RESEARCH OF THE CHINESE SPALLATION NEUTRON SOURCE STRIPPER FOIL*

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Abstract

In the injection process of spallation neutron source, the effect of the stripper foil is extremely critical, which is the key equipment to realize the conversion of negative hydrogen ions into proton injection. This paper mainly introduces the research of Chinese Spallation Neutron Source (CSNS) stripper foil. The CSNS stripper foil is a diamond-like carbon (DLC) foil with a thickness of 100 micrograms per square centimetre. This paper introduces the study of the thickness of the CSNS stripper foil, the installation method and the installation process in the tunnel site. Simultaneously, the influence of the gas flow rate of the vacuum chamber on the vibration of the foils is simulated. In the end of this paper, the research plan and follow-up of the experimental equipment of the stripper foil are introduced.

Fixing Method of the Foil at Present

The stripper foil is an important factor in ensuring the quality of beam in the design of spallation neutron source, heavy ion accelerator and medical accelerator, and it is the key equipment in the design of high current proton accelerator. The stripper foil system of the Chinese Spallation Neutron Source includes the main stripper foil and the secondary stripper foil in the RCS injection zone, and the foil collimator on the straight line to ring beam flow transport line.

The foil is 100μg/cm2 thick, i.e. a 500nm thick diamond-like carbon foil, with high specific heat capacity, good thermal conductivity, low density, low thermal expansion coefficient and high melting point up to 3800K, but at the same time the DLC foil is ultra-thin, fragile, which make it difficult to install and pump for vacuum, because the excessive pressure caused by air disturbances is likely to damage the foil. In this paper, we mainly study the stripper foil auxiliary installation device to realize the batch installation of the samples and this paper also had finished the aerodynamic analysis to ensure that the foil is intact in the process of vacuum.

Due to the repeated propagation of the circulating neutron beam, a large amount of energy is deposited on the diaphragm, resulting in a high temperature, it used to choose the high melting point, high emissivity stripper foil. Although the selected foil is the high melting point material, the alternating heat will still make the foil wrinkle, tear and other failure forms. The installation of the foil can affect the failure forms to suppress the deformation of the foil.

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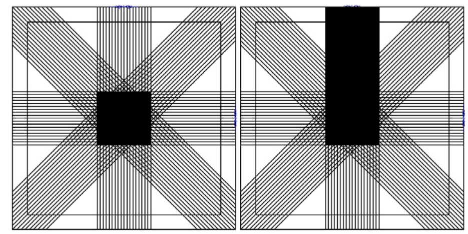

Figure 1: Fixed manner of stripper foil.

The rapid installation of the stripper foil is the key work of all accelerators. Most of the stripper foils are fixed as shown in Fig. 1. Concentrated fibres can effectively prevent the foil corners wrinkles, bending and other thermal stress release phenomenon due to high temperature, but so concentrated fibres is a major cause of beam loss.

Stripper Foil Batch Installation

Considering the beam envelope, beam path and other factors, the bilateral fixed form is used to foil installation. The foil can reach 1600K due to 4 times repeated injection [1-3] (see Fig.2), and the bilateral fixed with carbon fibres can effectively alleviate the thermal deformation. Figure 4 show the bilateral fixed form of the stripper foil [4]. But under the test, the foil could be destroyed when the corner swing about 10 mm to 15 mm (see Fig.3).

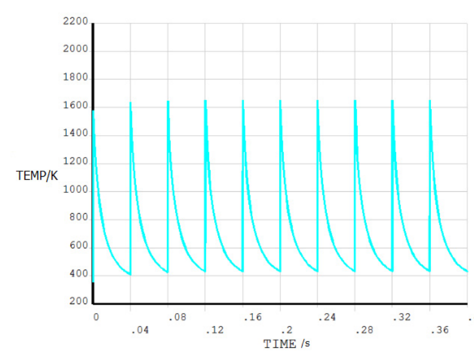

Figure 2: Alternating temperature field of the foil.

An auxiliary tooling had been designed for the foil installation, which include the frame, macro manual lift, positioning table, carbon fibre fixed roller and standard positioning block. The basement frame is first mounted on the tooling, then assembles the standard positioning block, carbon fibres in turn, lifts the positioning table through the macro manual lift to tension the carbon fibres, then the foil, carbon fibres by turn, and use the standard positioning block to alignment the foil position, at last fix the frame. The whole process is finished in the absence of air turbulence and vibration-free environment, and limb contact foils is not allowed (see Fig.5).

