INTRODUCTION ABOUT KEY TECHNIQUES OF CRITICAL EQUIPMENT IN CSNS*

L. Kang [1,2†], J.B.Yu[1,2], J.X. Chen[1,2], G.Y. Wang[1,2], H.Y. He[1,2], C.J. Ning[1,2], X.J. Nie[1,2], Y.J. Yu[1,2], A.X. Wang[1,2], J.S. Zhang[1,2], L. Liu[1,2], D.H. Zhu[1,2],
1. Institute of High Energy Physics, Beijing, China,
2. Dongguan Neutron Science Center, Dongguan, China

Abstract

CSNS that built in Dongguan had completed installation of accelerator equipment, and started debugging recently. CSNS will complete the completion acceptance in March 2018, and achieve the overall design goals with the proton beam power for targeting 100KW, also with the targeting energy of 1.6GeV in next three years. As a high energy and intense-beam proton accelerator, CSNS will produce lager doses of radiation during operation, some equipment such as stripping foil system, collimators, beam dumps, the equipment before target and proton beam window work in high radiation area, many design requirements about radiation resistance, long life and easy to maintain remotely were put forward. In addition, many magnets work in the environment with pulse repletion frequency 25Hz long-term, much work about vibration reduction and vibration measurement had been done. This paper mainly introduces the key techniques about these equipment.

INTRODUCTION

The China Spallation Neutron Source (CSNS) is a large device that uses the accelerated proton to bombard tungsten target and then produce neutrons [1]. As the accelerator part is a proton accelerator, with the feature of more radiation than electronic accelerator, it's necessary to consider the safety of equipment and manual maintenance. According to the international practice, the beam loss should be controlled less than 1W/m, in order to meet the requirement, on the one hand the whole beam loss of the ring is designed to be lost in a small range, on the other hand, the equipment with large beam loss such as stripping foil at the injection area, RCS transverse collimators, four beam dumps and the equipment in the area before target etc., all be designed with shielding and interface for quick remote operation. Figure 1 shows the layout of the main devices and the high beam loss areas.

Another feature of CSNS accelerator is the power of the RCS dipole and quadrupole magnets, which are excited by direct current (DC) biased alternating current （AC） with repeat frequency of 25Hz, and the coil will be caused to vibration by alternation Lorentz force. With the strong self-excited vibration, the girder system should be designed stable enough with high strength and accuracy to ensure the installation, alignment and operation of the magnets.

* Work suppported by National Natural Science Foundation of China (11375217)

†Email: kangling@ihep.ac.cn.

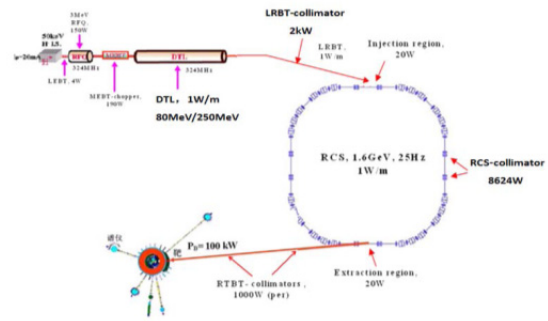
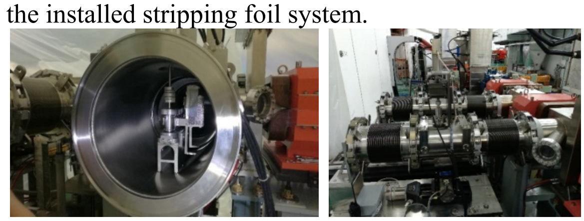


Figure 1: Layout of the main devices and beam loss.

STRIPPING FOIL SYSTEM

The stripping foil system contains a primary stripping foil and a secondary stripping foil, a carbon primary stripper foil of 100ug/cm^2 will be used to strip most electric charge [2], with the stripping efficiency of 99.7%, and the secondary stripper foil of 200ug/cm^2 will strip the last electric charge. Large amounts of energy deposition will be produced during injection, and the temperature will reach 1900K, for the short lifetime, the primary stripping foil is designed with foil online replace structure. The horizontal stainless steel strip is used in the structure, as shown in Fig. 2(a), with many advantages such as high capacity of foil library, high efficiency of replace foil, high precision of location and good repeatability of assembly and disassembly. Cam indexer is also used, for the theory of intermittent motion, high reliability will be got of revolving location. With the control system of three axes association, high repeated positioning accuracy will be got. These parts will complete replace of the failure foil without the CSNS be broken down. Figure 2(b) shows the installed stripping foil system.



(a) (b)

Figure 2: The stripping foil.

The foil labrary of primary stripping foil is designed to install 22 pieces foils with the lifetime about two years. To ensure the safety of workers while replace the failure foils in foil labrary, two sets of foil replace component had been processed, the component will be replaced if many failure foils need be replaced, as shown in Fig. 3. The special underframe is designed to replace the component quickly.

