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Experimental study on influencing factors of axial clearance for scroll compressor

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ABSTRACT

An experimental system of non-contact measurement has been established for a scroll compressor to analyze the influencing factors of axial clearance. Experimental method and installation for eddy current displacement sensors have been introduced in detail based on technical analysis. The output voltage input into a computer through analog oscilloscope is recorded by oscilloscope software. The axial clearance is calculated according to the relationship between the output voltage and displacement. The axial clearance is discussed under the influence of different rotary speed, temperature and position. The results show that the experimental schemes are reasonable to realize the detection of the dynamic axial clearance. Temperature and rotary speed are inversely proportional to the axial clearance. The effect of rotary speed on the axial clearance is more noticeable than that of the temperature. The axial clearance along the spread angle of scroll profiles is obviously fluctuating under the action of overturning moment.

Une étude expérimentale sur les facteurs influençant le jeu axial pour un compresseur à spirale

Mots clés : Compresseur à spirale ; Jeu axial ; Capteur du déplacement par courants tourbillonnaires ; Facteurs influents

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Nomenclature

X	displacement, mm
x_1	displacement obtained by sensor, mm
x_0	displacement between probe and fixed scroll, mm
K	proportionality coefficient
$U(X)$	output voltage with displacement X, v
$U(x_1)$	output voltage with displacement x_1, v
x	axial clearance, mm

1. Introduction

The scroll compressor has the advantages of compact structure, high efficiency, high reliability, low vibration, low cost, etc. It has been widely used in industries (Byrne et al., 2014), especially in gas compression and delivery, air conditioning and refrigeration (Blunier et al., 2009). It has been known that the sealing clearance has an important effect on the performance and reliability of the scroll compressor. The sealing clearance is influenced by many factors, such as axial gas force imbalance, contact friction and wear of the scroll teeth, thermal deformation caused by temperature loads, etc. The leak from the sealing clearance causes the reduction of exhaust volume and volume efficiency.

An increasing number of researchers give close attention to study on the sealing clearance. As for the theoretical researches, mathematical models of fluid flow inside the sealing clearance were established on the basis of thermodynamics and fluid mechanics. It was hard to verify the results obtained by finite-element analysis. Jianguo and Wen (2013) analyzed the heat transfer of orbiting scroll wrap based on solving the numerical temperature model. Rak (2013) evaluated numerical fluid mechanics and thermodynamics modeling procedure with a mesh deformation. Chen and Wang (2009) conducted the discussion on the leaking characters and analyzed the leakage and related factors in meso-scroll compressor.

The axial and radial clearances in the scroll compressor are usually considered to be a constant value. The leakage calculated using simulation models is imprecise because of the simplified analyses and assumed conditions. Kimata (2008) studied the clearances' optimization and the gas leakage reduced method for a new scroll compressor with 3D scroll. Li et al. (2006) introduced the material and structure of sealing element to prevent the leakage through axial clearance. Tang et al. (2011) proposed an axial-compliant mechanism to solve the leakage and control the leakage by keeping optimum clearance. In the experimental study, the researchers measured the axial clearance with the help of eddy current displacement sensor for the water-lubricated scroll air compressor. Yang et al. (2008b) designed an experimental procedure to measure the dynamic axial clearance in a scroll compressor by using an eddy current displacement sensor. The value of axial clearance was 75 μm and 49 μm at low and high speed, respectively.

According to the previous results, the researches concern with how to obtain the authentic value of axial clearance. Experimental study of axial clearance is relatively less. The researchers didn't analyzed the experimental study on the influencing factors of axial clearance. And that the axial clearance of different position was unknown. This paper introduces an experimental solution to analyze the influencing factors of axial clearance for scroll compressor. The factors consist of rotary speed of compressor, operating temperature and measuring position.

2. Experimental

2.1. Technical analysis

The axial clearance is determined by the structure of the scroll compressor. The original axial clearance between the fixed and orbiting scroll was measured by measuring tools when the compressor was not in operation. Tolerances of scroll plates were illustrated in Fig. 1.

Tolerances consisted of straightness, perpendicularity, planeness and parallelism, etc. As for the fixed and orbiting scroll, the tolerance of parallelism between top and bottom of scroll tooth was 0.01 and 0.005, respectively. That of perpendicularity between top and side of the scroll tooth was 0.01 and 0.005, respectively. The straightness of the bottom and side of the scroll tooth was 0.005.

The tooth height was 45 mm. However, the dimensional tolerance was different from each other. The upper and lower limit of dimensional tolerance for the fixed scroll was +0.015 mm and 0 mm, respectively. While those of the orbiting scroll were +0.005 mm and −0.013 mm. Thus, the maximum of axial clearance was 28 μm. The leakage was caused by the pressure difference between adjacent compression chambers.

As for the scroll compressor in the work process, there are several technical problems for experimental study on axial clearance. Firstly, the detection process is difficult because of the dynamic position of compression cavity. Secondly, it is necessary to choose an appropriate sensor to realize the clearance experiments. On the one hand, the top of scroll teeth and bottom of the fixed scroll will contact with each other directly under the action of the axial gas force or overturning moment. On the other hand, the axial clearance of a certain location inside the scroll compressor chamber changes rapidly as for the high rotary speed. The sampling frequency of the sensor used for experiments should accord with the changing frequency of axial clearance. Thirdly, the experimental datum should be recorded by the data acquisition system because they showed on the indicator can't be observed with the naked eye.

Thus, the measurement of axial clearance can be measured using non-contact measuring method and high speed data acquisition system. The variation of axial clearance can be obtained under different conditions by means of an eddy current displacement sensor. The feasibility of detecting and recording the axial clearance will also be discussed.

2.2. Experimental system

The experimental system includes a compressor system and data acquisition system, as described in Fig. 2.