A framework of prototype compressor impeller auto-test system

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Abstract—This paper presents a framework of prototype compressor impeller auto-test system. Two type performance test can be held in a unique pipeline layout. Work conditions are accurately under control. Status data is acquired synchronously and precisely. Performance evaluation is accomplished efficient. This framework is proved to be highly available to improve traditional manual test method.

I. INTRODUCTION

Compressors are critical equipments in many industries. The performance of the impeller, which is the core component of a compressor, directly infects the performance of the entire compressor. Therefore testing a prototype impeller plays an important role in the compressor industry.

The traditional manual test method is a time-consuming job and the accuracy of test results depends on the skill and experience of the operation crew. In this paper, we present a framework of building an automatic test system to accomplish the test.

Structure of the auto-test system is introduced in Part II. Part III shows a test flow and differences form the traditional manual test flow. As a conclusion Part IV summarizes the advantages of employing the auto-test system and presents further plans to improve this system.

II. SYSTEM STRUCTURE

The basic theory of the prototype impeller performance test is as follows: The impeller is installed in a single level compressor. When the test begins the rotation speed of the compressor is set to the designed rotation speed of the impeller. By changing the area of the compressor outlet section the work condition of the compressor is under control. The test system records status data of the compressor under different work conditions. By calculating the characteristic curve through that data and comparing the curve with the designed parameters, the performance of the impeller can be effectively evaluated \cite{1} \cite{2}.

Fig.1 shows the general structure of the system. A field data acquisition (DAQ) device collects status data of the compressor. A field controller handles the mechanical part of the system. A control room host processes status data, manages the test flow, and calculates the characteristic parameters of the under-test impeller. A main network charges the communication between devices which are presented above.

![Diagram of the system](image)

Figure 1. The general structure of the system
A. Pipeline layout

Conduit pipes are built surrounding the compressor as shown in Fig.2. In order to measure the flow of the gas running into the compressor, a throttle device is set before the inlet of the compressor. Valve #2 is installed after the outlet of compressor. By adjusting the opening of the valve the pressure of the gas running out from the compressor can be changed, as a result of which the work condition of the compressor is completely under control.

Two types of test is involved: open loop test and close loop test. Some of the valves are used to organize the pipeline for the very type. By opening valve #1, #3 and shutting valve #4, #6, the pipeline is then set to an open loop. On the contrary, opening valve #4, #6 as well as shutting valve #1, #3 could form a close loop pipeline.

When the impeller is under a close loop test, in order to ensure the stability of the compressor in every work condition, the pressure and temperature at the inlet of the compressor should maintain proper values. Valve #5 in the pipes is used to hold the access of the gas from the gas bottle. Valve #3 is used to release the gas from the pipeline. By controlling these two valves the stability of the pressure at the inlet is then guaranteed. In the close loop pipeline, a cooler is used to cool down the gas that runs from the outlet of the compressor. Valve #7 and #8 control the flow of the water in the cooler, which means the temperature of gas in the pipeline is also under control.

B. Field data acquisition

All pressure and temperature data which is necessary to calculate the performance parameters of the prototype impeller is generally acquired from the inlet and outlet of the compressor and differential pressure between the gas running in and out the throttling device as shown in Fig.3. By inserting probes into the pipe and connecting them to pressure transmitters with thin tubes, the pressure data is output as electric signals. Data of temperature is acquired by thermal couples. A NI PXI-SCXI combo [3] chassis with a real-time controller and DAQ devices is employed to collect signals from all instruments and sensors. Signals from the pressure transmitters are directly connected to PXI DAQ devices. Through a cold-end compensator which is used to avoid the
interference of ambient and a SCXI signal conditioning module, signals from the thermal couples are gathered by PXI DAQ devices as well.

In order to reduce the load of the main network, data from the field is preprocessed before transferring to the control room host.

C. Wireless data acquisition

There are some sorts of problems when setting sensor and acquiring data. Wiring problem is one of them. When it is hard to connect the sensors to the DAQ device, wireless transmitting through WIA-PA protocol is then employed. WIA-PA is an industrial wireless communication standard which is data-stable and suitable for realtime applications [4]. Sensors are connected to a wireless node which provides function of pre-process. Then data from wireless nodes are received by a WIA-PA gateway. The gateway directly communicates with control room host in the main network.

D. Field controller

A NI CompactRIO [5] device is employed as the field controller in the auto-test system.

The field controller handles all valves. Specifically, it first switches the pipeline between open loop and close loop by opening and shutting the proper valves that are presented above. Secondly, it used valve #2 to change the work condition. Last but not least, in close loop test two PID processes are implemented in the controller to maintain the temperature and pressure of gas running into the compressor by controlling related valves that are introduced in part II-B.

The other task of the field controller is to adjust the rotation speed of the motor that drives the compressor to ensure the safety and stability especially during the start procedure. A ProfiBus master module is installed in the controller to read statuses from and send commands to the inverter that drives the motor as a ProfiBus slave. During the start procedure the raise of rotation speed strictly follows a speed-time curve that is pre-set in the controller.

E. Control room host

Fig.4 presents the architecture of software in the control room host. It is a modularized software system. Every module is an independent process. A kernel module that manages a data tunnel and an event queue takes charge of all internal behavior of the system including starting and shutting down any other modules, exchanging data between modules by the data tunnel and scheduling modules by the event queue. This architecture guarantees that the system can easily be modified and extended.

Communication management module receives data from the field DAQ device and posts it to the data tunnel. At the meantime this module also sends commands and set values to the field controller.

![Figure 4. Architecture of software in control room host](image-url)
Data processing module processes the status data of the compressor. This module sends the processed data to the data tunnel as well as post monitor events to the event queue to inform the operator.

Test flow management module schedules the entire test. Before a test this module set the pipeline to required type and download the rotation speed adjustment curve to the field controller. During the test this module monitors the alteration of the temperature at the outlet section to determine if the compressor is under a stable work condition. After ensuring the condition is stable it records the data and sends command to the field controller to change work condition till the end of the test.

Data analyzing module calculated the performance parameters of every work condition through the recorded data and presents the characteristic curve of the prototype impeller. By comparing the curve with the design parameters this module evaluates the design and generates a final test report.

Database management module provides functions of saving and searching information about spec of sensors, design parameters of impellers, history data of tests.

Figure 5. Automatic test flow
III. AUTO-TEST FLOW

An auto-test flow is shown in Fig. 5.

As shown in Fig. 6 the auto-test system has increased the efficiency of the prototype impeller test by recording more work conditions as well as reducing the total test time. Furthermore, before employing this system it is a four people job to accomplish a test: one controls valves and the motor; two record the field data; one analyzes the data. Now only one operator in the control room can accomplish the same test all by himself.

Figure 6. Time comparation between using traditional method to record 6 work conditions and using auto-test system to record 8

IV. CONCLUSION

This research presents a framework of prototype compressor impeller auto-test system. Contrasting with the traditional manual test method advantage of this system is obvious:

- Accuracy of prototype impeller test is improved. The high performance DAQ devices guarantee that all signals are acquired precisely and synchronously.
- Efficiency of prototype impeller test is increased. The auto-test system can record more work conditions in less time.
- Cost of prototype impeller test is reduced.

Currently, pressure probes and thermal couples are all fixed. As a result, the flow field information of sections is not clear enough. A servo-drive system is planned to be employed to move the sensors to any position in a section. By representing the flow field information the results of the test can be more accurate.

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