OPERATION AND MAINTENANCE OF CHINESE SPALLATION NEUTRON SOURCE STRIPPER FOIL

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Abstract

The stripper foil system is the essential equipment of the spallation neutron source to achieve negative hydrogen injection. More than 99% of negative hydrogen ions complete the charge stripper in the primary stripper foil during the injection process. The remaining ions will lead to the in-dump after the secondary foil or absorbed by the negative hydrogen scraper. This paper introduces some work records of operation and maintenance of stripper foil system. Some improvement basis is provided for the upgrade of stripping foil by the analysis of these works.

INTRODUCTION

The Chinese Spallation Neutron Source stripper foil sys-tem includes the primary and the secondary stripper foil. The primary stripper foil is the critical equipment for stripping the negative hydrogen ion into the proton. The working principles of the system are shown in Fig. 1. 100 μg/cm2 diamond-like carbon foils are stand in the primary stripper foil, and the theoretical stripper efficiency is 99.7%. The remaining 0.3% particles cannot be complete-ly stripped, include negative hydrogen ions and H0 particles. The negative hydrogen ions that haven't been stripped will arrive at the negative hydrogen ion detection block of the secondary stripper foil and lead out the charge through the wire. However, H0 particles will continue to strip off one electron through the 200 μg/cm2 diamond-like carbon foil on the secondary stripper foil and become protons, leading into the dump in the injection region.

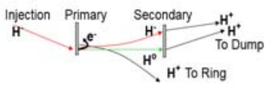

Figure 1:principles of the stripper foil system

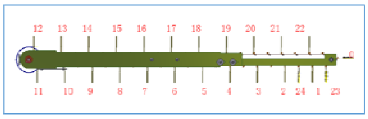

Figure 2: Distribution of the foils

THE REPLACEMENT NEEDS OF THE STRIPPER FOIL

According to the RCS beam tuning requirements, during the 2019 summer maintenance period, most of the foils need to be replaced with new ones. There were 24 foils placed on the primary stripper foil hung up during the 2018 summer maintenance period. All of the foils were HBC foils. Among them, 22 foils were 20 mm*60 mm in size, 14 were single-layer foils, and 8 were double-layer foils. Two foils were 40 mm*60 mm, and all are single-layer foils. The distribution of the foils was shown in Fig. 2, and 0 is the position reference without foil. The 1~22 had hung up the 20 mm*60 mm foils, the 23 and 24 had hung up the 40 mm*60 mm foils.

Although there is a backup foil system for the primary stripper foil changed, we replaced the foils at the RCS site instead of replacing the backup plan because not all the foils need to be replaced. We only replaced those used foils and added some test foils. We overcame some difficulties in the process of replacing the foil. These difficulties mainly include:

1. The peeling foil is thin and fragile, so it is difficult to install with the titanium frame, and it is more difficult to install on the equipment; 2. The dosage of stripper mem-brane in the injection area is large, so it is necessary to prevent the inhalation of membrane and dust; 3. There is a residual dose in the replaced membrane rack, so it must prepare for protection in advance; 4. The exposure of the vacuum section needs to control the clean environment in the tunnel and reduce or stop other jobs that cause interference; 5. The foil replacement site needs the assistance of multiple departments, including an accelerator radiation protection department, control department, vacuum department, etc.

STRIPPING FOIL INSTALLATION

Considering the beam envelope, beam path, and other factors, the stripper foils fixed bilaterally are better. As the temperature of the foil rises as high as 1600K after four times injection, the foil will bear thermal stress. The carbon foil is fixed bilaterally and supported by carbon fiber, which can effectively alleviate the thermal deformation of the stripper foil. The installation device of ultra-thin stripper foil comprises the underframe, micro distance manual lifting table, positioning table, carbon fiber fixed roller, and standard positioning block. In the assembly process, the base foils frame is first installed on the positioning table. The carbon fiber and the foil are assembled in turn, and the positioning table is raised by the micro manual lifting table to tension the carbon fiber. The supporting carbon fiber is completed, the standard positioning block is used for high-precision positioning of the foil, and finally, the clamping foil frame is installed. The whole process needs to be completed in the environment without air disturbance and vibration, and it is strictly forbidden to touch the foil by the body. The installation process is shown in Fig.3.

Figure 3: Bilateral fixed form of stripper foil

RUNNING SITUATION AND ANALYSIS OF STRIPPER FOIL

The pinhole of double-layer foil is significantly reduced, and the surface quality and strength of the double-layer foils are also better than those of the single-layer. According to the beam measurement and physical system measurement calculations, the stripper efficiency of the primary stripper foil is more than 99.4%. At the same time, because the pinhole of the double-layer foil is significantly less than the single-layer foil, the beam loss is substantially lower than that of the single-layer foil.

