based monitoring systems are used as good tools, although they do not fully utilize the information contained within the vibration data. These approaches to machinery diagnostics are generic rather than machine specific and the interpretation of the data is based on qualitative rather than quantitative information. Contrary to signal based monitoring systems, model based diagnostics systems developed in recent years [3] utilize all information contained in the continuously recorded vibration signals. These methods work either in the time or in the frequency domain depending on the malfunction type and the operating state for which the vibration data are available. Also, it can be used together with or alternatively to conventional signal based monitoring systems.

In the present paper different signal based approaches such as variation of mechanical impedance; wavelet analysis and model based methods are discussed for the on-line identification of cracks in a rotor system. A combined or hybrid approach of model and signal based methods is also presented. The fault-induced change of the rotor system is taken into account by equivalent loads in the mathematical model. The equivalent loads are virtual forces and moments acting on the linear undamaged system to generate a dynamic behaviour identical to the measured one of the damaged system [3]. The rotor has been modelled using finite element method, while the crack is considered through local flexibility change [4,5]. The crack has been identified for its depth and location on the shaft. The nature and symptoms of the fault, that is crack, are ascertained using the FFT/wavelet.

A rotor system with two flexible bearings and two rigid disks as shown in Figure 1, has been considered in the present analysis. The FE analysis has been carried out at a steady speed of 4420 rpm (73.7 Hz). In the beginning, the vibrations are considered at all the 48 degrees of freedom (DOF) of the model, and this is considered as a reference case. However, normally the vibrations are measured only with few sensors or transducers, hence, only for few DOF the measured vibration data are available. For such less DOF, the vibration data at all the DOF of the rotor are estimated using the modal expansion.

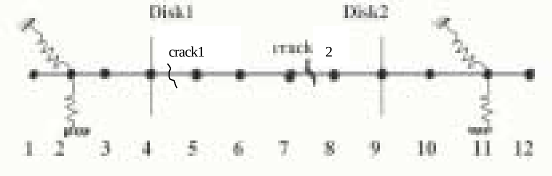
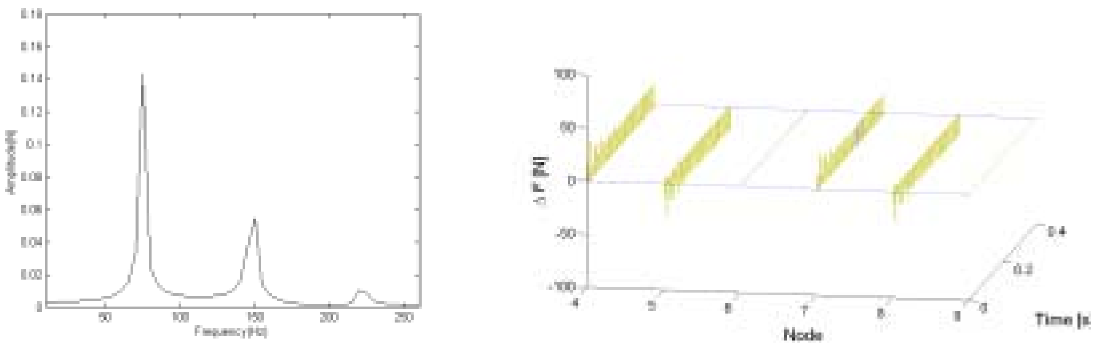


Fig.1 Schematic of Cracked Rotor System

The results showed that even for the small crack (1.4 mm out of shaft diameter of 20 mm) and with fewer measured data the crack has been identified effectively. If the structure is cracked in at least two positions, the problem of crack sizing and location becomes decidedly more complex. Relatively few authors have addressed the double crack assessment for structures. The symptoms of the present fault are found using the FFT (Fig.2a) of the time response, which shows the characteristics of crack, the 2X & 3X harmonic components (1st peak corresponds to 73.7 Hz, the running speed). The FFT could not identify the two cracks, however, the estimated equivalent loads (see Fig 2b.) identify the cracks domineeringly one in the 4th element and one in the 7th element.



(a) FFT (b) Equivalent loads

Fig. 2. Estimated Equivalent loads, for Cracks of depth 4mm in Elements 4 & 7

Vibration monitoring during start-up or shut-down is as important as during steady state operation to detect cracks especially for machines such as aircraft engines which start and stop quite frequently and run at high speeds. In the present paper a model-based method together with wavelet approach is also proposed for the on-line identification of cracks in a rotor while it is passing through its flexural critical speed. The crack has been identified for its depth and location on the shaft for different rotor accelerations. The nature and symptoms of the fault, that is crack, are further ascertained using the continuous wavelet transform (CWT). At low accelerations the sub harmonic resonant peaks are clear from CWT plot and even in time response plot. However, as the acceleration increases (Fig. 3) the sub harmonic resonant peaks are embedded in time response and these can be extracted by using CWT. Thus it is found that CWT is a powerful tool for detecting cracks particularly at high accelerations and low crack depths compared to time responses. In the present paper several other techniques like changes in mechanical impedance due to crack have also been discussed with experimental validations, for crack identification.

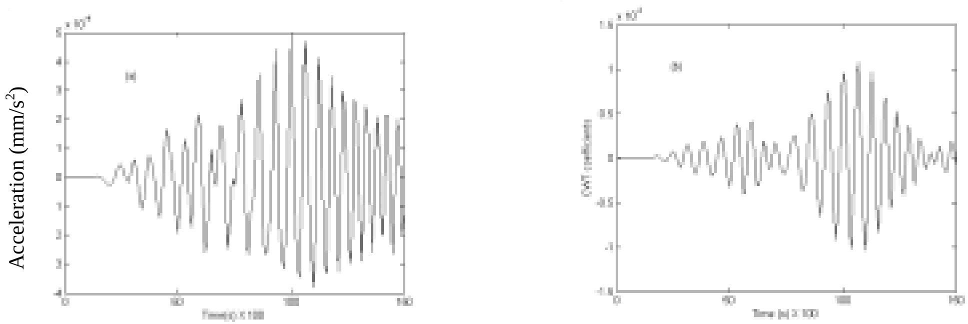


Fig. 3 Residual Vibrations for a crack in element 7, a = 100 rad/s^2 (a) Time (b) CWT

REFERENCES

1. Wauer, J., 1990," Dynamics of cracked rotors: Literature Survey " *Applied Mechanics Reviews,* 43: 13-17.
2. Dimarogonas, A.D., 1996,"Vibration of cracked structures: A state of the Art review" *Engg. Fracture Mechanics,* .55: 831-857.
3. Markert,R., Platz,R., and Seidler, M. 2000 ’’ Model Based Fault identification in Rotor Systems by least squares fitting’’, ISROMAC-8, Honolulu, Hawaii, March 2000.
4. Papadopoulos, C.A. and Dimarogonas, A.D.,1987, "Coupled longitudinal and bending vibrations of a rotating shaft with an open crack" *J Sound and Vibration,* 117: 81-93.
5. Sekhar, A.S.. and Prabhu B.S,.1994 "Transient analysis of a cracked rotor passing through the critical speed, " *J Sound and Vibration* , 173 : 415-421.