Figure 3: The foil replace componet.

RCS COLLIMATION SYSTEM

The CSNS/RCS transverse collimation system contains one primary collimator and four secondary collimators[3, 4]. All collimators are designed with structure of adjustable pore size, in which primary collimator consists of four symmetrical distribution scrapers with the thickness of tungsten slice of 0.17±0.005mm[5], each scraper is designed to move separately, and the drive device choose a motor to drive the lead screw guide. By using the feedback and compensation of control system, high accuracy of online regulation of scrapers will be achieved. The secondary collimators are designed with four copper absorbers, and the control system is same as primary collimator.

The thermocouple, ceramic bead, and feedthrough are used to get the temperature of scrapers and absorbers, forced air cooling or water cooling will be used if necessary. To satisfy the maintenance requirement, the iron and concrete shielding are designed around the collimators, and the motors, electromagnetic brakes and coders are set out the shielding. The six pieces resembling chain links of quick-release remote clamp is used for vacuum connection. Figure 4 shows the collimation system installed in tunnel.

Figure 4: Collimation system.

BEAM DUMPS AND BEAM WINDOW CHAMBERS

CSNS consists of four beam dumps, LRDUMP and LRDUMP1 at the end of LDBT, INDUMP at the injection area and RCSDUMP at the extraction area.

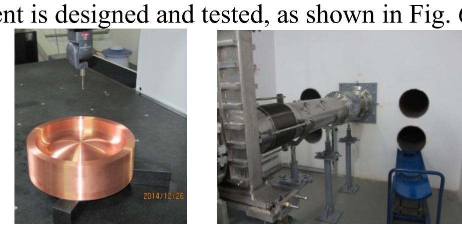
Beam window chamber is one part of the vacuum system to make the un-accelerator particles into iron shielding, it contains vacuum chamber, bellows, beam window, quick-release clamp and gidder. The chamber should satisfy the vacuum characteristics: (1) the static ultimate vacuum should be less than 1E-6Pa, (2) the total cover leakage rate should be less than 1E-10Pa·m^3/s·cm^2, (3) the thermal-outgassing rate should be less than 1E-11Pa·m^3/s·cm^2.

The total length of each chamber is about three meters, and the external diameter is about ϕ270mm to ϕ350mm. Each chamber is designed into two parts, and one bellows is installed to coordinate the setting error between the two parts, quick-release clamps are used to achieve vacuum connection, the assembly is shown in Fig. 5. Stainless steel and copper are used as the material of chambers.

Figure 5: Beam window chambers.

The beam windows are designed to spherical structure, and the sphere is the area particals go through, as shown in Fig. 6(a), so the diameter of the sphere should be over beam size. Considering local temperature increase caused by beam distribution, the sphere should have enough strength at the high temperature, and keep good working condition after long time use. Five thermaocouples are used to monitor the temperature around each beam window. The beam window is the component that beam will touch and go through, it should have good surface finish and the surface roughness grade should over 1.6μm. SUS316L and gild-cop (Glidcop®AL-15) are chosen as the beam windows' material, the sphere is manufactured grading transition from the sphere center to edge. The thickness of sphere center of the gild-cop LRDUMP is 1.5mm, the gild-cop INDUMP is 2mm, the SUS316L LRDUMP1 and RCSDUMP is 3mm, the thickness dimensional accuracy should be less than 0.1mm.

The disassembly and maintenance of the beam windows is also been considered and tested. The beam windows may be broken after long time use, then the failure beam window should be replaced, remotely disassemble instrument is designed and tested, as shown in Fig. 6(b).



(a) (b)

Figure 6: A beam window and one beam window chamber.

EQUIPMENT BEFORE TARGET

The area between accelerator and target is about 24 meters, the equipment contains magnets, vacuum chambers and beam diagnois equipment. In oreder to maintenance conveniently, the area is divided into seven parts. For the area is near the target, it will be highly activated after CSNS operation, all equipment should be designed for remotely installation and maintenance. To enhance the protection of recoil neutrons and decrease the activated gas, the tunnel is designed very narrow, even the first time to install the equipment, people cannot enter into it, and this also increases difficulty for equipment installation and maintenance. All equipment are designed specially, the vacuum chambers should be connected and tested remotely, the joint of water and electricity of magnets should also be designed out the iron shielding,

ISBN 978-3-95450-182-3

and the alignment for magnets should be completed remotely, as shown in Fig. 7.

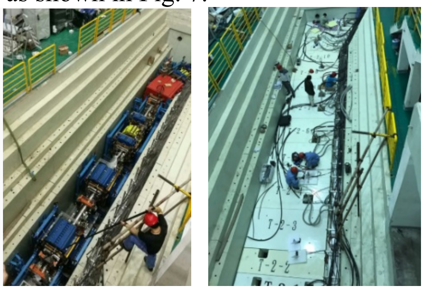


Figure 7: Remote alignment and water-electric connection.

