DESIGN OF DISTRIBUTED PUMPING SYSTEM USING NEG STRIPS FOR HALF*

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Abstract

The design of a distributed pumping system using NEG (Non-Evaporable Getter) strips for the slender beam pipes of the Hefei Advanced Light Facility (HALF) is presented. To achieve a high pumping speed and pumping capacity in a limited pumping space, a NEG strip with distributed pumping capacity was considered. A prototype of HALF vacuum chamber, which can be inserted into NEG strip and matched with magnet system, is designed. The activation temperature of NEG strip and the ultimate vacuum after activation are tested, and the results are in good agreement with those obtained from the simulation.

INTRODUCTION

Typically, in order to effectively evacuate the beam pipes of particle accelerators, a distributed pumping system is adopted because the beam pipe usually has a limited conductance. The commonly used pumps are distributed sputter-ion pumps (DIP) [1-3] or NEG (Non-Evaporable Getter) pumps [4-7]. A DIP is an integrated sputter-ion pump, and it utilizes a magnetic field of bending or quadrupole magnets. DIPs have been widely used in various accelerators. In addition, a NEG-coated beam pipe, which provides pumping action to the inner surface, is applied to various accelerators. However, the small capacity and high activation temperature of the film become unavoidable problems. Normally, the film can be activated at 180°C, but the activation temperature is gradually increased as the number of activations increases. The low gas desorption rate of the NEG coating, furthermore, may not be as effective because a uniform coating all over the pipe is impossible owing to the complicated structure, such as in the case of a beam pipe with antechambers [7]. A strip-type NEG, on the other hand, can be used anywhere, irrespective of the presence of magnetic fields, and they have been used widely since they were adopted on a large scale in LEP [8, 9].

Presented in this paper is the design study of a distributed pumping system using NEG strips in a narrow pumping space, where a beam pipe with antechambers for Hefei Advanced Light Facility (HALF) has been considered as an example. The activation temperature of NEG strip and the ultimate vacuum after activation are tested.

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EXPERIMENT

Experimental Setup

- The storage ring is responsible for accelerating the beam injected by the intensifier to the energy required by the storage ring, providing a high-quality electron beam for the high energy beam line to extract synchrotron radiation. As an important part of the storage ring vacuum system, its main task is to maintain a reasonable vacuum degree and ensure the stable operation of the beam. A typical stainless-steel antechamber for HALF storage ring vacuum system is shown in Figure 1. It can be inserted into NEG strip. After the vacuum chamber assembly is welded, a 20 μm thick copper film needs to be electroplated on the inner wall of the beam channel.

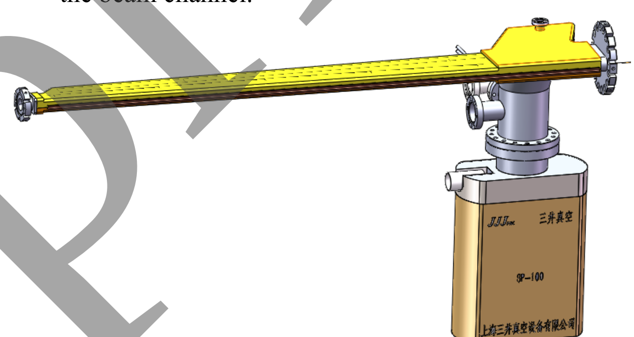

Figure 1: A typical stainless-steel antechamber for HALF storage ring vacuum system.

- According to the overall size requirements, in order to ensure the feasibility of getter integrated assembly, getter pills with a diameter of 13 mm were designed as getter units. TiZrV is a widely used low-temperature activated inspiratory material, and does not contain magnetic elements such as Fe, Co, Ni, etc. Therefore, the inspiratory material based on TiZrV system is selected to prepare NEG strips. According to the installation space requirements, the dimensions of the NEG bar are 930 mm long, 20 mm wide, and 20 mm high. The number of getter pills is 288, and the length of the external electrode of the NEG strip is 300 mm ~ 400 mm, as shown in Figure 2.

Figure 2: NEG pill and NEG strip.

- The vacuum chamber after inserting the NEG strip is shown in Figure 3.

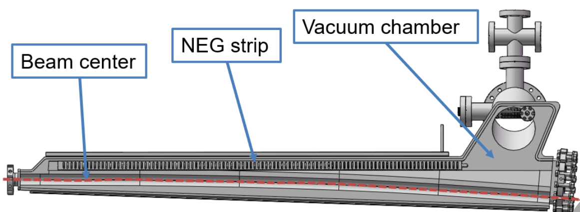

Figure 3: Vacuum chamber with NEG strip.

Experimental Procedures

In order to test the activation of the NEG strip and the ultimate vacuum after the installation of the NEG strip, the test device as shown in Figure 4 was built. The test system includes: 1. Mechanical pump, 2. Molecular pump, 3. CCG, 4. All-metal Angle valve, 5. Ion pump, 6. BAG1(P_1), 7. Vacuum Chamber, 8. RGA, 9. BAG2(P_2), 10. NEG strip, 11. Dc power supply.

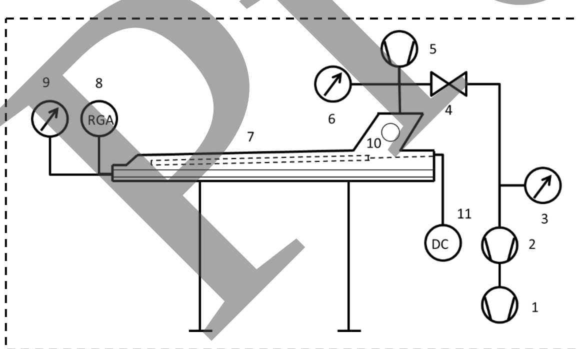

Figure 4: Test device diagram.

