

Design and Research of High Speed Unbalance Undetection Device for Tiny Impeller

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Abstract—A dynamic balance detection device with high transmission efficiency and expand-ability and a replaceable chuck step shaft as the rotating shaft is designed. It can be applied to the high-speed unbalance detection of micro impellers, which can eliminate transmission errors and prevent rotor turbulence. Reduce the function of supporting friction. Based on the research of impeller dynamic balance detection technology at home and abroad, combined with the theory of dynamic balance and the principle of dynamic balance detection device, a research program dedicated to the detection of micro-impeller dynamic balance is proposed, and the high-speed dynamic balance of small horizontal hard support for micro impeller is completed. The prototyping of the detection device and solving the key problems of the design of the measurement and control module and the data processing of the vibration detection. The dynamic balance test was carried out on a micro impeller with a dynamic balance of $1 \mu\text{m}$, which verified the reliability and operability of the device. It is beneficial to the improvement of the dynamic balance precision of the rotating machine, which lays a foundation for the high-speed dynamic balance correction of the micro-impeller and provides a certain reference for engineering testing.

Keywords—Tiny Impeller; High Speed; Dynamic Balance Detection; Device Design

I. INTRODUCTION

As a widely used rotary machine part, miniature impeller plays an irreplaceable role in the fields of aerospace and chemical industry. Machining errors and uneven materials are the main sources of impellers' dynamic unbalance, which directly cause wear and tear of mechanical devices, increase of working noise and bring great safety risks to operators. With the rapid development of science and technology, rotating machinery tends to be high speed, motors, small impeller structure and speed has been change to adapt to the development needs, in order to ensure the safety operation and application of mechanical parts life, through the dynamic balance technology of prevention of tiny impeller imbalance and in creating more economic benefit and social benefit at the same time to ensure a safe working environment. This paper aims to build an economical, precise and sustainable dynamic balance detection device for micro impeller with

high speed rotation to provide a basis for dynamic balance correction.

In this paper, the micro-impeller is taken as the detection object to design PLC as the main controller of the experimental platform, STM32 data acquisition and development board as the high-speed data acquisition device, and MATLAB as the modular integration device of vibration characteristic quantity extraction platform, so as to realize the measurement of dynamic unbalance of high-speed rotating micro-impeller.

II. WORKING PRINCIPLE AND FUNCTIONAL DESIGN OF DYNAMIC BALANCE DETECTION DEVICE

According to the actual requirements of dynamic balance detection, it can be concluded that the operation process is that the operator USES PC and lower computer devices to exchange information according to the preset process. Firstly, the controller starts the mechanical device and drives the impeller to rotate at a stable working speed. Then, the detection device is started to pick up the high-speed vibration signal and transmit it to the computer. Finally, the collected signals are imported into MATLAB data processing platform for processing and calculation. The working process of dynamic balance testing is shown in figure 1.

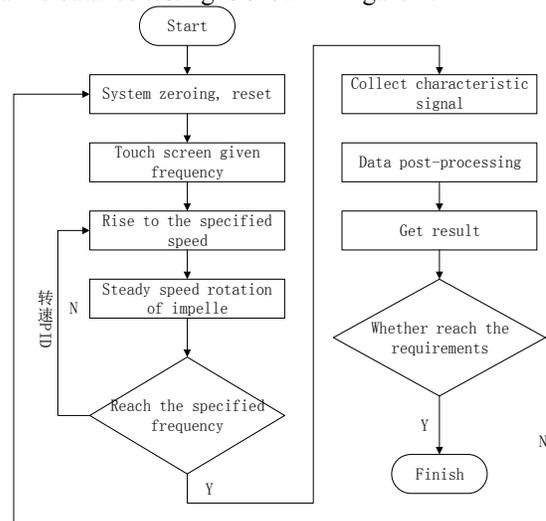


Figure 1. Flow chart of dynamic balance test

According to the process of the system in order to realize the function of the summary is as follows:

- 1) Has a boot automatically reset and reset function, keep the original error calibration on the accuracy of the machine.
- 2) Simplify the transmission link between the motor and the rotating shaft, reduce friction, improve the transmission ratio and improve the detection accuracy.
- 3) Highly automated monitoring process, fast response, reduce human error and effectively protect system security.
- 4) Realize follow-up adjustment of rotating speed to ensure the uniqueness of experimental variables.
- 5) Good human-machine interaction interface, enhanced visualization, intuitive and convenient operation.
- 6) The detection device has fast acquisition speed and short signal conversion time, and there is no obvious error in the acquisition and transmission of high-speed vibration signals.
- 7) Reasonable signal processing flow and dynamic balance quantity calculation method, and adopt the representation quantity value applicable to the object to be detected and experimental conditions.

