ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPGW046

KEY TECHNOLOGIES FOR REMOTE DETECTION OF CSNS RADIATION ENVIRONMENT *

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Abstract

China Spallation Neutron Source (CSNS) has been continuously running since September 2018. As the running time increases the radiation dose will also increases, and some equipment maintenance and testing must use special tools due to the high radiation dose. This paper mainly introduces several detection technologies which had been used in the CSNS radiation environment, such as remote-controlled vehicle using in front of the target station, strong magnetic field environment vibration measuring system, quick response (QR) code tracing patrol vehicle and remote image measurement system, etc. These technologies also have a guiding significance to other related fields.

INTRODUCTION

China Spallation Neutron Source (CSNS) is a strong neutron source device driven by a high-energy proton accelerator, which will produce a large dose of radiation during its running. CSNS began offering to users in September 2018, and the accelerator has provided beam to the target station for more than 3600 hours at the end of March 2019. With the increase of beam provided time, the radiation dose of the accelerator device increases accordingly. Due to the radiation dose, some inspection operations cannot be performed by using conventional methods. The CSNS mechanical design team had developed several special tools for equipment maintenance and testing, such as the remote vacuum leak detection equipment, strong magnetic field environment vibration measuring system, QR code tracing patrol vehicle and remote image measurement system. In the future, the remote disassembly and assembly technologies and tools which can be used in the radiation environment will also be developed to provide technical support for CSNS operation and maintenance.

REMOTE-CONTROLLED VEHICLE IN FRONT-24-METERS

The devices of CSNS located at the junction of the target station and ring to the target station beam transport line (RTBT-called front-24-meters), has been exposed to proton and neutron radiation during operation. After long-term accelerator operation, these devices will remain higher radioactive and cannot be directly touched by hands. When maintenance is required, the staff must stand on the tunnel shield for installation, disassembly or alignment measurement.

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The remote-controlled walking vehicle is mainly used as a remote platform for the maintenance operation of the front-24-meters to complete the drop and grab operation of the photography-specific alignment target ball, as well as the leak detection vacuum tube of the front-24-meters. The remote-controlled walking vehicle could stretch across the both sides of the tunnel and runs at the third step in the section of front-24-meters, as shown in Figure 1. The tunnel at the end of the RTBT is in the shape of a "horn".

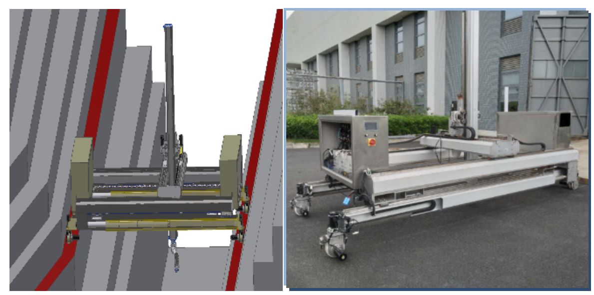

Figure 1: The remote-controlled walking vehicle.

The remote-controlled walking vehicle is composed of a walking extension mechanism and three directional translational lifting guide rails to realize the delivery of maintenance tools for alignment or detection operation. Maintenance tools can be lead to the specified location by the 3-meters-long vertical arm which can sufficient to balance 30kg. When walking at the third step, the remote-controlled walking vehicle will automatically extend the length according to the structure in span of the "horn" to ensure that the wheels always walk on the surface of the tunnel step.

Remote Target Drop-and-grab Device

The remote control walking vehicle can be equipped with the target drop-and-grab device to realize the photography-specific alignment target ball dropping and grabbing operation.

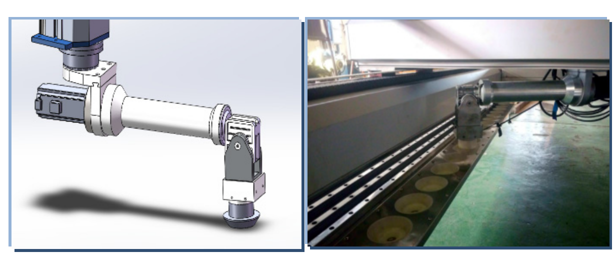

Figure 2: Remote target drop-and-grab device.

