BELLOWS WITH A NEW RF SHIELD MADE OF METAL BRAID FOR HIGH INTENSITY PROTON ACCELERATORS

N. Ogiwara#, J. Kamiya, Y. Shobuda, M. Kinsho, J-PARC/JAEA, Tokai, Japan

O. Koizumi, SUN-TECH Ltd., 4-2-1-504 Mikagenaka-machi, Higashinada, Kobe, Hyogo 658-0054, Japan

Abstract

In the 3 GeV-RCS (Rapid Cycling Synchrotron) in J-PARC (Japan Accelerator Research Complex) project, large-scale hydro-formed bellows were developed to adjust the gap between the ceramic ducts and/or between the ceramic ducts and the transport ducts. They have been equipped with a newly developed RF shield, because the usual beryllium-copper spring finger contacts were found to be very hard (roughly 1000 N/mm) owing to the large size. The newly developed RF shield is made of metal braid, which consists of wires with a diameter of 0.3-0.5 mm. Because of the spring effect, the contact can change shape easily. In addition, the shield can easily connect the different cross sections in a smooth fashion. Furthermore, this structure is almost free from the dust generation, which is one of the most troublesome problems for the usual spring finger contacts.

OUTLINE OF RCS BELLOWS JOINTS AS INTRODUCTION

At the 3-GeV RCS, the space for the bellows expansion joints so narrow that their requirements were strict. The typical free length and inner diameter of the bellows joints were ~100 mm and ~400 mm, respectively; nevertheless, the axial and lateral displacements were needed to be ±10 mm and 5 mm, respectively. Where, a spring rate of less than 100 N/mm was needed for avoiding the damage to the ceramic ducts. Therefore, we have developed the hydro-formed bellows as flexible as the welded ones[1]. Then the basic structure of the bellows joints was decided as shown in Fig. 1. As a result, the typical expansion joints have the length of around 120 mm. The required displacements are easily obtained with a spring rate of ~10 N/mm.

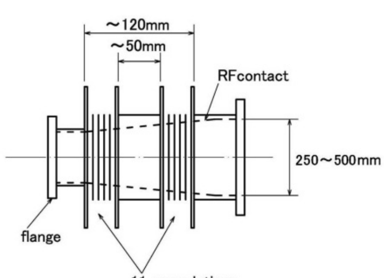

Figure 1: Basic structure of the bellows joints.

#ogiwara.norio@jaea.go.jp

Of course, these bellows joints should be equipped with the RF shield[2]. As the usual beryllium-copper spring finger contacts were found to be very hard (roughly 1000 N/mm) owing to the large size, we have developed a new type of RF shield. This time, we have constructed reserve bellows with the RF shield made of SUS 316L wires to improve the reliability of user operation. Thus, we have an opportunity precisely to examine the performances of the RF shield, which will be mentioned below.

BASIC STRUCTURE OF THE NEW RF SHIELD

The newly developed RF shield is made of metal braid mesh, which consists of bundles of wires. Each bundle has 10-24 wires with the diameter of 0.3-0.5 mm. For example, 96 bundles are used in the RF shield with the diameter of 130 mm. First, the cylindrical braid with the diameter of 130 mm is prepared. Then the cylinder is formed into the shape according to the mold. Finally the ports of metal plates are welded as shown in Fig. 2.

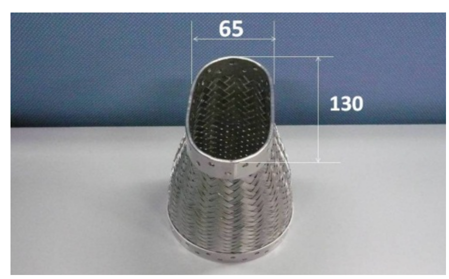

Figure 2: Example of the newly developed RF shield.

This type of RF shield can change shape easily and connect the different cross sections in a smooth fashion. Furthermore, this structure is almost free from the dust generation, which is one of the most troublesome problems for the usual spring finger contacts. These features will be shown below.

PERFORMANCES

Displacement and Repulsive Force

Two types of RF shields, as shown in Fig. 3, were made experimentally to investigate their movability. The one is for adjustment from the cross-section of circle to that of circle (type A). Its diameter and the height are 250 mm and 170 mm, respectively (see Fig. 3). The other (type B) is for adjustment from the circle to the race-track. The race-track has the long side of 250 mm and the short

ISBN 978-3-95450-122-9

side of 180 mm. The height is 170 mm. These shields are made with the SUS316 L wires with the diameter of 0.3 mm. Cylindrical braid is composed of 128 bundles with 24 wires, and then is formed into the shapes as mentioned above.

