DESIGN AND SIMULATION OF A TEST MODEL FOR A TRI-SPOKE CAVITY AT RIKEN *

L. LU, N. Sakamoto, K. Suda, K. Yamada, O. Kamigaito,
RIKEN Nishina Center for Accelerator-Based Science,
RIKEN, 2-1, Hirosawa, Wako, Saitama 351-0198, JAPAN

Abstract

A design for a tri-spoke-type superconducting cavity for uranium beams with β = 0.303 and a 219 MHz operational frequency is presented. And a test model designed and assembled by two end-wall flanges and one triparted part of the designed tri-spoke cavity, was expected to be built using the same fabrication technology that is supposed for Nb cavity manufacture. The designs and simulations of the tri-spoke cavity and the test model will be reported in this paper.

INTRODUCTION

Very heavy ions such as uranium can be accelerated to very high energy using an accelerator chain, which consists of a new linear injector named RILAC2 with a powerful superconducting ECR ion source and four booster cyclotrons in the RIKEN RI-beam factory (RIBF) [1-4]. However, two charge-stripping sections cause an increase in the phase width of the beam in subsequent cyclotrons. Thus, we aim to design a tri-spoke type superconducting cavity as a rebuncher in order to focus the beam in the longitudinal direction. This tri-spoke cavity would be placed between fRC and IRC. The frequency of the tri-spoke cavity was chosen to be 219 MHz, which is the 12th harmonic of the fundamental frequency of 18.25 MHz. This frequency yields a cell length of $\beta\lambda/2 = 207$ mm at β = 0.303 [5]. The total voltage is estimated to be a few megavolts at this frequency.

We have not experiences and facilities of fabrication of superconducting cavity. Thus, the novelty of SC rf technology, the complexity of mechanical construction, and use of electron beam welding, a substantial effort should first be invested and researched in fabricating a test model from oxygen-free copper. The test model is assembled from two end-wall flanges and a triparted tri-spoke cavity, as shown in Fig. 1 [6]. The parameters of the tri-spoke cavity and the fabrication model are listed in Table 1.

Table 1: Parameters of tri-spoke cavity model and fabrication model

Parameter	Tri-spoke	Test model
Frequency (MHz)	219	228
Length (mm)	828.8	346.4
Cavity Dia. (mm)	580	580
Beam Bore (mm)	15	15
R/Q (Ω)	241.21	155.6
E_{pk}/E_{acc}	2.75	2.04
H_{pk}/E_{acc} (Oe/MV/m)	58.21	
G (Ω)	81.17	79.4
R_{res} @ 4.2K (nΩ)	25	25
Q @ 4.2K (Ω)	3.25E+09	3.17E+09
Power@ 4.2K (W)	0.42	0.45

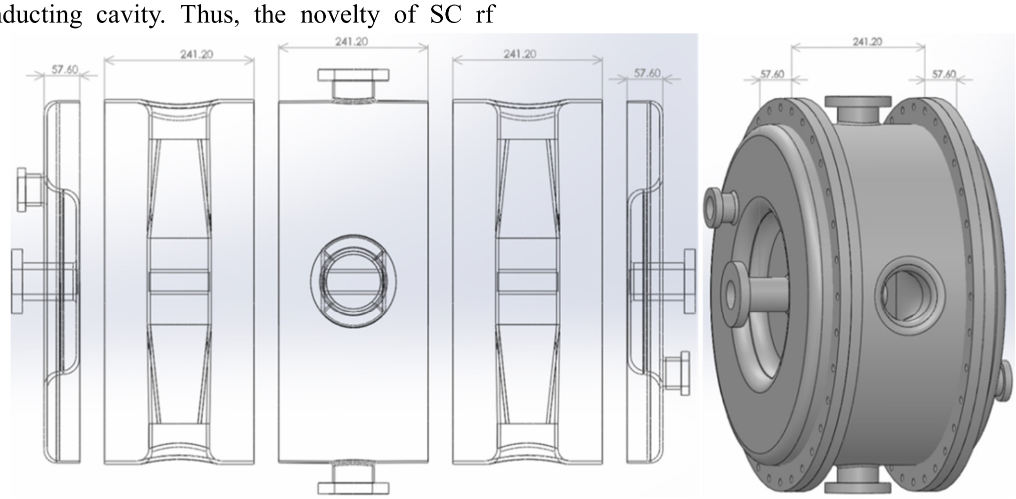

Figure 1: Images of wall flanges and triparted cavity parts (left) and the assembled image of the test model (right).