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Figure 3: Broken experiment of CSNS stripper foil.

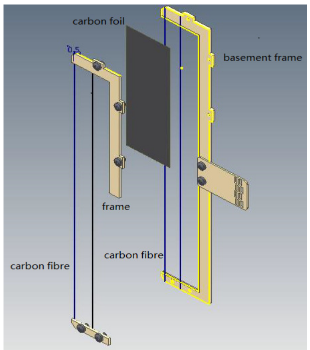


Figure 4: Bilateral fixed form of stripper foil.

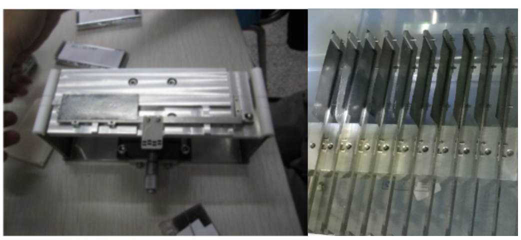
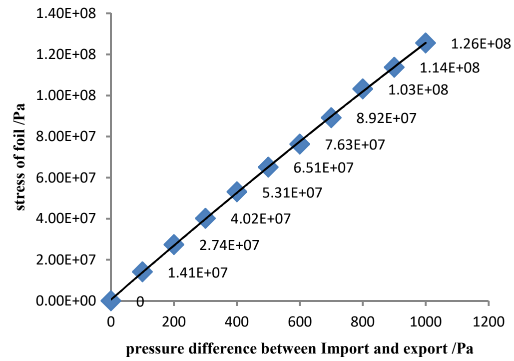


Figure 5: Stripper foil installation set and the samples.

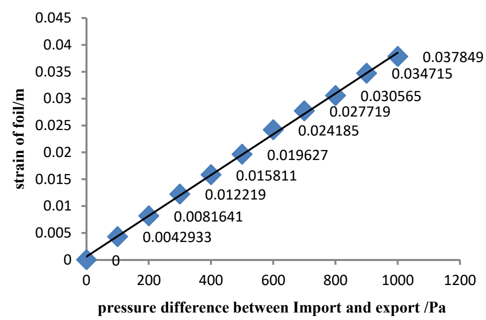
Aerodynamics Analysis of Stripper Foil

The stripper foil system needs to operate in an ultrahigh vacuum environment of 1E-6 Pa. The gas flow may cause the foil vibrate or oscillate, which will cause the foil damaged and seriously affect its lifetime [5, 6]. In this paper, the vacuum suction speed is obtained by analysis the effect of the vacuum pumping speed on the foil to ensure the foils' lifetime. The two modules, workbench fluent and static structural, are used to finish the calculation. The stress and strain on foil was found by setting different pressure drop between import and export, using the reverse calculation method, and then compare with the maximum allowable stress and strain to get the pressure drop limit between the import and export. The maximum stress and strain distribution of different pressure are shown in Fig. 6. As shown in Fig. 6, the deformation of the foil under 300 Pa different drop pressure is under the affordable range.

Fig.7 shows the residual values, and the import and export imbalance error is 0.0065%, which can determine the convergence of the calculation. Fig. 8 shows the pressure distribution of the foil under the 300 Pa pressure drop between import and export. Fig. 9 shows the separation of airflow of the stripper foil vacuum system, and the flow velocity is almost zero around the foil. Fig. 10 is the distribution section of the air disturbance around foil, and the other stress-strain distributions are similar to those graph with different values. Figure 11 shows the export pressure distribution and Fig. 12 shows the stress and strain distribution on the foil. Based on the experience, the foil will be destroyed when it swing more than 12 mm or more. When the pressure drop 300 Pa between the import and export, the maximum stress is 4.02E07 Pa, the maximum strain is 12.2 mm, the foil is likely to be destroyed.



a. Maximum stress distribution of different pressure.



b. Maximum strain distribution of different pressure.

Figure 6: Maximum stress and strain distribution of different pressure.

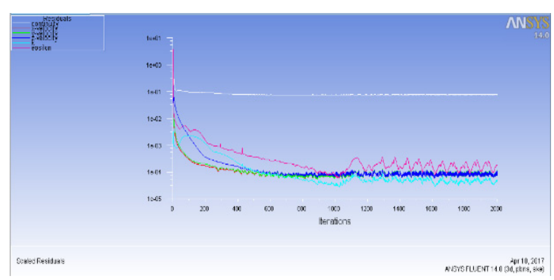


Figure 7: Aerodynamics analysis residual curve.