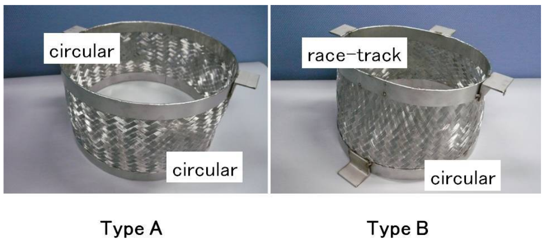

Figure 3: Two types of RF shields for investigation of their movability.

First of all, the axial displacement of ±10 mm, and the perpendicular displacement of 5 mm were found to be easily obtained for the both types of shields.

Then the axial and lateral displacements as a function of load were examined. Typical results are shown in Fig. 4: (a) for the displacement along the axis of the type A, and (b) for the perpendicular displacement of the type B. For the type A shield, the spring rates for the axial and lateral displacements are ~10 N/mm and ~40 N/mm, respectively. For the type B shield, the spring rate for the axial displacement is ~ 20 N/mm. And the spring rates for the displacement perpendicular to the axis are ~40 N/mm along the long side of race-track and ~60 N/mm along the short side, respectively.

These results demonstrate well that the new RF shield has enough large displacements and enough low spring constants.

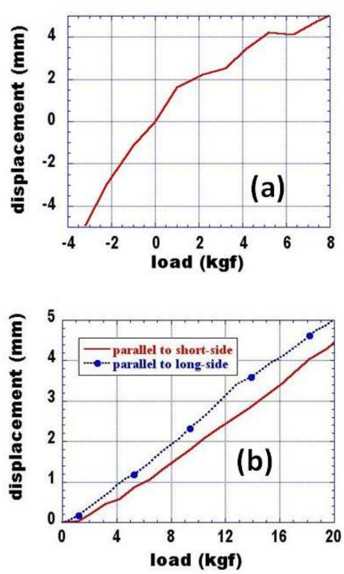

Figure 4: Displacements as a function of load; (a) along the axis of type A, (b) lateral to the axis of the type B.

Dust Generation Due to Abrasion

We will demonstrate that the new RF shield hardly generate the dust particles due to abrasion. The measurement method is as follows. After scraping samples together, all the generated dust particles are gathered by rinsing the samples with ultra pure water of 500 cc. Then all the dust particles with the diameter of greater than 0.5 µm were filtered out on the filter paper. Then the particles with the diameter of greater than 1 µm were counted, because of the limitation of counting technique. As the mean diameter of the dust particles is reported to be 50 µm[3], above treatment is supposed not to lead the serious counting errors. First of all, the results for Be-Cu and SUS316L are presented. The shape of the test pieces is 6 mm×6 mm×180 mm. The same two pieces are set in a crossed way, and they are scraped 10 times together with the stroke of 20 mm. The contact weights are 55 g for Be-Cu and 52 g for SUS316L, respectively. After the test pieces were rinsed in the ultra pure water of 500 cc, the dust filtered out on the filter paper were counted as mentioned above. Results for the Be-Cu and SUS316L are shown in Fig. 5 (a) and (b), respectively. Comparison with the background data shows clearly that the abrasion generates the dust particles for the both samples.

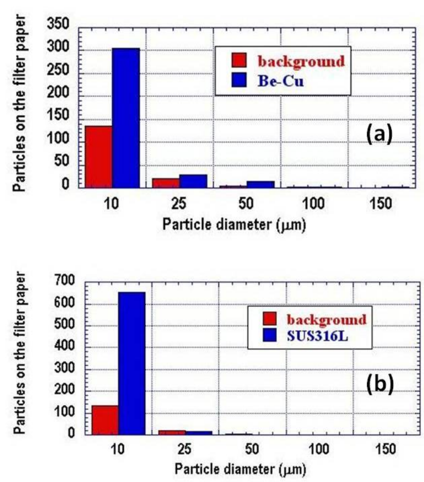

Figure 5: Dust generation due to abrasion; (a) for Be-Cu, (b) for SUS316L.

Then the RF shield was examined. The shield was newly prepared for the examination. The shield is made of SUS316L wires of 0.5 mm in a diameter. The shape is shown in Fig. 2. It was displaced along the axis 20 times with the stroke of 10 mm. Then the whole of the RF shield was rinsed with the ultra pure water of 9000 cc. This washing water was divided into 18 units with the volume of 500 cc. From these 18 units all the dust particles were gathered on the filter papers individually. On every 18 filter papers, the particles were observed to be less than the background level. Typical results are shown in Fig. 6. Where, average particles on all filters for 18 units and the ones on the last filter are shown.