III. DESIGN AND IMPLEMENTATION OF THE SYSTEM

A. Mechanical vibration module design

The basic premise of micro impeller special dynamic balance detection system to realize its own function is to provide suitable vibration platform. Reasonable mechanical vibration platform can reduce the complexity of related system development and technical research. The main function of the machine body in this system is to provide regular and measurable vibration signals for the impeller. Based on the analysis of the mechanism of mechanical vibration and the characteristics of the tested object, it is determined that the ontology is a small horizontal rigid and hard supporting structure, so as to ensure the adaptability and detection accuracy between modules. From rotator general machinery structure analysis to vibration mechanical design requirements, determine the mechanical module by the drive unit, transmission unit and supporting units, including:

- 1) Drive unit mainly complete frequency converter drive set according to speed smooth high speed motorized spindle spinning process, can response fast and convenient and reliable control.
- 2) The transmission unit mainly completes the stable operation of high-speed motorized spindle, which drives the impeller at the experimental speed by directly connecting the rotating shaft. Relevant characteristic quantities are measured by using the rotating shaft part. The structure is stable and reliable, and the intermediate transmission link is omitted to realize 1:1 efficient transmission.
- 3) The supporting unit includes the whole frame, etc., which provides suitable supporting force and convenient and flexible position adjustment mode for each part, and the structure is firm and flexible. The mechanical vibration module design is shown in FIG. 2.

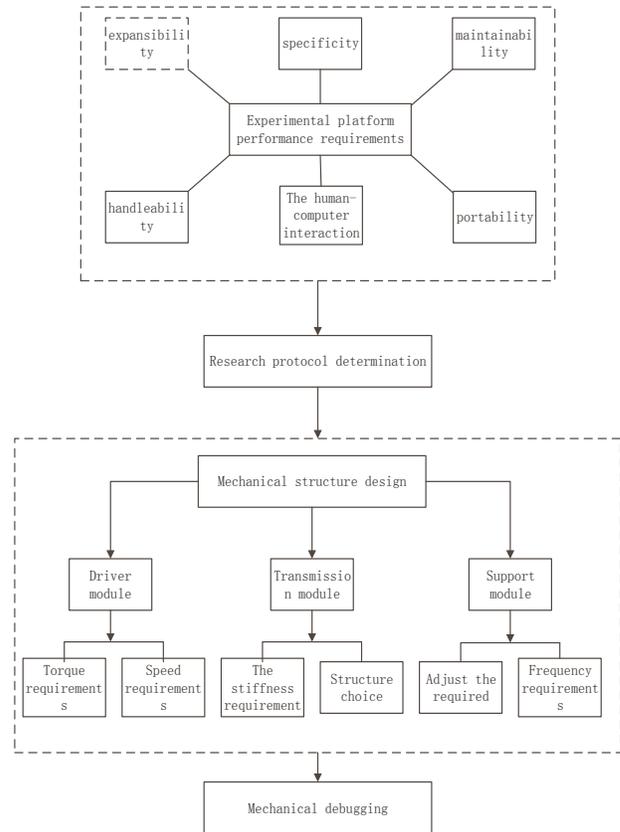


Figure 2. Hierarchical structure design of mechanical vibration feeding module

B. Measurement and control module design

As an intelligent special measuring device, micro impeller special dynamic balance measuring device requires good mechanical structure and safe and reliable measuring and controlling system. The measurement and control module is mainly composed of the control system with PLC as the main controller and the data acquisition system under its control. As the core control device, PLC is mainly used to issue action commands, control the coordinated operation of mechanical devices, human-computer interaction devices and detection devices, and ensure the accuracy of the process and the immediacy of action.

This system is mainly aimed at the detection of the moving balance of high-speed micro impeller. In order to ensure the accuracy of setting sampling period and sampling points, the reference frequency needs to be accurately controlled. Therefore, the system needs to collect and feedback the rotating speed. The amplitude and phase of vibration are the indexes to characterize the unevenness of micro impeller. In conclusion, it can be concluded that the system is used to detect the three characteristic quantities of rotation speed, amplitude and phase.

