STATUS OF SUPERCONDUCTING QUARTER WAVE RESONATOR DEVELOPMENT AT MHI

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Abstract

MHI's activities for development of Superconducting Quarter Wave Resonator (QWR) are reported. MHI has experiences of developments and fabrications of several superconducting ellipse cavities. And now MHI is developing the superconducting QWR for heavy ion accelerators.

INTRODUCTION

Mitsubishi Heavy Industries (MHI) has supplied the superconducting RF cavities and the cryomodules for various electron accelerator projects, such as a STF and c-ERL project at KEK [1][2]. Moreover, MHI is developing the superconducting low beta cavities for proton or heavy ion accelerator using cultivated technique by electron accelerator development. Now MHI develops the superconducting Quarter Wave resonator and cryomodule for RIKEN RI beam Factory(RIBF) upgrade project[3][4] in collaboration with RIKEN and High Energy Accelerator Research Organization (KEK).

This report describes Frequency analysis of QWR cavity, forming test for cavity parts and status of preparation of manufacturing equipment for QWR cavity.

QWR CAVITY AND CRYO MODULE

In collaboration with RIKEN and KEK, MHI designs the prototyping of the superconducting QWR cavity and cryomodule. The cross section and the structure of QWR cavity are shown in Figure 1. The superconducting QWR cavity is made by pure niobium, and the formed or machined parts of QWR cavity are assembled by electron beam welding (EBW). The resonance frequency of the prototype superconducting QWR cavity for RIKEN RIBF upgrade is 75.5MHz, Height is 1055mm and inner diameter is 300mm.In order to correct a machining error and a welding error in process of manufacture, after the subassembly of cavity, it is necessary to perform adjustment processing.

Scheme drawing of the prototype cryostat for QWR cavity is shown in Figure 2. It is the design which can store two superconducting QWR cavities. An operating temperature is 4.2K and 40K Thermal shield cooled by a small refrigerator is installed. [5]

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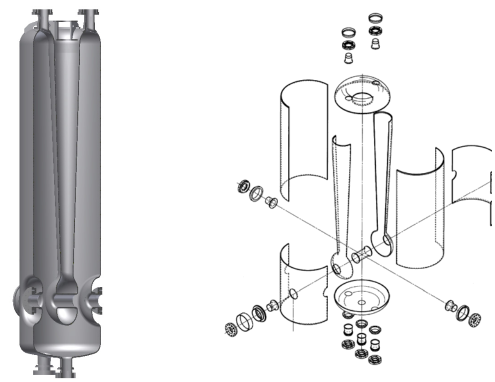

Figure 1: QWR cavity.

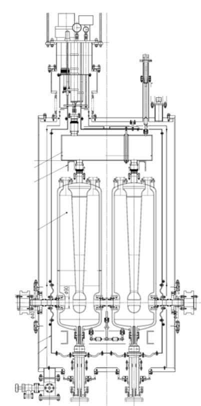

Figure 2: Cryomodule for QWR cavities.

FREQUENCY ANALYSIS OF QWR CAVITY

In order to determine the manufacturing procedure and the adjustment value of parts for frequency tuning, MHI did the frequency analysis using electromagnetic field analysis software MWS in collaboration with KEK. The model of analysis is shown in Figure 3. The following cases were assumed as a dimensional change in a process of manufacture.

A: The length change of the body lower part
B: The length change of the body upper part (A stem is also included)
C: A gap of a drift tube and the body

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Case A is most important. The body lower part would be the last point of welding. If the length change of the body lower part shows the sufficient frequency sensitivity, the frequency adjustment procedure would become simple and easy.

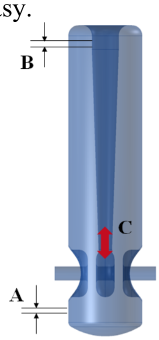


Figure 3: Calculation model of QWR.

Analysis results are shown in Figure 4. The frequency sensitivity of case A is 1.2 kHz/mm, and is about 1/60 of the sensitivity of case B and case C. For example, when a 0.3-mm error occurs into the portions of B or C in welding etc., if it adjusts only in the portion of A, about 18-mm adjustment length is needed, and it is not realistic. These results show that the case A is not enough and the frequency adjustment of QWR cavity needs the combined methods including case A.

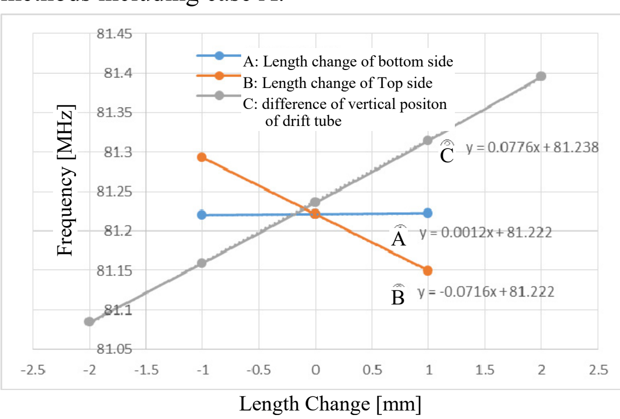


Figure 4: Results of calculation.

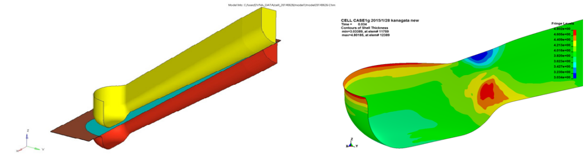
STEM PART FORMING TEST

The drift tube part and stem part of the center of a QWR cavity can be manufactured separately, but in order to reduce the number of welding point, we have tested to press drift tube and stem in one piece.