*luliang@riken.jp
*Work supported by Foreign Postdoctoral Researcher

ISBN 978-3-95450-122-9

DESIGN

Designs and Simulations

In order to train technicians and for practice in welding technique, a test model will be built from copper sheets using the same fabrication technology that is expected to be used in Nb cavity manufacture. Feedback from this model will be helpful for Nb model design and eventual Nb model fabrication through low temperature tests. The test model is designed to be assembled from two end-wall-flanges and one triparted cavity, as shown in the right part of Fig. 1.

Tri-spoke cavity and test model designs have been optimized using Microwave Studio (MWS) software [7]. Fig. 2 and Fig. 3 show the main geometrical designs of the tri-spoke cavity and the test model used for optimization. The position of the coupler was designed to be at the center of the cavity, oriented in the vertical direction of the 2nd stem. The vacuum port can be installed on either side. This symmetrical position of this design is attractive as the magnetic field is zero in this region [8-9]. Two maintenance ports for cavity cleaning were designed in the side wall because the magnetic field is not concentrated in these positions.

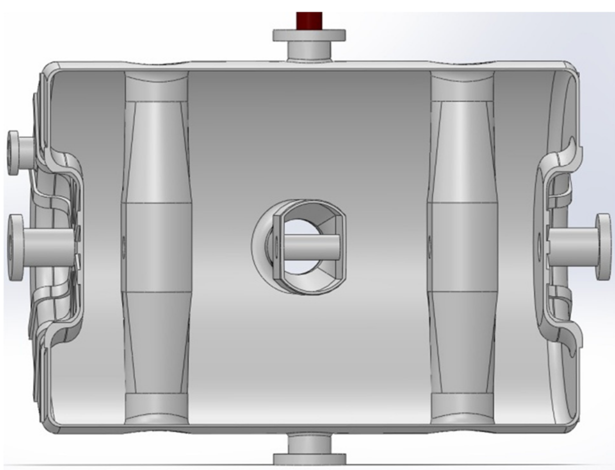

Figure 2: Cross section of the tri-spoke cavity with stiffening ribs.

Electron beam welding and normal braze techniques, which will be adopted in the manufacture of this test model, will be studied in this training process. The test results of the model will also be studied for feedback on RF cavity and cavity mechanical design. A full scale Nb test model, identical to the copper test model, will also be manufactured and assembled after low temperature testing of the copper model is complete.

The RF cavity is designed to minimize the peak surface electric and magnetic field ratios: E_{peak} / E_{acc} and B_{peak} / E_{acc}, respectively. Surface electric and magnetic fields in an optimized cavity are shown in Fig 4. The main RF parameters of this cavity are summarized in Table 1.

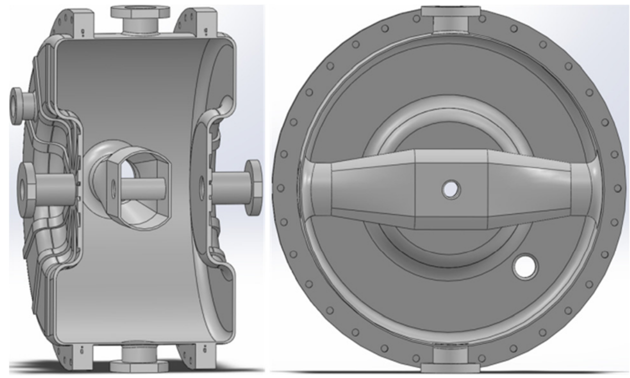

Figure 3: Cross section of the test model with ribs.

