Development of Ultrasonic Testing System for Large Diameter Hollow Shaft

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Abstract
Large diameter hollow shaft is one of the most important components of the large-size rotary machines and it should be implemented nondestructive testing routinely. A new designed ultrasonic nondestructive testing system for large diameter hollow shaft was completed in China recently. The working principle and the structure of this system were described in this paper. The test results for homemade hollow shaft were also presented. It was justified that the performance of this system was better than some commercial ones.

Keywords: Large diameter hollow shaft, nondestructive testing, ultrasonic testing

1. Introduction
To reduce weight, enhance torsion intensity, large diameter hollow shafts are used in most of large-size rotary machines, such as main shaft of power plant and drive shaft and transmission shaft of Electric Multiple Units. Large diameter hollow shafts should be implemented nondestructive testing routinely to find crack, corrosion and stress concentration area.

At present, testing systems of large diameter hollow shafts are produced by German, Japan and Italy mainly. Two types of testing systems were imported from German and Japan for shafts testing of Electric Multiple Units in China. However imported testing systems are expensive. And the after service is difficult for far distance. Therefore, it is the urge demand to develop our own testing systems of large diameter hollow shafts.

2. Main characteristics of the system
Our own testing system of large diameter hollow shafts is developed for automatic fast and overall testing of all kinds of hollow shafts. Fig. 1 shows its photograph. The testing results are perspicuous and ready to make judgments for inspectors. The main characteristics of the system are as bellowing.
2.1 Multi-angle testing probes with multi-mode

Refer to the “Ultrasonic testing techniques of hollow shafts in the CRH series EMU”, regulation of Ministry of Railways of China, it shows that the frequency of probe is from 2.5 MHz to 5 MHz, and the refraction angle of transverse wave of the angle probe is in range from 40° to 70°, ±45° recommended. In this system, there are 7 probes of 4 MHz, with angle of ±45°, ±70°, ±63° and 0° dual crystal contact probe. The ultrasonic beams coverage regions of the probes are shown in Fig. 2. It can test longitudinal and horizontal inner and outer surface defects of inside shafts.

![Figure 2: Beams coverage regions of testing probes](image)

2.2 Reliable probe push and pull mechanism

The travel of the push and pull mechanism is up to 2.7 m. Velocity of the mechanism is from 3 mm/s to 10 mm/s. Rotate speed is from 30 rpm to 200 rpm. Sensors and switches for security and state like limit switch, end position switch, place location switch, start position switch are placed on the mechanism.

2.3 Compact main computer

Ultrasonic testing module and probe location process module are combined in the head of the system, and they share one data line for data transfer and control. Therefore, wires number of the system is reduced, and reliability of the system is assured.

2.4 Humanization software design

Software of the system include control module, data process module, result imaging module, database manage module and remote inquiry module. In the control module, parameters of each channel of ultrasonic testing can be set. Independently and adjusted separately or overall. Parameter techniques files can be made and read. Data of all testing channels can be displayed as A-scan, B-scan or C-scan modes separately or simultaneously. Fig. 3 and Fig. 4 show the interfaces of the play back of ultrasonic testing results of hollow shaft, and of the one through the internet remote calls, respectively.
2.5 Optimized oil coupling

Oil coupling system includes multiple filtrations to avoid harm of impurity to testing system and Influence of testing result. Oil coupling system is a closed loop circulation. The oil can be replaced termly and reclaimed to avoid environment pollution. The filters in the system can be disassembled and cleaned to avoid jam of oil. The oil coupling system was controlled by a real-time monitoring system.

2.6 Extensible electromagnetic testing function

Presently either UT or ET was employed in design of testing system of large diameter hollow shafts. In this system, the new idea to combine both UT and ET was realized by extensible design to affiliate with electromagnetic testing function. Therefore both surface testing and inner testing can be done in one system.

3. Combination of the system

The system is combined with rotatable probe, ultrasonic testing system, mechanic control system, push and pulls system, oil coupling system and industrial computer, shown in Fig. 5.
3.1 **Mechanic control system**

The mechanic control system controls probe rotating mechanism, push and pulls system and oil coupling system. The CAN bus is used for communication between several control units.

3.2 **UT system**

The UT system excites probe to produce ultrasonic wave, and receives signal feedback. Then the signal is magnified, A/D converted and filtered. UT system transfers data and communicates to main computer via net interface. Fig. 6 shows sketch map of ultrasonic testing system.

3.3 **Main computer**

Main computer is used to control ultrasonic testing system and mechanic control system. Testing data from UT system is processed and displayed by main computer. With network technique, the software system can connect with device information manage system or server for remote data management.

4. **Performance and application of the system**

Performance of the system is as bellowing.

1) 8 channels UT with separate parameter setting of each channel.
2) High precision machinery for probe push and pull, with admissible error of ±2mm in axial movement, and ±0.1° in circumferential rotating.
3) Display of A-scan, B-scan and C-scan.  
4) Functions of auto-testing, judging, recording, replaying and network transmission.  
5) High efficiency of testing, with speed of 3mm/s to 10mm/s.  
The system has been used to test standard large diameter hollow shafts of Electric Multiple Units for hundreds times, which shows the system was stable and reliable. Testing results show the performance of the system is equal with imported systems.

Reference