- After baking and degassing the system without NEG strip (180℃, 48h), DIP pumping was used alone to test the limit vacuum of the vacuum chamber.
- The NEG strip is activated after the system on which the NEG strip is installed is baked and degassed (180℃, 48h). Test the limiting vacuum under the joint extraction of DIP and NEG strips.

RESULTS AND DISCUSSION

Molflow software was used to simulate the ultimate vacuum of the vacuum chamber. The outgassing rate was set to 3×10^{-12} mbar·L/s/cm^2, the pumping speed of the DIP was 100 L/s, and the pumping speed of the NEG strip was 2.4 L·/s/cm. The model is shown in Figure 5.

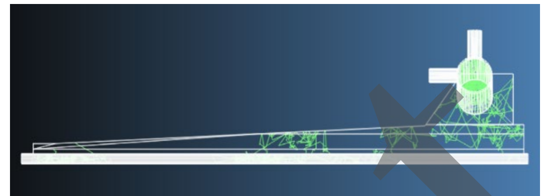

Figure 5: Vacuum calculation model.

The vacuum simulation results without NEG strips are shown in Figure 6. The vacuum degree (P_1) at the DIP port is about 1.09×10^{-7} Pa, and the vacuum degree (P_2) at the other end is about 2.77×10^{-8} Pa. The farther away from DIP, the worse the vacuum. The two ends differ by about an order of magnitude.

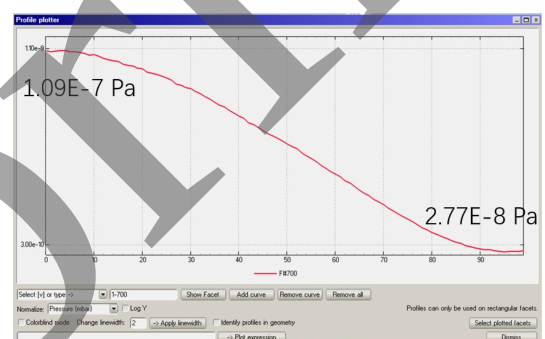

Figure 6: The vacuum simulation results without NEG strips.

As can be seen from Figure 7, when there is a NEG strip, the vacuum degree (P1) of the DIP port is about 8.78×10^{-9} Pa, and the vacuum degree (P2) of the other end is about 9.04×10^{-9} Pa. The best position for vacuum is in the middle of the pipe, about 6.41×10^{-9} Pa. A more uniform vacuum distribution occurs throughout the pipe.

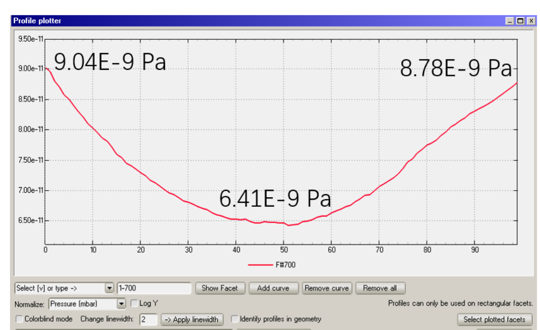

Figure 7: The vacuum simulation results with NEG strips.

The actual test results are shown in Table 1. In a test system without NEG strips, at the completion of 48h of baking, P_1 is about 2.7×10^{-8} Pa and P_2 is about 1.0×10^{-7} Pa. After 72h of baking, P_1 is about 2.7×10^{-8} Pa and P_2 is about

9.9×10^{-8} Pa. At the 90th hour of baking, P_1 is about 2.5×10^{-8} Pa and P_2 is about 9.9×10^{-8} Pa. In a test system with NEG strips, at 48h after activation, P_1 is about 9.2×10^{-9} Pa and P_2 is about 9.6×10^{-9} Pa. After 72h of baking, P_1 is about 8.8×10^{-9} Pa and P_2 is about 9.3×10^{-9} Pa. At the 90th hour of baking, P_1 is about 8.1×10^{-9} Pa and P_2 is about 8.7×10^{-9} Pa.

Table 1: Ultimate Vacuum Test Results

Time	**Without NEG strip**		**With NEG strip**	
	P_2(Pa)	**P_1(Pa)**	**P_2(Pa)**	**P_1(Pa)**
48h	1.0E-7	2.7E-8	9.6E-9	9.2E-9
72h	9.9E-8	2.7E-8	9.3E-9	8.8E-9
90h	9.9E-8	2.5E-8	8.7E-9	8.1E-9

The actual test results are close to the simulation results. It can be considered that after high temperature degassing, the outgassing rate of the system is about 3×10^{-12} mbar·L/s/cm^2. The pumping speed of NEG strip can reach 2.4 L·/s/cm. With the increase of time, the limit vacuum of the vacu-um chamber where NEG strips are installed is still slowly decreasing.

CONCLUSION

After heating at 180°C for 48h, the limit vacuum test was carried out on the system without and with NEG strip installed. The test results are compared with the simulation results. The main conclusions are summarised as follows:

1) From the beginning of the test, the combined pumping effect of NEG strip and DIP in the same time is significantly higher than the vacuum maintenance ability of DIP alone, and the long-term pumping vacuum by DIP alone is not better than 1.0×10^{-8} Pa.

2) With the increase of time, the limit vacuum of the vacuum chamber where NEG strips are installed is still slowly decreasing.

3) Systems with NEG strips have a more uniform vacuum distribution.

4) The actual test results are in good agreement with the simulation results, and the reliability of the test results is high.

5) The outgassing rate of the system is about 3×10^{-12} mbar·L/s/cm^2. The pumping speed of NEG strip can reach 2.4 L·/s/cm.

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