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RESEARCH AND DEVELOPMENT PROGRESS OF CEPC RF SHIELD BELLOWS*

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Abstract

The circular electron positron collider (CEPC) is a candidate for the next-generation electron positron collider, which can be used to accurately measure the Higgs and electroweak bosons. The RF shield bellow is a vacuum component necessary for the construction of CEPC. Therefore, a RF shield bellows prototype with an elliptical cross-section was designed and processed for technical verification. Based on the traditional interdigital structure, a special contact force testing device was also designed to reduce measurement errors. The on-off status of the circuit was used by the device to determine whether the spring finger was pulled up, thus reducing the influences of human factors in the measurement process. It can be known from the measurement results of the model machine that the contact force of the spring finger is between 120 g and 130 g, which can satisfy the technical requirements.

INTRODUCTION

CEPC is a large-scale scientific facility being planned by the Institute of High Energy Physics. Its main objective is to produce a lot of clean Higgs particle cases through the collision of electrons and positrons near the place with the energy of 250 GeV in the center-of-mass system, accurately measure its nature, and do the in-depth study of basic problems such as the origin of mass to find the clues of new physics beyond the standard model [1].

The perimeter of CEPC is 50 km [2]. A lot of bellows should be installed to compensate for the installation errors and thermal expansion. In the high-current accelerator, through the discontinuous vacuum chamber structure, the beam current produces the electromagnetic field in the surrounding environment, commonly called the wakefield, which has the counteraction on the beam current and produces the impedance. The radial dimension of a corrugated pipe changes greatly axially. It has a discontinuous vacuum pipe structure. Therefore, the corrugated pipe used for the high-current particles should have an RF shield in it.

SHIELD STRUCTURE

The RF shield structure should have the following features. It should be consistent with the upstream and downstream internal lumens, which improves the continuity of the structure of the corrugated pipe and reduces the impedance. The axial tension and compression and radial deflection are allowed, which does not affect the functions of the corrugated pipe. When the beam current passes, the continuous path of the mirror wall current is formed, which keeps good electrical contact and reduces the leakage of the higher-order mode and instability of the beam current.

In recent decades, various kinds of shield structures have been developed, including finger-type shield, pls-type shield, comb-type shield and Ω -Type shield, etc.

Compared with other structures, finger-type shield can achieve lower impedance, larger tensile compression and larger radial offset, and its structure is simple, which is suitable for the requirements of CEPC. Therefore, CEPC RF shield bellows prototype adopts finger-type shield structure.

KEY PARAMETERS

Contact force: The contact force should be controlled in a reasonable scope. If it is too small, the electrical contact cannot be guaranteed. If it is too big, the wear in the process of motion will be increased [3]. With the reference of experience in BEPC Ⅱ and KEKB, this indicator is determined as 125 ± 25 g.

Radial offset: The objective of this indicator is to compensate with the corrugated pipe when the elements on the 2 sides have big position errors. The value is determined as 2 mm.

Tension and compression: It can be stretched by 5 mm and compressed by 12 mm.

Dimension in the pipe: 75 mm × 56 mm.

STRUCTURAL DESIGN AND PROCESSING TECHNOLOGY

As shown in Fig. 1, the shield structure consists of 3 parts, including the spring-finger, contact finger, and inner tube.

The spring-finger is the core of the whole shield structure. It is made of a nickel alloy plate 0.4 mm thick. The end of the finger bends outward. In the contact part, there is a raised structure with a bigger curvature. It is used to ensure that the contact with the contact-finger is the point contact and prevent the heat caused by unreliable contact. To ensure good electrical contact, the surface of the spring-finger is plated with silver.

The contact-finger is made of beryllium copper. Its width is 4.5 mm - 5.5 mm. The width of the gap between fingers

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is 0.5 mm. It is used to remove the gas between the corrugated pipe and the shield structure.

The inner tube is made of stainless steel. The part contacting with the contact-finger on the lateral side of its end protrudes compared with its body, thus avoiding the heat caused by the unreliable contact with the contact- finger.

To ensure the consistency of the spring-finger, the forming mould and welding fixture was specially designed. After the forming of the spring-finger, it was welded with the fixing-ring by the welding fixture, and then welded and fixed with the endplate. Finally, two prototype RF shield bellows are manufactured, one of which is shown in Fig. 2.