The double-layer foils adopt bilateral and auxiliary carbon fiber fixing methods. The beam passes through the area and the foil folds. Due to the restraint of the carbon fiber, the foil does not show significant warping and damage. The deformation and simulation analysis results of No.5, No.6, and No.8 foils are shown in Figure 3. There is a specific residual dose in the replaced foil holder, and the surface dose measurement records of each foil holder are shown in Table 2. The maximum residual dose was measured on the No. 5 foil holder, reaching 2100 μSv/h, because the No. 5 foil was last used before the shutdown, and the decay time was the shortest.

The double-layer foils are fixed by bilateral and auxiliary carbon fiber, and the foils are wrinkled when the beam passes through the region. Due to the constraint of carbon fiber, the foils do not appear extensive edge warping and damage. The actual deformation is consistent with the analysis results in Fig. 4.

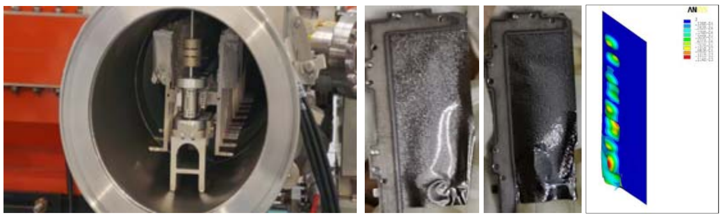

Figure 4: Failure mode of foils

Position	γ dose rate value μSv/h	Replacement foil information	
		Material	Thickness μg/cm2
Surface of primary stripper foil	37	/	/
Surface of secondary stripper foil	39	/	/
Foil No.24	5.38	Double-layer HBC	185
Foil No.5	2100	Double-layer HBC	100
Foil No.6	390	Double-layer HBC	100
Foil No.8	755	Double-layer HBC	100
Foil No.9	/	Double-layer HBC	100
Foil No.10	/	Single-layer GRM	100
Foil No.11	4.07	Double-layer HBC	120
Foil No.12	/	Double-layer HBC	120
Foil No.13	80.5	Double-layer HBC	120
Foil No.14	/	Double-layer HBC	135
Foil No.15	/	Double-layer HBC	135
Foil No.16	/	Double-layer HBC	135
Foil No.17	3.19	Double-layer HBC	150
Foil No.18	/	Double-layer HBC	150
Foil No.19	2.73	Double-layer HBC	150
Foil No.20	/	Double-layer HBC	150
Foil No.21	/	Double-layer HBC	150
Foil No.22	/	Double-layer HBC	170

Table 1: 2018.09~2019.07 Long-term running foils information

Position	γ dose rate value μSv/h	Replace foil information	
		Material	Thickness μg/cm2
Surface of secondary stripper foil	480	Double layer HBC	200
Foil No.1	163	Double layer HBC	100
Foil No.2	429	Double layer HBC	100
Foil No.3	80	Double layer HBC	100
Foil No.4	78	Double layer HBC	100
Foil No.5	666	Double layer HBC	100
Foil No.6	1240	Double layer HBC	100
Foil No.7	18.1	Double layer HBC	100
Foil No.8	163	Double layer HBC	100
Foil No.10	4.9	Double layer HBC	100
Foil No.11	6.7	Double layer HBC	100
Foil No.13	2.5	Double layer HBC	100
Foil No.14	13.9	Double layer HBC	100
Foil No.15	9.1	Double layer HBC	100
Foil No.17	7	Double layer HBC	100
Foil No.18	5.8	Double layer HBC	90
Foil No.19	9.2	Double layer HBC	110
Foil No.20	4.4	Single layer GRA	100
Foil No.23	23.6	Double layer GRA	100

Table 2: 2019.10~2020.07Long-term running foils information

STRIPPING FOIL INSTALLATION

There is still insufficient maintenance convenience in operation and maintenance of CSNS stripper foil. Each time, the foil is not entirely replaced but partially replaced. As a result, it is impossible to replace the whole set of foil replacement modules and all the foils together. It takes a long time to replace dozens of stripped foils on site. For this reason, considering the significant increase of radiation dose in the injection area of CSNS-II, a new foil storage structure will be adopted for CSNS-II stripper foils, as shown in Fig. 5. This structure can integrate 16 foils, occupy less space, and be replaced remotely by a robot. The maintenance personnel only need to place the foils Library in the designated position that the robot can reach. It is expected to shorten significantly the time for personnel to replace the foils library. The related structural design is under test, and the prototype is expected to be completed in 2022.

CONCLUSION

The operation and maintenance of the stripper foil sys-tem is the crucial work of the annual RCS ring mainte-nance of the CSNS. The use of the stripper foil is also the key data that need long-term monitoring. Through the annual operation and maintenance, various types of data with important reference values have been accumulated. Due to the long-term process, the dose in this area is high-er than that in other areas. Maintenance work needs to be adequately prepared in advance. At the same time, the close cooperation of the technical safety office, technical support department, control system, vacuum system, and radiation protection system is required to complete the maintenance task.

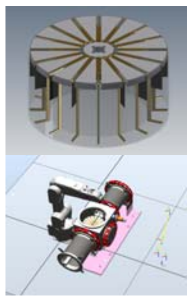

Figure 5: Conceive of CSNS-II stripper foils

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