High-speed Balancing Technology and Equipment

高速平衡技术装备（英文版）

Yuewu Wang, Sheping Tian, Xilin Xu et al. Editors

王悦武 田社平 徐锡林 等 编著

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内容提要

本书主要介绍挠性转子的高速平衡技术装备，阐述了挠性转子高速平衡技术的基本概念与原理、高速平衡机及高速平衡、超速试验室的构成及基本设计方法、DG系列高速平衡机产品的技术规格参数等。

本书可供从事高速平衡技术专业的工程技术人员和研究人员参考，也可作为高等院校高年级本科生、研究生及教师的参考用书。

Abstract

This book gives an introduction to the high-speed balancing technology and equipment of flexible rotors, explaining the fundamental concepts and principles, construction and basic design of high-speed balancing machines and overspeed test camber as well as the technical specifications of DG-series high-speed balancing machines. This book is intended for engineering staffs and researchers in the filed of high-speed balancing, as well as senior undergraduates, graduate students and university teachers.

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High-speed balancing technology and equipment

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China's first self-developed 200t high-speed balancing equipment

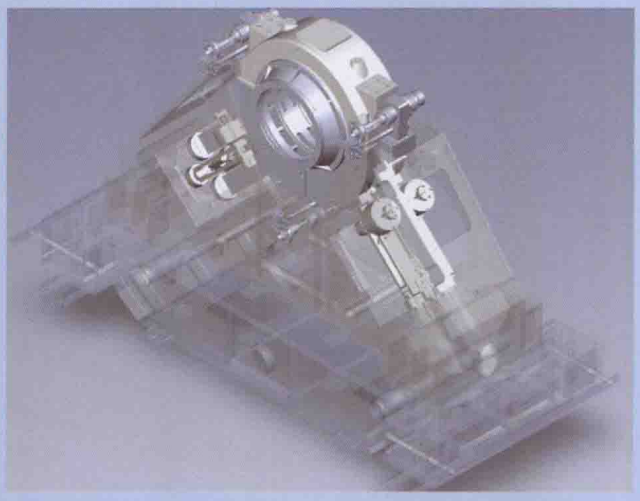
China independently developed the first high-speed balancing equipment in the late 1970s. It has a bearing span of 16m, and is able to balance rotors of 8 to 200 tons, with maximum diameter of 6.1m and maximum axial length of 18m. The speed range is 180 to 3,600rpm, and the highest overspeed can reach up to 4,320rpm. It has been used for high-speed balancing and overspeed testing of large turbine generators, steam turbines and generator rotors and has been playing an important role in the manufacturing of large-scale power plant equipment for almost four decades.

100t high-speed balancing and overspeed test chamber

The test chamber was built in 2008. Its core-the high-speed balancing machine-was designed and manufactured by Shanghai Schiak Testing Machinery Co., Ltd. With strict quality control, the test chamber fully met the design requirements on the first try. The picture above shows a 76t generator rotor being transported by flatcar to the test chamber.

A turbine Rotor waiting for high-speed balancing

The picture shows a large turbine rotor mounted on the flatcar waiting to be moved into the explosion-proof vacuum cylindrical body for high-speed balancing and overspeed test. The rotor and two mechanical supports on both sides were carried by two flat cars into the cylindrical body. After the mechanical supports fell into place with the help of oil cylinders, the flatcars withdrew. When the test finished, the flatcars again moved the supports and the rotor out of the cylindrical body.



The mechanical support of high-speed balancing machine

The mechanical supports not only support the rotor with certain mass for high-speed rotation, but also have to transmit the unbalance vibration signal correctly and reliably to the electrical measuring unit for further processing. So this requirement has to be considered in the design of mechanical supports.

The explosion-proof vacuum cylindrical body

The explosion-proof vacuum cylindrical body is one of the most important parts of the test chamber, exhibiting high strength, air tightness, and capability of explosion-proof and anti-armor-piercing. Fracturing of blades, running away of counterweight blocks, or even breaking and bursting of impellers may occur during the high-speed balancing or overspeed test of rotors. To reduce the friction power of the rotors with blades or with multi-stage pump at high speed, the high-speed balancing or overspeed test must be carried out under vacuum condition.

