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Method and experiment of Temperature Collaborative Monitoring based on Characteristic Points for tilting pad bearings

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ABSTRACT

High power rotating machinery require bearings that can perform under extreme conditions. Tilting pad bearing temperatures exceeding their design limits may cause unit downtime or failure. Through the analysis of tilting pad bearing lubrication characteristics, including temperature distribution and oil film pressure distribution, supplemented by a minimum oil film thickness analysis, a method named Temperature Collaborative Monitoring based on Characteristic Points is proposed. Using factory unit test bench, the geometric characteristics and the operational characteristics of the tilting pad bearing unit are analyzed. A reasonable arrangement of the bearing temperature measurement points is presented. A large amount of temperature data for the main-pad and vice-pad are obtained. Experimental results verify the feasibility of the proposed measurement method.

1. Introduction

Generating units including turbo-generators, hydroelectric generating units, nuclear power generating units, and other energy facilities are typically high-power rotating machinery. Sliding bearings used in these units are one of the most important components in maintaining normal operation of the rotating machinery. During the development of generating units, there have been many major accidents caused by journal bearing failure. Accidents have happened in units such as the USA Arizona power station in 1956 [1], the Pittsburgh power station and Japan's Hainan 600 MW power plant in 1972 [2], and the USA PSI company 475 MW unit [3], which resulted in large damage. Survey results indicated that these accidents were closely related to the failure of sliding bearing. With the development of high-parameter, high-power, and flexible direction units, bearing performance should receive more attention. The tilting pad journal bearing is an important kind of bearing used in several units that is better than other journal bearings. Many theoretical studies have been conducted on modeling [4–10], parameter identification [11,12], special structures [13–16], and bearing-rotor systems [8,17]. Experimental studies on the same were also carried out [16,18–20]. It is worth noting that a kind of active tilting pad bearing [21,22] was studied in the past several years. Due to the advantage of being more stable, tilting pad bearings have been widely used in energy equipment.

The temperature of the tilting pad bearings exceeding their design limit is the main reason for bearing failure. This problem occurs frequently in steam turbines and has a significant influence on the safety and economy of the unit. The bearing pad temperature directly affects the normal operation of rotating machinery. There are many factors influencing the temperature of the pad directly or indirectly, such as unit oil inlet temperature, shaft alignment, unit inlet mode, bearing installation, bearing lubricating oil, cooling system effectiveness, thermal design, and improper thermal transformation. One reference [23] reported a unit that could not be accelerated due to bad oil jacking, oil leakage, and severe rotor wear. Thus, in-depth theoretical analyses and temperature monitoring tests for sliding bearings are warranted. For theoretical analyses, the finite element method is commonly used to analyze the temperature field of the bearing [9,10,24–26]. For temperature monitoring, previous studies [19,20] determined the temperature distribution in the bearing through experimentation. There are certain theoretical and experimental studies for general tilting pad bearings. However, experimental data of big journal bearings with a diameter of larger than 800 mm are very rare for industrial applications.

This paper presents Temperature Collaborative Monitoring based on Characteristic Points (TCMCP) for tilting pad bearings. An applica-

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tion case is given which can provide the basis for the design and installation of similar bearings in the future through comparisons between the experimental results and the theoretical calculation data.

The structure of this paper is as follows. The principle of temperature collaborative monitoring based on characteristic points is described in Section 2. Section 3 concentrates on the experiment details and data processing. Finally, a brief conclusion is given in Section 4.

2. Temperature Collaborative Monitoring based on Characteristic Points (TCMCP)

2.1. Principle

The TCMCP method is based on a deep understanding of the lubrication performance of tilting pad bearings. Three factors should be considered to establish the theoretical model of a tilting pad bearing: 1) For compressible fluid lubrication, it must satisfy the Reynolds equation in steady flow for oil film bearing loads; 2) As the non-compressible lubricating medium, the lubricating oil film energy equation is combined without considering the influence of the heat radiation of the premise; and 3) The viscosity temperature equation is adapted considering the change in temperature with the viscosity of the bearing lubrication medium. Through the numerical solution of the theoretical model, the temperature distribution can be obtained.

In this paper, a kind of three-tilting-pad bearing is taken as the research object, as shown in Fig. 1. There is a pivot-pad, a main-pad, and a vice-pad in the bearing. The pivot-pad is supported by an elastic fulcrum element which exerts a downward reaction force on the journal by adjusting the floating amount of the elastic support. The main-pad and vice-pad are load-sustained pads with different loads. The detailed parameters of the bearing can be found in Table 1.

The simulation of the temperature field is given and the obtained characteristic data are analyzed to provide a theoretical basis for the establishment of the test method. The measurement flow is displayed in Fig. 2.

The temperature distribution on the surface pad of the test bearing as obtained through numerical calculation is presented in Fig. 3.