When MHI develops the forming method for niobium part of superconducting cavity, following procedure is generally adopted.

1) The check of the fabricability and the design of forming tools by forming analysis.
2) The forming test using test material
3) Modification of forming tools and condition
4) The forming test using niobium material.

Elastic-plastic analysis was carried out using analysis software LS-DYNA. We checked the existence of generating of a crack and wrinkles, board thickness distribution, required pressing load, forming die shape, etc (see Figure. 5). Then the forming tools ware designed.



a) Model b) Contour plot of thickness

Figure 5: Forming analysis model and result.

The forming test was done using test material (aluminum), and we checked that it could fabricate without a crack and wrinkles. The drift tube part was 0.5 mm or less in accuracy, and change of thickness was ±10% or less. Although the influence of spring back was seen in the stem part, it was considered that this influence can be repaired by the correction press using a partial forming tool.

Finally, the forming test using a niobium material was carried out. This test region was around the drift tube part which was the most transformation area. We checked that it was being able to fabricate also with a niobium material without a crack and wrinkles. The accuracy of form was of 0.5 mm or less and thickness was ±15% or less (see Figure. 6).

a) Aluminum b) Niobium

Figure 6: Forming test.

QWR CAVITY PRODUCTION EQUIPMENT

MHI is planning to install equipment for surface preparation in order to integrate total process of production of superconducting RF cavity.

MHI already had the electron beam welding equipment, a vacuum heat treatment furnace, and Class10000 (ISO-7) clean room.

In addition to this equipment, the following equipment is due to be installed.

These specifications which are based on the specifications of KEK's equipment were decided after consultation with KEK.

Moreover, MHI and KEK will carry out together the verifications of equipment after introduction.

BCP Equipment

MHI will install the Buffered Chemical Polishing (BCP) equipment for the inner surface polish of QWR cavity. The acid is injected from lower port of QWR cavity, and circulated (see Figure 7).

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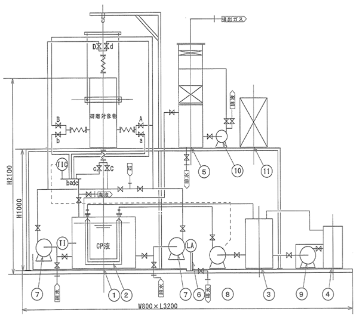
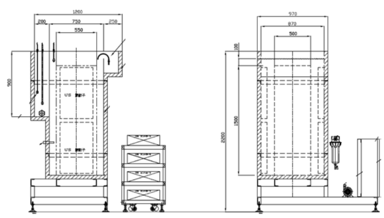


Bath:
HF+HNO_3+H_3PO_4
Capacity:
100 L
Temperature control:
14~20 degree C

Figure 7: BCP facility.

Ultrasonic Cleansing Apparatus

The ultrasonic cleansing apparatus for washing the cavity after BCP will be installed. The cleaning position of cavity is vertical. The rinsing liquid is pure water (see Figure 8).

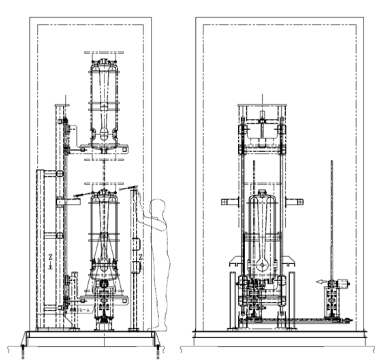


Size:
L500mm x W550mm
x H1500mm
Vibrator:
40kHz, 2000W x 4
Rinsing liquid:
Pure water

Figure 8: Ultrasonic rinsing equipment.

HPR Equipment

The High Pressure Rinse (HPR) equipment and the ultrapure water system for injecting and washing high-pressure ultrapure water on the surface in a cavity will be installed. This equipment is installed in Class10000 clean room in our factory, and the cavity after washing is taken out in the clean area as described in Figure 9.

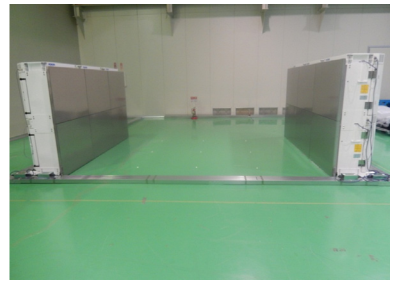


Water pressure:
10MPa (Max)
Flow rate:
10 L/min
Rinsing liquid:
Ultra-pure water

Figure 9: HPR Equipment.

Clean Area

Class100 (ISO-4) clean area is newly established in the existing Class10000 (ISO-7) clean room. Clean area passes a coherent air current from a side wall, and generates clean room (See Figure 10).



Cleanliness:
Class 100 (ISO-4)
Type:
Horizontal coherent flow from side wall
Location:
Inside of class 10000 clean room

Figure 10: Clean area.

FUTURE SCHEDULE

MHI will finish the detail design of superconducting QWR cavity and cryostat in collaboration with RIKEN and KEK and a prototype QWR cavity is manufactured. Moreover, the Introduction of new production equipment will be completed by October, 2015, and a verification examination will be carried out in collaboration with KEK after that. The inner surface-preparation work of the prototype superconducting QWR cavity is due to be done from February, 2016 after the completion of verification test.

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