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Performance Analysis of Rotating Shaft of Air Compressor for Hydrogen Battery

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Abstract: The rotating shaft is the key component of the air compressor connecting the bearing seat and turbine disk for hydrogen battery, and its working reliability affects the safety of the air compressor.The rotating shaft is the key component of the air compressor for hydrogen energy battery connecting the bearing seat and turbine disk, and its working reliability affects the safety and life of the air compressor. The performance analysis and comparison of the typical structure of the rotating shaft of an air compressor are carried out, which provides experimental data for the vibration of an air compressor and lays a theoretical foundation for the relevant design of enterprises.

Keywords: Hydrogen energy battery; Air compressor; Performance analysis

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1. Introduction

The air compressor for hydrogen battery car is the gas supply component of fuel cell, and the rotating shaft is the core structure of the air compressor, so it must have enough strength, and the influence of resonance at critical speed on the air compressor should be avoided. Han Yongjie et al. found that the hydrogen battery system with centrifugal air compressor has higher working efficiency and better air humidification performance. Ren Tianming et al. optimized the rotor design of air compressor, which greatly increased the critical speed of air compressor and reduced the rotor loss.[1]

2. Air compressor for hydrogen battery

As the "lung" of hydrogen energy battery, air compressor is composed of rotor shaft, stator, turbine, volute, etc. It is the core component of hydrogen energy battery and transports clean air with rated parameters for the stack. Typical air compressors include twin-screw type,[2] Roots type and centrifugal type. Centrifugal air compressors are widely used because of their high efficiency, small volume, oil-free and low noise.[3]

Centrifugal air compressor uses impeller to rotate gas, and realizes the transformation of energy form under the action of speed reduction, pressure expa

Using software to create a three-dimensional model of the airnsion and centrifugal pressure increase. The rotor directly drives the turbine to rotate at high speed, and the diffuser pressurizes the gas and outputs it. Therefore, the strength reliability and structural stability of air compressor shaft play an important role in air compressor.

3. Performance analysis of rotating shaft

Compressor shaft, on the premise of ensuring the dynamic characteristics of the structure and the accuracy of the results, the characteristics of the rotor system such as holes and rounded corners are simplified, which can speed up the calculation cycle and reduce the complexity of this research.

3.1 Overview of theoretical basis of analysis

Modal analysis, as an important basic part of dynamic analysis, usually uses finite element method to analyze the natural frequency. The method of obtaining vibration frequency by modal analysis usually consists of two parts, namely experimental modal analysis and computational modal analysis. Experiment is a modal experiment method that uses experimental research and instruments to collect and identify parameters. In this paper, the finite element analysis method will be used for modal analysis, that is, the computer will be used for modal analysis of the rotating shaft. Modal analysis can be divided into free modal analysis and constrained modal analysis, which will be analyzed in this paper.

3.2 Performance analysis of rotating shaft

The structural performance of the rotating shaft is analyzed by finite element method, and the natural frequency is calculated and analyzed. The format of 3D model is converted and imported into Hypermesh, and the speed axis of air compressor is meshed. The speed axis is divided into 17,114 units, and 40Cr profile is adopted. The free state performance of the finite element model of the rotating shaft is analyzed, and the sixth-order natural frequency of the rotating shaft of the air compressor is obtained in the following table.

Order	Frequency	Ultimate Stress
First	2084	255.7

Second	2103	258.2
Third	2583	284.7
Fourth	2629	287.1
Fifth	5197	233.0
Sixth	5253	233.9

It can be seen from the table that when the frequency of the air compressor shaft is 2084-5253Hz, the maximum stress is almost the same at different frequencies, and the air compressor shaft has no obvious deformation and stable structure.

3.3 Performance analysis of rotating shaft of air compressor with turbine

On the basis of the designed three-dimensional model of the rotating shaft, add a matching turbine, establish a three-dimensional CAD model, convert it into a corresponding format file and import it into the software hypermesh in the same way. Similarly, hexahedral grid unit is used as the main unit form to mesh the rotating shaft of air compressor with turbine, and the unit size is set as 10mm. The results show that the speed axis of the turbine is divided into 31897 units, including 9359 nodes. In order to ensure the comparability of the two experiments, the same materials as the first experiment were used.[4]

After adding the model turbine, import the software, divide the rotating shaft with turbine into 31,897 units, adopt 40Cr profile, and then analyze the model with the above method, and get the sixth-order natural frequency of the rotating shaft of the air compressor with turbine as shown in the following table.

Order	Frequency	Ultimate Stress
First	1012	67.8
Second	1015	67.1
Third	1174	74.9
Fourth	1724	83.0
Fifth	1731	82.5
Sixth	1961	49.0

It can be seen from the table that when the frequency of air compressor shaft is 1012-1961Hz, the maximum stress is almost the same at different frequencies, and the maximum stress of air compressor shaft is at the edge of turbine, which accords with the design theory.

4. Summary

Based on the performance analysis of the rotating shaft of the air compressor for hydrogen battery, the conclusion is as follows:

(1) Whether or not the turbine is used has a great influence on the final result of the rotating shaft. If follow-up research and optimization are carried out on the rotating shaft of air compressor, other components such as turbine and connected bearings should be taken into account.

(2) When the working speed of the air compressor for hydrogen battery is 50,000-80,000 rpm, there is partial resonance. Therefore, the air compressor should be prevented from working at this speed for a long time, and its control strategy should be optimized.

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