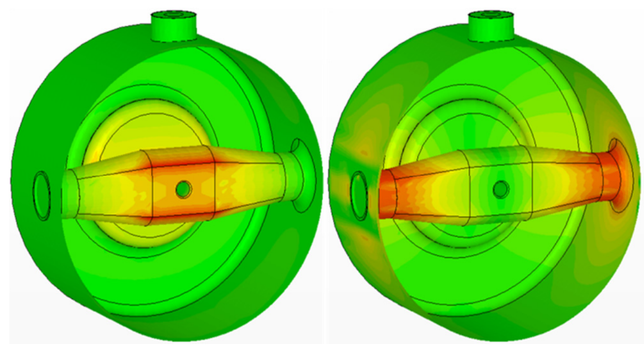

Figure 4: Surface electric (left) and magnetic (right) fields in the test model. The field strength increases as the color changes from green to yellow to red.

The walls and spokes will be formed from 3 mm thick copper sheets. End wall flanges will be made from a 5 mm thick sheet. The initial cavity fabrication design will specify that the spokes will be formed in halves and seam welded together. Cavity walls will also be manufactured from two 3 mm thickness halves and longitudinally welded. Two press-formed end wall flanges will be assembled from cavity walls by two connection ring ribs in test model manufacturing. A conductor and a metal O-ring will be adopted in the connection ring rib. All cavity welds will be formed using outsourced electron beam technology. The outer cavity stiffening structure will be brazed to the cavity body.

However, there are other opinions about the manufacturing method which is use numerical control machine (NC) tools to shape the spokes from Nb ingots or bulk copper. The assembly method should then include two flanges with stiff ribs. However, the design and fabrication of a stiff cavity with an inflexible structure are attractive for our research because a buncher cavity with an inflexible frequency shift is not required for a high power system.

The manufacturing method of shaping spokes using NC machine tools has been discussed. Further, the simulation of the maximum displacement using a model with ribs has been discussed along with the relationship between the

ISBN 978-3-95450-122-9

displacement and the tuning effects. The design of stiff ribs was discussed for several structure types. The final rib design and the simulated results for the maximum deformation of a rib model are shown in Fig. 5 using Microwave Studio. The total pressure acting on the surface of the cavity is set to 0.121325 MPa. The observed 0.39 mm deformation is tolerable and easy to tune. The calculated pressure sensitivity (df/dP) is -172 Hz/mBar.

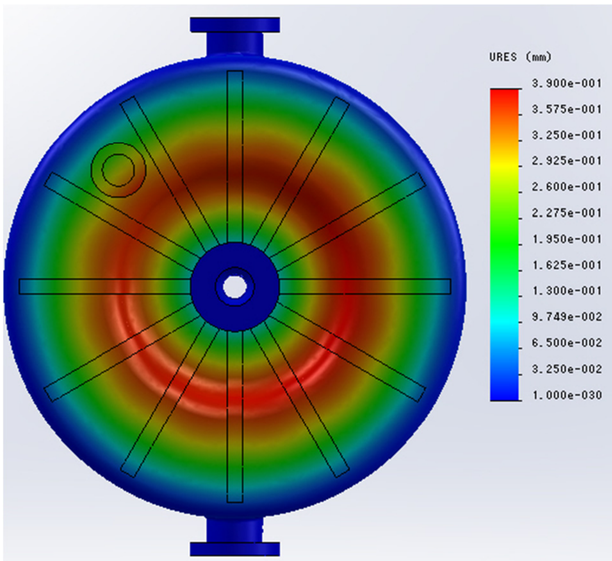

Figure 5: The image of the maximum displacement of the test model with ribs.

This cavity tuning method will be adopted for the end-wall tuners. Inward deformation of the end-walls (the region of high electric field shown in the left side of Fig. 4) increases the capacitance and hence reduces the frequency. Both the tuning effects of the tri-spoke cavity and the test model are shown in Fig. 6. As shown in Fig. 6, both the frequency changes of the tri-spoke cavity and the test model decrease linearly with tuning length.

