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A predictive maintenance procedure using pressure and acceleration signals from a centrifugal fan

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Abstract

This work describes a predictive maintenance procedure with a particular application to the diagnosis of unexpected events related to fluid-dynamics operating conditions in turbomachinery. The application of the procedure to a centrifugal fan is presented. The work includes an experimental study of the fan spectral behavior, revealing the characteristic frequencies of the different phenomena involved. Afterwards, a code has been developed which monitors on-line signals to detect any undesired event by comparing the levels of selected frequencies with those that obtain in normal operating conditions.

Keywords: Aeroacoustics; Centrifugal fan; Predictive maintenance

1. Introduction

The strong development of electronics and computers, and its application to dynamic signal analysis, has prompted the appearance of reliable predictive maintenance

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systems. This type of maintenance is also known as condition-based maintenance, on-condition maintenance or condition-directed maintenance and it is conceived to detect the onset of a failure, avoiding critical damages of high cost components before they might happen, thus reducing overall maintenance costs. Possible faults are detected by monitoring representative parameters by signal analysis techniques and comparing signals during normal and abnormal conditions.

In practical applications, predictive maintenance can use different techniques, like the analysis of vibrations, the analysis of the potential contaminants in the lubrication system, the control of the energy consumption, the control of the temperature in selected positions or the analysis of the noise generated by the machine; in conclusion, the measurement of the parameter or parameters that could be considered representative of the operation of the machine. Among all these techniques, the analysis of vibrations is the most frequently used.

On the other hand, with respect to the signal processing, the frequency analysis is, by far, the more widely used. The FFT (fast Fourier transform) algorithm provides the signals spectra. By means of the observation and comparison of the peaks amplitude at different frequencies, it is possible, in many cases, to analyze the different malfunctions and to establish diagnosis criteria. In the case of large rotating machinery, the spectral analysis is not sufficient to identify correctly each failure [2]. In these cases, more sophisticated analysis techniques are needed, like phase spectra, holospectra and orbit diagrams.

Among all the possible signals generated by an installation or a machine, it is not easy to associate a change of a parameter and its cause. So, before the development of predictive maintenance systems, it is always preferred to make experimental studies on the installation or the machine, in order to verify the sensibility of possible signals to typical failures. This is particularly true in the case of fluids machinery, because of the variety and complexity of the phenomena involved in the interaction between the machine components and the flow itself. Not only is the vibrational response to purely structural excitations affected by such flow-machine interaction, but in fact fluid-dynamic excitation is dominant in many cases.

In particular, this work deals with a centrifugal fan. During the energy transfer between the fan and the fluid (atmospheric air in this case), non-steady fluid-dynamic forces are produced, both at single frequencies and with broad-band spectra. The former are usually associated with the frequency of rotation, the blade passing frequency and their harmonics. Excitation at the frequency of rotation may be provoked by impeller whirling, when the impeller has an orbital motion coupled to the rotation, by unbalances and by small manufacturing imperfections in the impeller. Excitation at the blade passing frequency (BPF, frequency of rotation multiplied by the number of blades of the impeller) is a consequence of the finite thickness of the blades, which causes flow disturbances in the volute associated with the passage of each blade.

In addition, high turbulence levels are generated when the fan is operating at off-design conditions (i.e., flow-rates lower or higher than the best efficiency one), due to the incidence angle of the incoming flow with respect to the blades of the impeller. In centrifugal fans, instability phenomena at partial load may affect the aerodynamic