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Vertical guide rail and belt wheel are installed in the vertical arm of the remote control walking vehicle, and the ball drop-and-grab mechanism could be sent to the target position by the arm. The ball drop-and-grab mechanism is designed by simulating the structure of human arms. A rotating motor is installed at the arm position, which can rotate 360 degrees. The ball adsorbent mechanism is installed at the end, which can be rotated at a certain angle to achieve the placement of the target ball directly below or on the wall, as shown in Figure 2.

Remote Vacuum Leak Detection

In order to solve the leakage detection problem of the remote online vacuum seal of front-24-meters, a vacuum leak detector had been developed based on the remote-controlled vehicle. The vacuum leak detection device has a semi-circular arc guide rail, which can rotate around the vacuum tube. The sliding block on the guide rail is equipped with a leak detection and helium sample probe, which can be used for leak detection around the vacuum tube in the range of 270 degrees. The remote leak detector could detect the leak point accurately by adjusting the three-dimensional position adjustment module and controlling the on-off state of the vacuum valve. The leakage point area is determined qualitatively within 270 degrees of the welding seam and flange joint of the common ring pipe vacuum chamber, as shown in Figure 3.

Figure 3: Remote vacuum detection.

The testing results show that the leakage rate changes significantly when the detection device is close to the leakage point. Compared with helium spraying detection by manual control, the leakage rate error is smaller. It can effectively detect the vacuum leakage area, and the experiment process is only controlled by a single independent remote operation, which can realize automatic detection.

THE SMART VEHICLE

The smart vehicle is designed for automatic inspection when the tunnel cannot be entered [1]. Smart vehicle and the host computer control system use the wireless network for data communication. The operation command can be send to the car through the network in the central control room. The vehicle walking movement information is recorded on each QR code with the functions of walking, obstacle avoidance and stability measurement. The vehicle scans the QR codes to get the movement information of going straight, turning left, turning right and stop.

Smart vehicle is mainly composed of vehicle body, McNamee wheels motion module, a lifting module, a parallel six-degrees-of-freedom platform, an electrical module and a control panel. The main body of the vehicle is constructed of high-strength hard aluminium alloy and aluminium profiles. Smart vehicle is equipped with four sets of McNamee wheels motion platform, which can realize forward, horizontal, oblique, and rotation and combination sports. Lifting module can bear more than 2000N and achieve 0-500mm range of lifting movement, as shown in Figure 4.

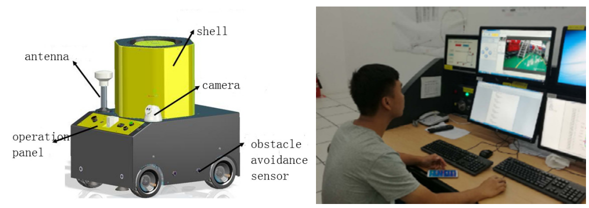

Figure 4: Smart vehicle and the central control.

The smart vehicle had completed the test of the tunnel automatic tracking walking and remote central control in August 2018.

REMOTE IMAGE MEASUREMENT TECHNOLOGY

The smart vehicle can be equipped with a photogrammetric camera to measure the magnet and other equipment. To ensure that the photogrammetric camera is in a horizontal position, a six-axis platform is installed on the vehicle, with can automatically adjust the horizontal position with the accuracy of 0.001 degree. The photogrammetric camera photographs the characteristics of the object at different positions and directions, after image scanning processing, logo recognition, image matching, spatial triangle intersection and other processing, the 3d coordinates of the object are obtained. In CSNS tunnel or laboratory tests, the average stadia can reach 8m, and the measurement accuracy can reach 0.08mm, as shown in Figure 5.