The central control monitoring room

The central control monitoring system consists of the unbalance measurement system, drive control system, auxiliary measurement monitoring system, etc. The operators can operate and control the system devices and launch unbalance measurement directly from the control room.




The computer numerical control machining centers

To seek greater development of enterprise, Shanghai Schiak Testing Machinery Co., Ltd. has prioritized the development of Large Intelligent High-speed Balancing Machines. The company invested tens of millions of RMBs for plant relocation and renovation, additions of large digital machining centers and high precision measuring instruments to meet the needs of processing, assembling, debugging and precision testing of the major components of high-speed balancing machines such as the mechanical support. The pictures show the workers are machining the mechanical supports.

The quasi high-speed balancing machine installation site

The quasi high-speed balancing machine is a new type of high-speed balancing machine which is suitable for high-speed balancing and overspeed test of flexible rotor with low tonnage. This machine uses roller/bearing support, featuring convenient installation and maintenance, reliable operation and low manufacturing cost.

4.5t high-speed balancing and overspeed test chamber

Shanghai Schiak Testing Machinery Co., Ltd. has invested huge amounts of capital to build the 4.5t high-speed balancing test chamber. The chamber is equipped with signal measurement and analysis system with central control, split-screen display, to achieve video automatic control. It is used for high-speed balancing and overspeed test of flexible rotors with masses below 4.5t (maximum speed of 8,000r/min), test and research of rotor dynamics.

创高速平衡技术之基

立民族工业装备之本

Foreword

With the development of science and technology, rotating machinery becomes increasingly large-scale and high-speed. The operating speed of large-scale machinery, such as turbine generator, and high-speed turbines is mostly close to or exceeds its flexural critical speed so that the rotor exhibits characteristics of flexible rotors. Such rotors must be balanced at high-speed before delivery, so high-speed balancing equipment has become vital in such balancing, and ensures the stable, reliable and safe operation of the high-speed rotating machinery. Modern high-speed balancing technology and equipment involve mechanics, hydraulics, electronics, sensors, computers and many other technical fields, and stand at the cutting edge of the manufacturing industry. In the 1970s, China successfully designed and built its first 200t large-scale high-speed balancing machine independently, and became one of the few countries with the capacity to design and build such machines. This machine has become a critical tool for Shanghai Turbine Co. , Ltd. to test the rotors of steam and gas turbines and is still in service today.

Innovation and reform are the only way for Shanghai to further its scientific and technical development. How would the innovation drive reform? I would say that reflection and innovation will change the mode of high investment in equipment and plant into a mode relying on technical progress and workers' knowledge. As the only manufacturer of highs-speed balancing machine in China, Shanghai Schiak Testing Machinery Co. , Ltd. has shipped multiple sets of high-speed balancing equipment in recent years. I think it is very commendable that apart from daily research and development work, the company's core team of experts, professors and technicians could take the efforts to summarize their experience into this book.

This book is not only a summary of high-speed balancing technology and

its equipment, but also a valuable contribution to the revitalization of China's industry.

Dinan Huang
CEO of Shanghai Electric (Group) Corporation
May, 2013

Preface

Rotor balancing technology has a unique position in equipment manufacturing industry of the national economy. All rotating machinery, from precision gyro navigator to ordinary wheels of traffic vehicles, from turbine rotors weighing hundreds of tons to light meter rotor with a few grams, and even micro-electromechanical rotor components, from the satellites rotating just a few revolutions per minute to the machine tool main shafts rotating hundreds of thousands per minute, the performance of the rotors is closely related to the quality of balance. Statistics show that the rotor dynamic unbalance is one of main causes of vibration and noise, reducing equipment life and reliability and constraining product quality and performance. Unbalance reduction is a fundamental problem in the process of production, manufacturing and application of the rotating electromechanical products. High-speed balancing technology is a high technology in balancing technologies and provides a guarantee for operation safety and reliability of high-speed rotating machinery. At present, high-speed balancing test has become a routine process for flexible rotors such as steam turbine, generator, turbine compressors and other large rotating machinery. It can be said that high-speed balancing technology plays an important role in reducing the unit vibration and noise, improving the unit working speed and working conditions, ensuring normal and safe operation of units and extending life cycle of rotating machineries.