Each part of the equipment is designed with remote hoisting girder, and pre-alignment should be completed before installation, then the girders will be installed in the tunnel accurately. Figure 8 shows the vacuum connection of two parts. Each remote hoisting girder will complete remote auto-alignment and positioning through four high accuracy ball-sockets. The weight the heaviest part is about 45t, the influence of elastic deformation and plastic deformation should be considered, and all structures should meet the strength requirement. The installation accuracy of each part reaches 0.02mm.

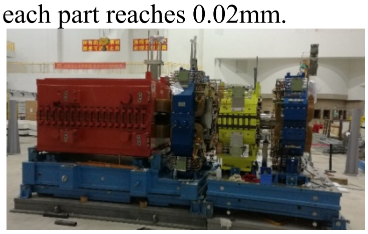


Figure 8: Vacuum connection experiments of two parts.

VABRATION MONITORING AND REDUCTION STUDY

The CSNS dipole and quadrupole magnets in RCS are excited by direct current (DC) biased alternating current(AC）, with the frequency is 25Hz, and the changing magnetic fields will lead to large eddy currents in the magnets[6]. To decrease the influence of magnet vibration and increase magnet lifetime, vibration isolation should be considered in the design of dipole magnet girder. Four-point supporting adjusting scheme is used to increase the girder stiffness, and excitation frequency is avoided by suitable design. The split style of girder can effectively decrease the coupling while adjustment, and cut down the regulation time.

For high positional accuracy of dipole magnet, the amplitude of dipole magnet should not be too large, in addition, to decrease the influence to other equipment, vibratory force caused by dipole magnet should be insulated, and the specialized vibration isolators are used (Fig. 9). The vibration isolator has good performance of radiation-resistant, anti-fatigue and creep deformation resistance. With the frequency of 25Hz, the vibration amplitude in elevation direction can decrease 65.7%, the transverse direction can decrease 65.5%, and in beam direction can decrease 31.4%. The maximum noise pressure of dipole magnet is 67.31 dB, this level meets design requirement and won't hurt the staves even work longtime beside it.

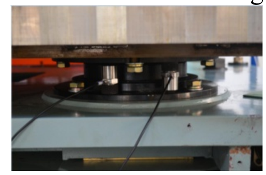


Figure 9: Vibration isolator.

The lifetime of magnets and girders will be decreased after longtime vibration, in order to monitor the influence caused by vibration, the online vibration monitoring system is been developed, and the vibration of each magnet is been monitored, the vibration amplitude of all magnets is less than 20μm, as shown in Fig. 10. Long-term monitoring the operation of the equipment can anticipate the potential failure, and ensure the normal operation of equipment.

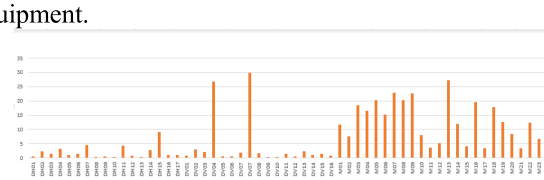


Figure 10: Vibration online monitoring results.

SUMMARY

All the accelerator equipment have been installed and tested several times, now CSNS is ready to operation. Many problems were found while processing and installation, much improvement had been done. With the purpose of reducing equipment fault, the online vibration monitoring of magnets will be done and recorded in the following time. The remote maintenance tools used in high radiation area are now been designed, and remote alignment, remote vacuum detection and disassembly by using robot or manipulator arm are now in considering.

REFERENCES

[1] S.Wang, S.X.Fang, S.N.Fu *et al.*, Introduction to the overall physics design of CSNS accelerators [J]. *Chin Phy C*, 2009, 33(2), pp, 1-3.

[2] Z. X. He, J. Qiu, C. H. Li *et al.*, Wrinkle analysis and mounting optimization of the primary stripper foil for CSNS. *Chin Phy C*, 2013, 37(10), pp, 107003.

[3] T.Wei, Q.Qin., Design of the two-stage collimation system for CSNS/RCS[J]. *Nucl. Instr. Meth. Phys. Res. A*, 2006, 566(2), pp, 212-217.

[4] N.Wang, S.Wang, N.Huang *et al.*, The design of beam collimation system for CSNS/RCS, *in Proceedings of HB2010*, pp°572-575.

[5] Y.Q.Zou, N.Wang, L.Kang *et al.*, Thermal analysis and cooling structure design of the primary collimator in CSNS/RCS [J]. *Chin Phy C*, 2013, 37(5), pp° 057004.

[6] R. H .Liu, H. M. Qu, J. S. Zhang *et al.*, Study of the dynamic characteristics of the AC dipole-girder system for CSNS/RCS. *Chin Phy C*, 2014, 38(7), pp, 077003.