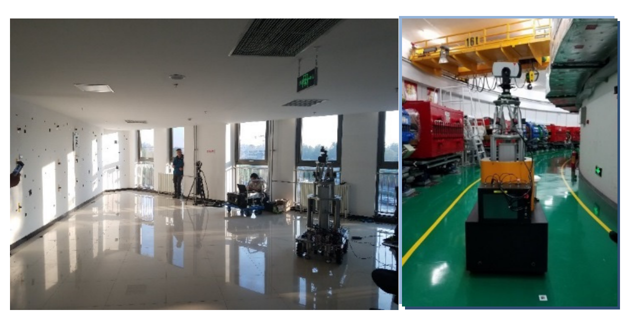

Figure 5: Photographic alignment measurement test.

VISUAL VIBRATION MEASUREMENT

Vibration measurements are usually measured by piezoelectric acceleration sensors [2, 3]. But when the measured objects (such as the ceramic vacuum chambers) are located inside the magnet, the sensors cannot work normally because of the strong magnetic field during the operation of

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the magnet. The visual vibration measurement technology had been developed in order to solve the problem of vibration measurement of ceramic vacuum chamber. The visual vibration measurement system is built on the smart vehicle equipped with a binocular optical camera. It mainly realizes the vertical and longitudinal (beam direction) vibration measurement of the ceramic vacuum chamber, and the measurement accuracy is up to 1.5 microns.

During the downtime in August 2018, binocular camera visual vibration measurement system had been used to conduct the first test on the ceramic vacuum chamber, as shown in Figure 6. The visual vibration measurement system connected the central control system by the RCS ring wireless network, and the vibration measurement can operate in the central control room. Test results show that, under the influence of magnet 25Hz AC field, the amplitude of ceramic vacuum chamber is up to 19 microns.

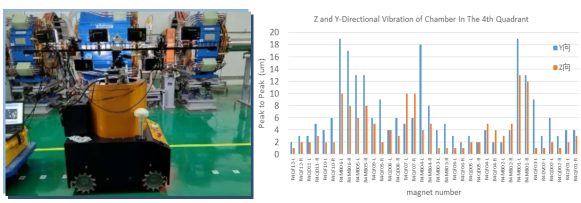

Figure 6: Visual vibration measurement.

LASER VIBRATION MEASUREMENT

Another non-contact visual vibration measurement technique studied in CSNS is laser vibration measurement. Laser vibration measurement becomes the main research method because of its high precision and convenience. The direction of laser vibration measurement is perpendicular to the object surface (vertical magnet horizontal direction), which makes up the deficiency of visual direction measurement in binocular optical camera visual vibration measurement. During the downtime in the summer of 2018, the vibration of the magnet and the vacuum chamber had been measured by the laser vibration measure system, and the tested result are shown in Figure 7.

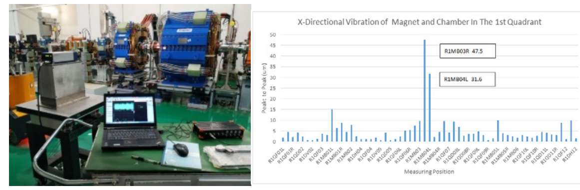

Figure 7: Laser vibration measurement system.

In the process of detection, the chamber with large amplitude are carefully checked according to the test results, and one of the vacuum chamber's installation position had been found changed, and then the position of vacuum chamber had been corrected to avoid damage caused by vibration.

CONCLUSION

CSNS mechanical design team have studied a variety of remote maintenance technology to provide technical support for the operation and maintenance. In the future, the remote disassembly and assembly technology and tools of radiation environment equipment will be further studied. The smart vehicle can be equipped with a radiation dose detection device, which is used to monitor the radiation dose in the tunnel. Various remote detection techniques can also be used in HEPS projects, CEPC and other projects.

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