They are found to be as low as background level. In addition, total number of the dust particles in the used water of 9000 cc is only 2100. As a result, the dust generation hardly occurs in the newly developed RF shield.

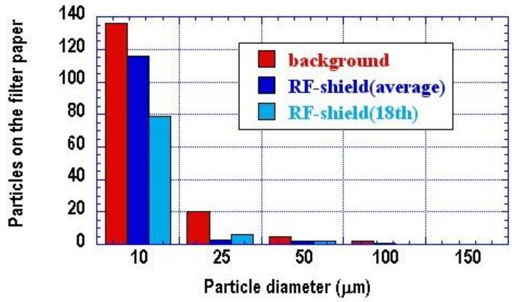

Figure 6: Dust generation from the RF shield.

Outgassing From the RF Shield

As the new RF shield is made with the mesh, which surface area is 3-4 times larger than that of the usual finger contact RF shield, we have vacuum-fired the mesh at 750°C for 10 h in order to reduce the outgassing from the RF shield. Then, the outgassing rate from the mesh with the surface area of 4.5 m^2 was measured by through–put method. For the first 150 h, the rate at RT was measured, and then the mesh was baked out at 150°C for 30 h. The rate has been continuously measured for 300 h. After 150 h from the start of pumping, the outgassing rate of 10^{-8} Pam/s was observed. Here, the main gas species is H_2O, which may be ascribed to the adsorbed ones on the mesh surface during the air exposure. After the bake out at 150°C, the main gas specie is changed to H_2. Then the rate became less than 10^{-9} Pam/s 200 h after bake-out. From these results, we have concluded that the outgassing from the RF shield can be controlled to be negligibly small.

Beam Coupling Impedances

As mentioned above, the new RF shield changes gradually and smoothly the shape of the cross-section, the shield is hoped to reduce the beam impedance. Preliminary experiments were carried out with the coaxial wire method[4]. For comparison, we prepared two devices under tests: one is that a brief plate with a race-track aperture is sandwiched by two cylindrical chambers, the other is an RF shield which is composed of two shields shown in Fig. 2. Inside the shield, the circular cross-section is gradually and smoothly connected to the race-track, and the race-track to the circular cross-section, respectively.

The typical results are shown in Fig. 7. Here, the imaginary parts of longitudinal impedances are shown as a function of frequency. Clearly, the impedances for this type of shield become smaller than the race-track aperture.

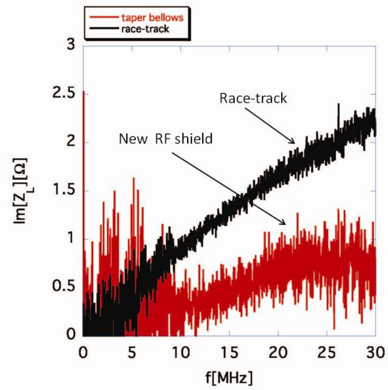

Figure 7: Imaginary parts of the longitudinal impedances for the race-track aperture and for the new RF shield, respectively.

CONCLUSIONS

We have developed a new type of RF shield for the large-scale bellows joints. This shield is made of metal braid, which consists of wires with the diameter of 0.3-0.5 mm. This time, we have examined the mechanical performances of this shield, using the experimental products made with SUS316L wires. The followings are confirmed:

(1) This RF shield can stand alone, and the original shape is easily restored after the release of the load due to the spring action of the braid mesh.

(2) The shape is easily changed with the rather small load, and the displacements are rather large. Typical spring rate is ~10-20 N/mm, and the parallel and perpendicular displacement are ~±10 mm and ~5 mm, respectively.

(3) This shield can easily connect the different cross sections in a smooth fashion. And the smoothness is maintained after the displacements.

(4) This shield is found to be almost free from the dust generation, which is one of the most troublesome problems for the usual spring finger contacts.

In addition, the outgassing from the braid is confirmed to be so small that vacuum properties are maintained in a good condition. Finally, the newly developed RF shield works well in order to reduce the beam impedance, although the precise examination is needed.

REFERENCES

[1] N. Ogiwara et al., Vacuum, **84** (2010) 723.
[2] N. B. Mistry, and Y. Li, in *Handbook of Accelerator Physics and Engineering*, ed. A. W. Chao and M. Tinger (World Scientific, Singapore, 1999) p. 338.
[3] Y. Suetsugu et al., Vacuum, 47 (1996) 629.
[4] F. Caspers, in *Handbook of Accelerator Physics and Engineering*, ed. A. W. Chao and M. Tinger (World Scientific, Singapore, 1999) p. 570.

ISBN 978-3-95450-122-9