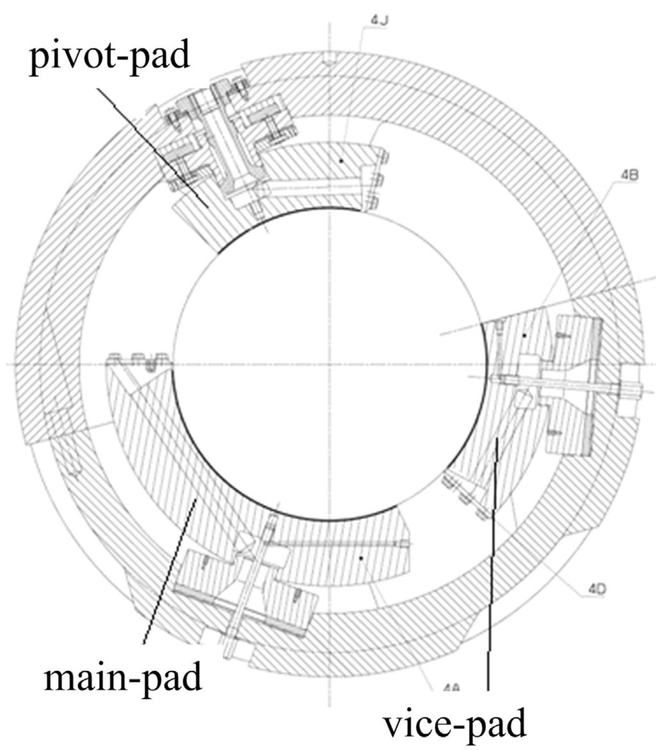

Fig. 1. Overall structure of the bearing.

Table 1
Geometrical and working parameters of test bearings.

Geometrical parameters		Working parameters	
diameter/mm	800	lubrication oil	VG46#
width/mm	510	work speed/rpm	1500
radial thickness/mm	170	inlet temperature/°C	45
pad number	3	inlet L/min	702
Clearance ratio	0.0015	Load/T	110/135

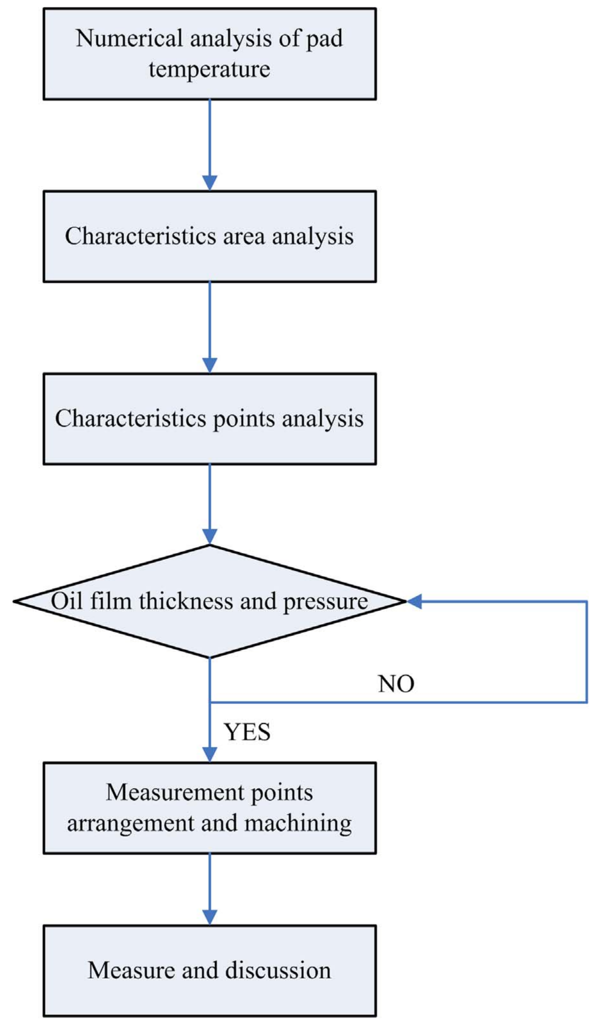

Fig. 2. Flow chart of measurement.

Fig. 3(a) and (b) show the temperature distribution of the main-pad and vice-pad, respectively. Numerical analysis shows that the highest main-pad temperature is 100 °C for the same area of minimum film thickness. The inlet oil temperature of the vice-pad is higher than that of the rest of the pad. The temperature rise in the vicinity of the inlet is also slightly higher, but still smaller than that of the main pad.

Through the analysis, the necessary arrangement of temperature measurement points can be determined: 1) more measuring points should be arranged near the outlet oil pad edge where the temperature may exceed the limit; 2) the temperature measurement points should be as close as possible to the mid-plane to make the measured data be approximate to the actual values; and 3) the pivot position is a special position where more measuring points should be located.

Simultaneously, in order to avoid the influence of the measuring points on normal operation of the bearing, it is necessary to check the position of each measuring point against the oil film pressure distribution and the minimum oil film thickness. Therefore, the numerical