C. Design of signal processing module

Due to the influence of external and internal factors, the signals obtained during vibration testing of objects by

sensors and data acquisition devices must be doped with unnecessary interference components. In the signal processing process, unnecessary signals should be eliminated to strengthen the signals in the required frequency band, so as to restore the actual vibration information. Firstly, a series of preprocessing is carried out to calibrate the physical units of the data collected from the experiment, so as to ensure the synchronous acquisition of the rotational speed signal and vibration signal. Then the acquired signal is correlated filtered to get the fundamental frequency vibration signal. Finally, the fast Fourier algorithm is added to the formula of amplitude and amplitude conversion to obtain the amplitude and phase of the operating frequency. The vibration signal processing module is mainly composed of software platform, which mainly deals with the vibration signal and the dynamic balance quantity. The module in this system is mainly composed of serial port assistant and MATLAB data processing platform to achieve data transmission and processing. Signal processing module implements the following functions: (1) will be collected in the mixed signal acquisition and maintenance of the computer, as the original data, and to prepare for subsequent signal processing. (2) the required fundamental frequency signal is extracted from the complex mixed signal, and the dynamic unbalance characteristic quantity is calculated.

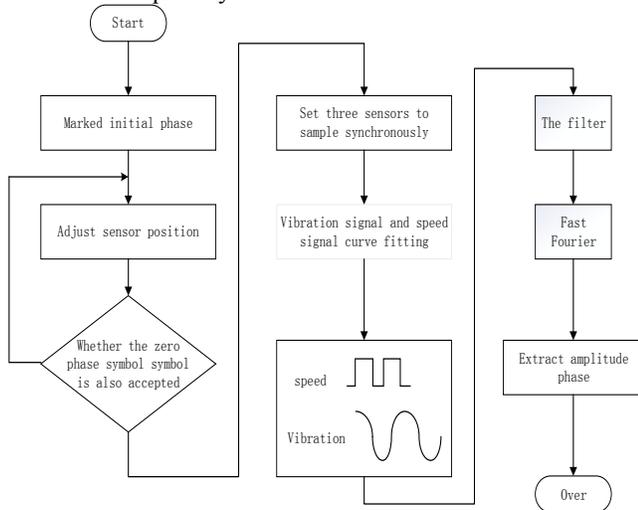


Figure 3. Signal processing flow

IV. COMPONENT SIMULATION ANALYSIS AND DEVICE IMPLEMENTATION

A. Component simulation

The special small impeller dynamic balance testing system to achieve its miniature of high-speed rotating impeller into the function of the dynamic balance test, first of all should provide target for its stable operation of machinery, good mechanical structure for subsequent experiments provide a reliable premise condition, reduce the complexity of the subsequent application development, improve the detection precision of the experiment. The critical speed of target impeller is obtained by finite element analysis, which

determines the overall frame property of the device. Firstly, a 3d model of the target micro impeller is established in UG and saved in x_t format recognized by ANSYS. Then, modal analysis was performed on the impeller in ANSYS workbench16.2, and the material was set as hard aluminum alloy material, free mesh partition was adopted, and the first-order resonance frequency of the impeller was calculated to be 445hz.

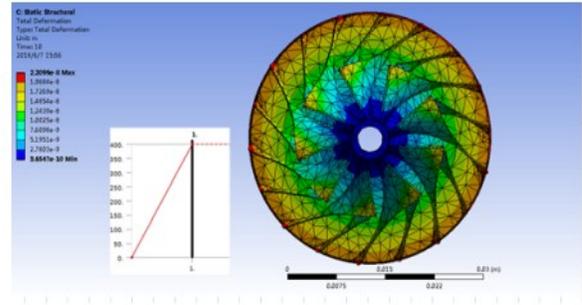


Figure 4. Impeller modal analysis

In order to realize the requirement that the device can detect impeller with different diameters, the rotating shaft needs to be designed to facilitate the replacement of impeller with different diameters. In order to adapt to the impeller structure characteristics, the rotor design for cascade, the trapezoidal short of 6 mm M4 threaded shaft front car, will be small impeller is installed on the trapezoidal short axis, can through the tiny impeller nut fixed position, make its and the location of the short ladder shaft relative static, top chuck connected to optical axis, front end can be stuck different degree of trapezoidal short axis. This short shaft not only facilitates operators to clamp tiny impeller in specific experimental operation, but also reduces the stress and deformation caused by the step shaft during processing, which has flexibility and reliability. The design is shown in FIG. 5, and the critical speed analysis is shown in FIG.6.