Compared with low-speed balancing technology, high-speed balancing technology is mainly used in balancing correction and overspeed test of large flexible rotors. As the main process equipment for high-speed balancing, high-speed balancing machines have not only the functions of low-speed balancing machines, but also those of high-speed balancing test, overspeed test and rotor dynamics research and testing. The principle, structure and performance of high-speed balancing machines have special requirements. With the development of engineering

technologies, especially computer technologies, balancing technologies including high-speed balancing technology are always evolving dynamically. For example, the circuit technology and computer technology have changed the display mode of electrical measuring unit of balancing machines from the early mechanical measurement (mechanical gauge and phase meter), electronic measurement (electronic amplifier, filter etc.), to micro-controller (embedded system) based electrical measurements. In addition, the digital signal processing technology has also greatly enriched the high-speed balancing technology. The electrical measuring units of modern high-speed balancing machines are no longer simply to measure the unbalance, but also have a wealth of data processing and analysis functions.

At the same time, in order to ensure rotation of the rotor in a state of high security during the test, reduce or eliminate the resistance of air to correctly balancing flexible rotors, the process of high-speed balancing and overspeed test are usually carried out in high-speed balancing and overspeed test chamber. The chamber is usually a separate building structure, which is composed of driving system, explosion-proof vacuum cylinder, gates, vacuum pump room, oil lubrication system, control room, auxiliary room, etc. to ensure smooth and safe running of high-speed rotors and direct monitoring of the system operations.

China had developed the first set of high-speed balancing machine independently which was equipped in a steam turbine plant since the early 1980s. Up to now, many enterprises have equipped high-speed balancing machines with different tonnage to meet the demand of large-scale rotating machinery balancing. Nevertheless, few literatures about high-speed balancing technology and equipment could be found. The aim of this book is to summarize and popularize the high-speed balancing technology.

High-speed balancing technology involves a variety of techniques. We try to give a comprehensive introduction to the principle of high-speed balancing, design of high-speed balancing machines, composition of the high-speed balancing and overspeed test chamber from a system point of view. We also try to allow the readers to have an overall, global understanding on the latest trends of high-speed balancing technology.

This book is divided into five chapters. The chapters are outlined as follows:

Chapter one which is authored by Xilin Xu gives a brief description of the

basic concept of high-speed balancing technology. Chapter two which is authored by Xilin Xu and Sheping Tian discusses high-speed balancing of flexible rotors. Chapter three which is authored by Yuewu Wang and Sheping Tian describes the machinery of high-speed balancing machines. Chapter four which is authored by Sheping Tian, Jue Yang and Xiaojue Lin presents design of electrical measuring unit. Chapter five which is authored by Yuewu Wang introduces the composition and basic design principles of high-speed balancing and overspeed test chamber. The appendixes which are authored by Zhiqing Zhao and Lin Qin give the technical data sheet of DG and HY-VG Series High-speed Balancing Machines and an introduction to Shanghai Schiak Testing Machinery Co., Ltd.

This book is not possible without the work of many individuals. The authors would like to acknowledge Mr. Kexiong Fan, chairman and general manager of Shanghai Schiak Testing Machinery Co., Ltd. He proposed this writing program and gave financial assistance for publication. The authors also acknowledge Mr. Zhiyan Zhou, former chairman of Shanghai Schiak Testing Machinery Co., and Mr. Weiming Fan, vice president of The Second Industrial Engineering Design & Research Institute, China United Engineering Corporation. Further thanks go to technical staff of Shanghai Schiak Testing Machinery Co., Ltd. and colleges of Department of Instrument Science and Engineering, Shanghai Jiao Tong University.

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