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Fan fault diagnosis based on symmetrized dot pattern analysis and image matching

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ABSTRACT

To detect the mechanical failure of fans, a new diagnostic method based on the symmetrized dot pattern (SDP) analysis and image matching is proposed. Vibration signals of 13 kinds of running states are acquired on a centrifugal fan test bed and reconstructed by the SDP technique. The SDP pattern templates of each running state are established. An image matching method is performed to diagnose the fault. In order to improve the diagnostic accuracy, the single template, multiple templates and clustering fault templates are used to perform the image matching.

1. Introduction

The running state of fans has a direct impact on the safe and economic operations of a power plant, and the reliability, security and economy of a fan depend on its efficient operation, real-time status tracking evaluation, accurate diagnosis and repair. Thus it is of great significance to carry out fault diagnostic research of fans and enhance the capability of running state diagnosis during the operation of a fan.

Vibration signals generated during rotation of a fan are closely related to the type, extent and location of the mechanical failure of the fan, and contain a wealth of equipment state information. Fan diagnosis based on vibration signals has the advantages of convenient detection, wide applicability, non-contact measurement and multidimensional measurement, and has become one of the most widely used methods for fan fault monitoring and diagnosis. It is necessary to analyze the signals after sufficient vibration signals are collected. General signal analysis methods are primarily performed in the time domain, frequency domain or time–frequency domain. However, due to fan's non-stationary characteristic, the signal of interest is usually at a low magnitude compared to the background noise; therefore, general signal analysis methods have limitations in vibration-signal-based fan diagnosis. For example, the frequency domain analysis of Fast Fourier Transform is not suitable for the treatment of non-stationary signals [1], due to its low resolution ration. The time–frequency domain analysis of Wavelet Transform may lose the information contained in the high-frequency section [2]. The Wavelet Packet Transform can divide the frequency band into multiple levels and further decompose the high frequency part [3], but the signal should be denoised first, which makes the real-time fault diagnosis difficult.

As a new signal processing method, the symmetrized dot pattern (SDP) analysis can fully describe the characteristic of a signal and express it in visual graphics. The technique is particularly effectively compared with other techniques when the

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signal of interest has a low magnitude compared to the background noise [4]. The technique was first conceived for the visual characterization of speech waveform [5–7]. Recently, researchers developed the SDP-based technique through the reconstruction of SDP images from hydrodynamic pressure signals and proved the use of pressure signal visualization to be effective in the early stall-warning of fans [8,9]. Moreover, Yang et al. [10] noted that applying SDP can identify the differences between the sound signals generated by normal and faulty engines to realize the diagnosis of abnormal sounds. The SDP technique is utilized to analyze the vibration signals in this paper, and the SDP pattern templates of each running state are established. Finally, the image matching technique is used to diagnose the faults.

The remaining sections of this paper are organized as follows. Section 2 introduces the experimental setup for simulating fan mechanical failures. Section 3 gives a brief overview for the mathematical framework of the SDP technique, depicts the SDP patterns of fan vibration signals and analyzes the differences between them. Section 4 describes the image matching method. Section 5 is the focus of this article, presenting the application of the SDP analysis and image matching in fan mechanical fault diagnosis. Concluding remarks based on the results constitute the contents of Section 6.

2. Experimental measurement of fan vibration signal during different operation states

2.1. Fan description

Different mechanical vibration measurement experiments were conducted on a centrifugal fan test rig (model number: 4-73 No. 8D) at the North China Electric Power University. This type of fan has been widely used in the domestic power plants of China, and is relatively easy to meet the similarity law in the operation. Thus, the experimental simulation of the mechanical fault characteristics of this fan is of high potential and industrial significance for practical applications in many power plants. The experimental fan structure is shown in Fig. 1. The impeller includes 12 wing type blades, a cone curved front disc and a flat rear disc. The casing is welded by ordinary steel plate. The convergent and streamlined collector is bolted to the inlet side of the fan. The axial guide vane is installed in front of the air inlet, being used to adjusting the flow (adjustment range: 0°–90°). Inlet and outlet pipelines are connected to the fan, and a signal conditioning unit is connected with a computer. The motor model is Y180L-4 and the rated power is 22 kW. The frequency converter is used to adjust the rotational speed and the precision is 0.3 rotations.

2.2. Signal measurement and acquisition system

With excellent low frequency characteristics, high sensitivity, simple structure, strong anti-interference ability, an eddy current displacement sensor (IN-81, Schenck, Germany) is selected to measure the vibration signal. It is mainly composed of eddy current probe, preamplifier and extension cable. Its sensitivity is 8 mV/μm, displacement measurement range is 0–1.5 mm and operating frequency range is 0–10 kHz. Five eddy current sensors were mounted on both sides of the fan bearing, which non-contact measured the horizontal direction, vertical direction and axial vibration displacement signal of the bearing. The distribution of the mechanical vibration measuring points is shown in Fig. 2. Using the non-contact measurement, the eddy current sensors were fixed on a specially machined vibration sensor holder through the threaded connection. The sensor mounting bracket was fixed on the basic rail with bolt. The mounting positions of the sensors have

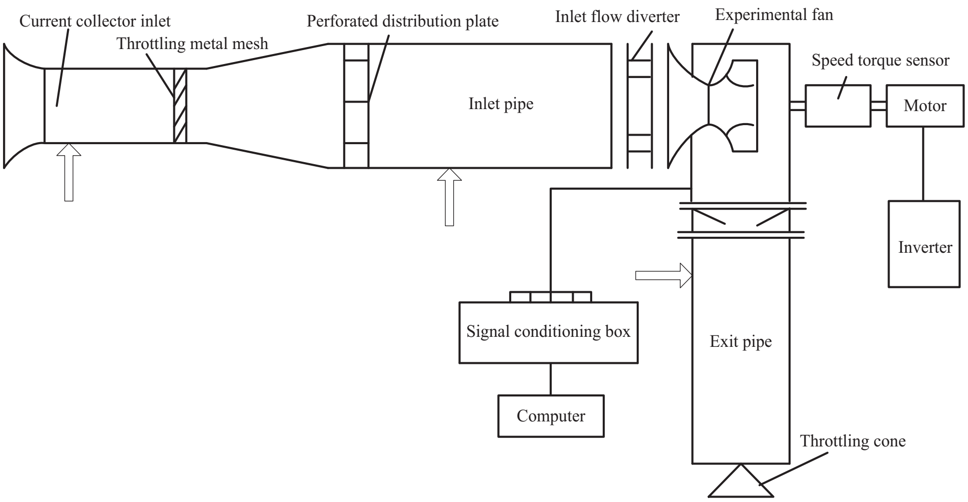

Fig. 1. Experimental fan structure.