An Expert System of Crack Monitoring and Diagnosing for Rotating Machines*

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ABSTRACT

In this paper an expert system of crack monitoring and diagnosing for rotating machines, with simulated experience of the experts, is proposed. The difference in the vibrational behaviors between a crack and other defects which may appear to give same information as that of a crack is discussed. A flow chart is provided to show how the expert system works. The system contains three data moduli: the first one furnishes the standard fault information, the second stores the condition of the machine and the third records the faults of the machines. The whole system is divided into two parts: Block A is for tiny crack while block B is for more serious happenings. The diagnosis process is divided into three main steps:

1. Prechecking the total vibration level on all measured points of a machine.
2. Processing the signals from transducers into proper form.
3. Diagnosing whether there is a crack on the shaft by means of the direct method of pattern identification in fuzzy mathematics. The system possesses a self-learning function.

INTRODUCTION

Once a crack or other faults occur on the rotating machines, the production line will be forced to stop and what is worse, catastrophe may ensue with breaking of the shaft. (Jack 1977) It is therefore the wish of all operators to be able to predict the crack, if any, ahead of time. A perfect expert system can help the operators to judge whether there is a crack on the shaft of a machine or not and whether the machine can run safely or not from the information obtained by measuring and analyzing vibration of a machine as an experienced expert.

From the early 80's, a number of enterprises started to monitor the vibration condition of important rotating machines in order to change their periodical maintenance to a planned way with economical benefit. Afterwards the progress of research in diagnosing faults and condition

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monitoring gives further benefit. At present, the widespread interest is on the expert system. However, so far, to the authors' knowledge, most expert systems for diagnosing faults in rotating machine remain yet to undergo the crucial test, (Shi et al. 1991, Guan et al. 1991) and some of the so-called diagnosis softwares as commodities have actually only the function of condition monitoring.

It is believed that a successful expert system should own the self-learning function, i.e. it is able to learn the diagnostic experience accumulated by itself during operation and correct erroneous diagnosis caused by the particular machine or structure.

this paper proceeds along this line.

THE VIBRATIONAL BEHAVIOR OF A CRACKED SHAFTING

A crack may be detected by ultrasonic wave, X-ray, magnetic-particle, color permeation, electric potential difference, acoustic-emission method, etc. But for rotating machinery the vibration measurement method is more favorable, because it requires only simpler instrument and can be processed while the machine is operating. In this instance the information used for monitoring and diagnosis comes from vibration signals of rotating machines. Therefore it is particularly important to understand the vibration behavior of cracked shaft.

Once a crack appears on a shaft, the bent stiffnesses change with time due to the open-close effect. For a well balanced horizontal shaft under its first critical speed, the unbalanced force acting on it is generally smaller than the gravity. For this reason, whether a crack is open or close is decided mainly by the gravity. The stiffnesses of a cracked shaft $k_x$, $k_y$ and $k_{xy}$ can be expressed as follows: (Zhao & Luo 1990)

$$k_x = k_o - 1/2 \Delta k_x (1 - \Delta k_x)$$ (1)

$$k_y = k_o - 1/2 \Delta k_y (1 - \Delta k_y)$$ (2)

$$k_{xy} = 1/2 \Delta k_{xy} (1 - \Delta k_{xy})$$ (3)

where $k_o$ is the stiffness of the uncracked shaft; $\Delta k_x$, $\Delta k_y$, and $\Delta k_{xy}$ are the differences between maximum and minimum values of the stiffnesses of a cracked shaft respectively; and $\Delta k_x$, $\Delta k_y$, and $\Delta k_{xy}$ are the normalized stiffness increments corresponding to stiffnesses $k_x$, $k_y$ and $k_{xy}$ respectively. Fig. 1 shows the curves $\Delta k_x$, $\Delta k_y$ and $\Delta k_{xy}$ vs.