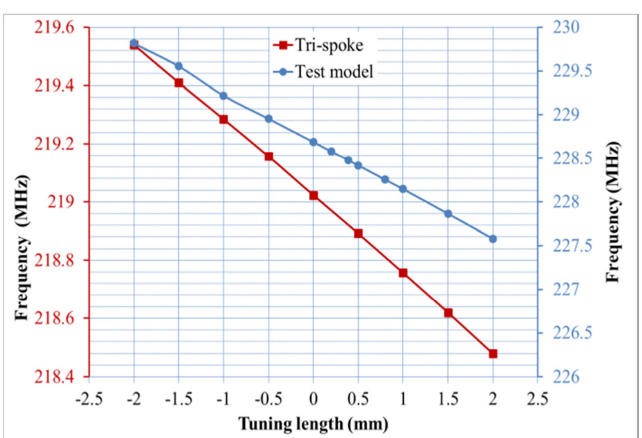

Figure 6: Shifts in resonator frequency of the tri-spoke cavity (red line) and the test model (blue line).

The details of coupler design are not finalized, but calculations of the external Q (Qext) are being simulated. The simulated results obtained using MWS are presented in Fig. 7.

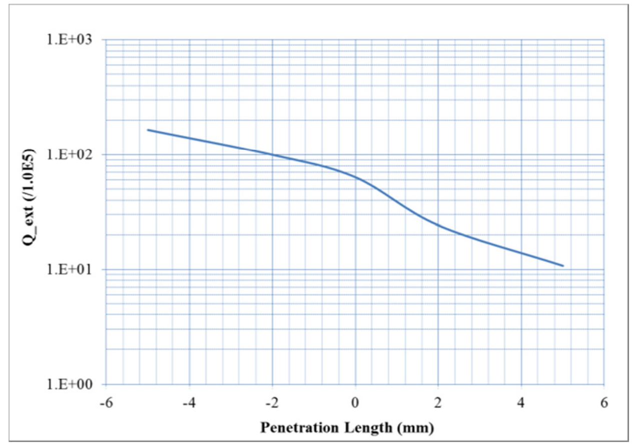

Figure 7: The Qext dependence on the penetration length of the coupler.

FUTURE WORK

There are three important works to be considered in the future: post processing, design of the power coupler, and the design of the helium and vacuum vessels. For post processing of the cavity, such as surface polishing, cleaning, and baking, we have begun to study the basis of these techniques and prepare the equipment for initial research. The power coupler will be designed as a coaxial structure with inner and outer conductors and is required to contain both warm and cold insulating windows, which enable the whole coupler to be divided into warm and cold sections. The design of the helium vessel and the vacuum vessel will be considered after the measurements of the fabrication model are complete.

REFERENCES

[1] Y. Yano, Nucl. Instr. and Meth. B261 (2007) 1009.
[2] Y. Higurashi, *et al.*, in Proceedings of IPAC10, Kyoto, Japan, THPEC060, (2010).
[3] K. Yamada, *et al.*, Proceedings of the IPAC10, Kyoto, Japan, MOPD046, (2010).
[4] K. Suda, *et al.*, Proceedings of the IPAC10, Kyoto, Japan, THPEA023, (2010).
[5] L. Lu, N. Sakamoto, et al., Proceedings of the SRF2011, Chicago, USA, MOPO028, (2011).
[6] L. Lu, N. Sakamoto, et al., Proceedings of IPAC2012, New Orleans, USA, WEPPC018, (2012).
[7] "CST Microwave Studio ™", Version 2011
[8] E. Zaplatin, W. Braeutigam, et al., Proceedings of the EPAC2004, Lucerne, Switzerland (2004).
[9] G. P. Zinkann, S. Sharamentov, et al., Proceedings of PAC2005, Knoxville, Tennessee, USA, WPAT082, (2005).