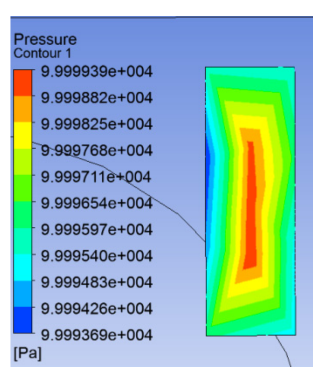


Figure 8: Pressure distribution of the foil.

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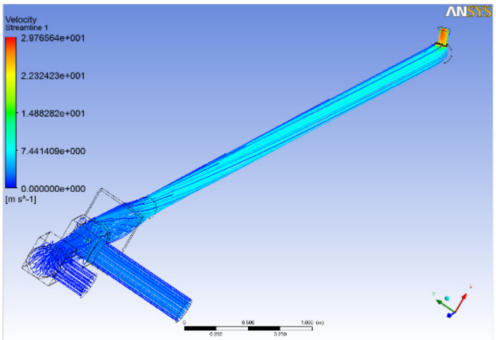

Figure 9: Separation of airflow of the stripper foil system.

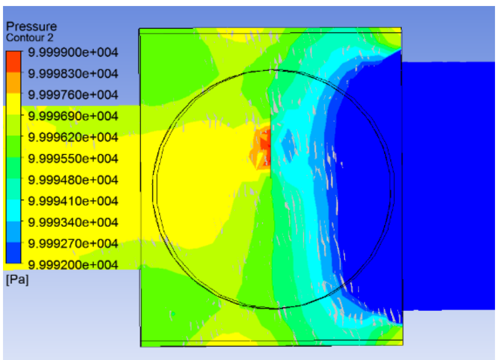

Figure 10: Distribution section of the air disturbance around the foil.

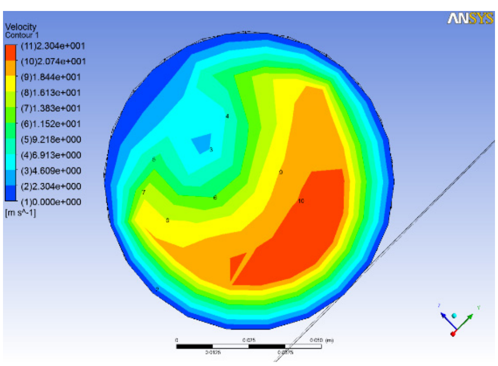

Figure 11: Export pressure distribution.

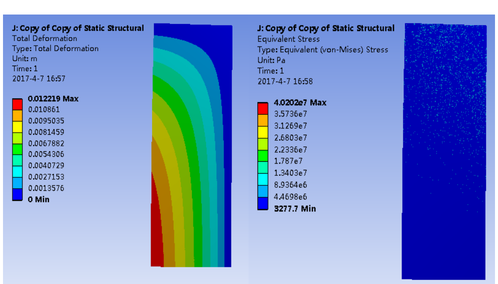

Figure 12: Stress and strain distribution on the foil.

Vacuum Obtain Test of Stripper Foil System

From Fig. 11, the conservative speed is 4.609 m/s at the export, the radius is 0.03 m, so the flow speed is 13 L/s. The maximum pumping speed of the mechanical pump which we used to obtain the system vacuum environment is 8 L/s, and foil didn't vibrate or sway during this process, as the picture shows in Fig. 13. At last, the system vacuum level is better than 2.1E-7 Pa.

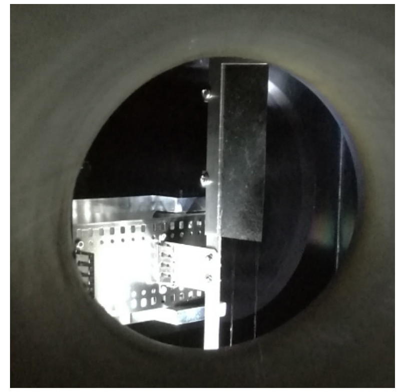

Figure 13: Situation of the foil during the process of the vacuum obtain.

CONCLUSION

The ultra-thin and fragile characteristics of the foil caused it difficult to install and vacuum obtain. In this paper, an auxiliary installation set was designed for foil installation, which achieve batch installation of the sample. The pressure distribution and stress distribution of the foil, air disturbance around the foil, and airflow separation of the vacuum system had been calculated, by which the vacuum obtain program was developed without destroy the foil, and at last the system vacuum is better than 2.1E-7 Pa.

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