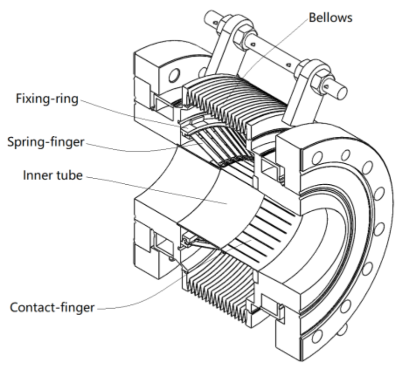

Figure 1: Schematic diagram of the structure of the RF shield bellows.

Figure 2: Prototype of RF shield bellows.

TESTING

The contact force is the key indicator in the development of the prototype. To reduce the human factors in the process of testing, the testing device of contact force was specially designed, as shown in Fig. 3. The polyimide tape with a thickness of 0.1 was pasted on the beryllium copper with a thickness of 0.1 for the insulation of beryllium copper and inner tube. The overall thickness of beryllium copper and polyimide is the same as that of the actual contact-finger. One end of the indicator light (or a multimeter) is connected to the spring-finger and the other end is connected to beryllium copper. The force gauge is connected to a spring with a proper elastic coefficient. The other end of the spring is connected to a soft coil, which gets close to the contact point between the spring-finger and beryllium copper and hooks the spring-finger.

When the testing tensile force is smaller than or equal to the contact force, the relative position of the spring- finger and beryllium copper does not change. The tensile force changes into the tensile deformation of the spring, and the status of the indicator light does not change.

When the tensile force just begins to be greater than the contact force, the spring-finger is pulled up, the beryllium copper has an open circuit, and the indicator light turns off. At this time, the reading of the force gauge shall be equal to the contact force to be tested.

If a 10-round spring with a wire diameter of 0.4 and an outer diameter of 10 is used, its elastic coefficient is calculated with the formula as 0.03 N/mm. If the device is used to control the force gauge and move up by 0.2 mm each time, the tensile force of 0.006 N can be produced. In this way, the tensile force can be controlled and changed from small to big, until the contact force is tested.

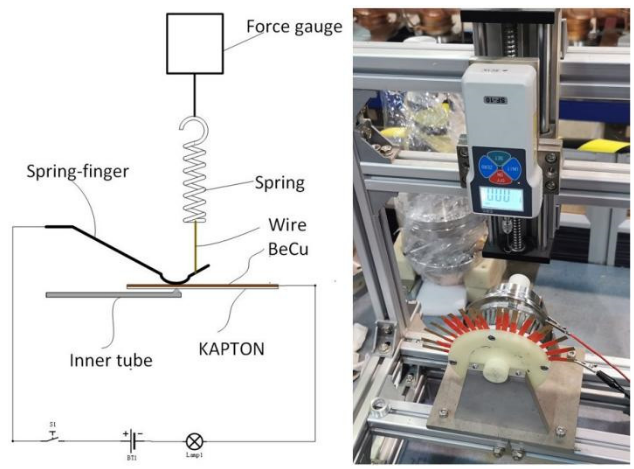

Figure 3: Schematic diagram of the testing device of contact force and its physical photograph.

The above method is used to test the contact force of the prototype, and the results are shown in Fig. 4: The contact force is 120 g - 130 g, which meets the acceptance requirements.

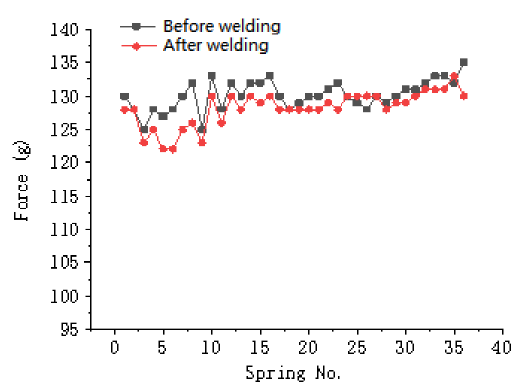

Figure 4: Contact force test results of RF shield bellows prototype.

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CONCLUSION AND PROSPECT

The prototype of cepc RF shield bellows has achieved preliminary results. The contact force meets the technical requirements, and the new contact force test method has been proved to be simple and the result is feasible. Next, the reciprocating tensile compression test will be carried out to verify its fatigue life.

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