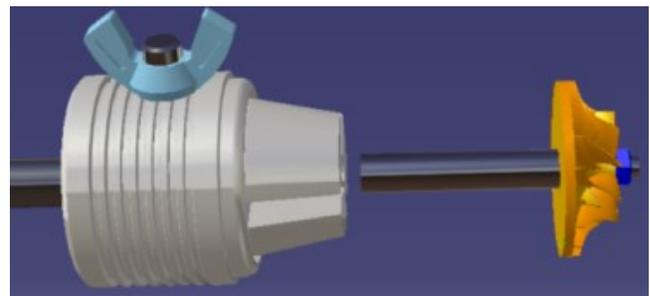


Figure 5. Chuck chuck step shaft design

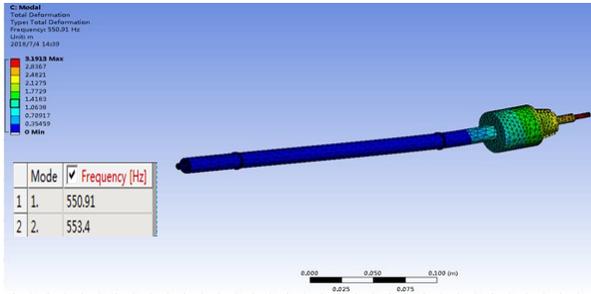


Figure 6. Analysis of the first critical speed of chuck chuck step shaft

B. Analysis of the first critical speed of chuck chuck step shaft

The special dynamic balance testing platform of micro impeller is an experimental tool used to test the vibration performance of micro impeller at working speed. Controlled by computer, vibration amplitude can be extracted to indicate the magnitude of vibration quantity. After continuous trouble-free running test, the performance of the equipment is stable and reliable. The experiment machine is controlled by PLC, with fast response, adjustable running frequency and collection time, and touch screen parameter setting, which makes the operation intuitive and simple. Compact appearance, easy to install and sustainable maintenance and improvement, acrylic protective cover to ensure transparent and safe operation environment, effectively reduce the impact of noise.

As the natural frequency of the body is far greater than the maximum adjustable frequency of the frequency converter, the adjustable frequency range is calibrated according to the high-speed motorized spindle, with the minimum frequency modulation of 60hz and the maximum frequency modulation of 400hz, and the detection rotation frequency range suitable for this device is 60-400hz. Stable operation refers to the time from the machine steady running time, motor startup rose to a specified speed stable operation, after 60 s maximum is determined by bearing thermal state, access to relevant data show that the type of bearing in the, in the absence of any external heat balance measures thermal stability imbalances in continuous run of 90 minutes, so the machine stable operation time of 1-90 min.

V. PLATFORM EXPERIMENTAL VERIFICATION

In order to verify the feasibility of the research route, the target small impeller with known dynamic balance was tested on the platform. An experiment was conducted to detect the moving balance of the target micro impeller at the fundamental frequency of 160HZ. FIG. 7 shows the original vibration signal intercepted from the whole cycle, and FIG. 8 shows the regular fundamental frequency vibration signal after correlation filtering. It can be seen that the device can extract the effective vibration characteristic signal of the miniature impeller at high rotating speed.

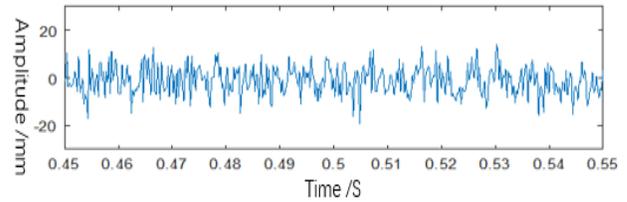


Figure 7. Full cycle interception of the original signal

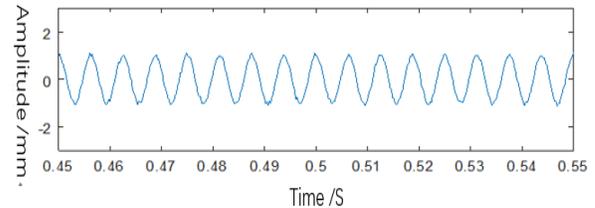


Figure 8. Whole period interception of fundamental frequency vibration signal

The ultimate purpose of dynamic balance test is to detect the unbalance of micro impeller and judge whether the standard parts meet the factory precision requirements. Based on the system standard analysis value, the relative error is obtained by processing and calculating the experimental data. According to table 3, it can be concluded that the precision error of the special dynamic balance detection system is within 5%. According to the ISO 1940-1-2003 requirements for dynamic balancing machines, the detection error for dynamic balance detection devices is allowed to be 5%. It shows that the research scheme is correct, the stability of the whole system is good and the precision is high, which can accurately measure whether the micro impeller dynamic balance reaches the standard.

VI. CONCLUSION

This device can measure the dynamic unbalance of micro impeller rotating at high speed, design and analyze each module of the device, and theoretically verify the rationality of the device design. The testing experiment of micro impeller with known dynamic balance is carried out on the device, and the actual reliability of the device is verified. Compared with the existing dynamic balance detection device, the design structure design is targeted, the implementation cost is lower, has a good practical application prospect.

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