DEVELOPMENT FOR MASS PRODUCTION OF SUPERCONDUCTING CAVITY BY MHI

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Abstract

Mitsubishi Heavy Industries (MHI) has developed the manufacturing process of superconducting cavities for a long time. In this paper, recent progress of our work will be reported.

INTRODUCTION

MHI has improved our superconducting technology to take part in the production design and manufacturing of the cryomodules including the superconducting cavities. Figure 1 shows the schematic view of cERL in KEK. MHI produced the injector module of cERL shown in figure 2 which contains three 9-cell cavities. We performed the production design and fabrication of the parts and assembly of the cryomodule at KEK. We also fabricated the main accelerator module for cERL shown in figure 3. The assembly of the cryomodule was also performed by MHI at KEK except the assembly in the clean room. These cryomodules conform to Japanese high pressure gas safety law [1][2][3].

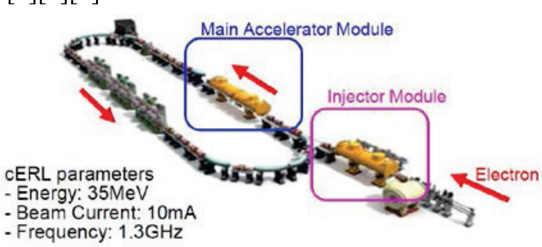

Figure 1: Schematic view of cERL in KEK.

Figure 2: Injector module of cERL in KEK.

Figure 3: Main accelerator module of cERL in KEK.

The high intensity electron gun will be requested for the next generation ERL. As a plan for the future, we have developed SRF electron gun in collaboration with KEK [3]. We designed the 1.3GHz 1.5-cell elliptical cavity for the superconducting RF electron gun. The spec and the electric field distribution of the gun are shown in figure 4. As the first step, we designed the shape of the cavity and analysed the electric field distribution by SUPERFISH.

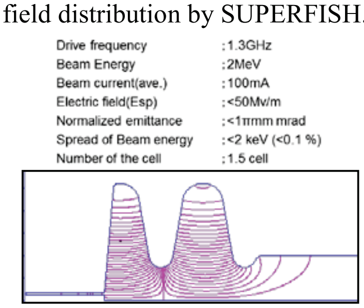

Figure 4: Spec(left) and electric field distribution (right) of superconducting RF electron gun.

Figure 5 shows the simplified schematic and the photos of the parts before assembly.

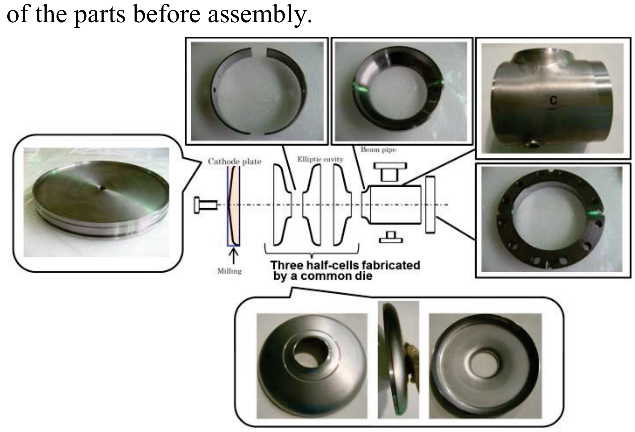

Figure 5: Manufacturing procedure of the half-cells.

We fabricated the Prototype#1 shown in figure 6. This cavity is under the preparation of the vertical test in KEK. The result will be reported soon. Now, we are studying the

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choke structure and the coupling calculation of the input coupler and so on.

Figure 6: Prototype#1.

Cu plating for the input coupler requires high intensity electric conductivity to suppress RF resistance and low thermal conductivity to supress the heat transfer. Thin copper plating film on the stainless steel plate and high RRR are required.

We are developing the manufacturing method of high power input coupler for the purpose of low RF loss for high power and low heat penetration in collaboration with KEK. We fabricated the Cu plating sample by periodic reverse copper electroplating. And, we measured RRR of the Cu plating on the stainless steel bars. 3 samples (t=10,20,30 μm Cu plating on t=1mm stainless steel plate) were prepared and measured RRR of each sample. However, it is difficult to measure directly the resistivity of the Cu plating. So we measured both Cu plated/unplated samples and calculated RRR. Heat treatment also has an influence on the resistivity. Therefore, we measured both with/without heat-treated(800℃) samples.

Figure 7 shows the cross section of the samples. We measured the thickness of the sample by the laser microscope.

Figure 8 shows the results of the measurement. We found RRR of Cu plating without heat treatment satisfied the requirement. On the other hand, the heat treatment decreases RRR of Cu plating on stainless steel. We are preparing the measurement of the chemical composition of the Cu layer.

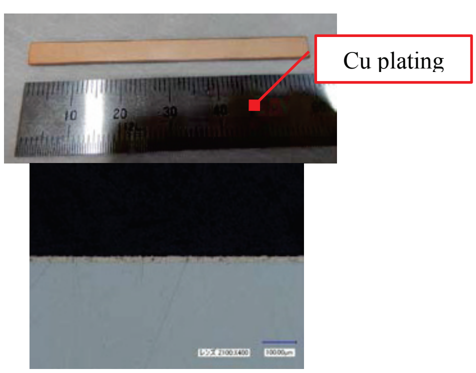

Figure 7: Sample (left), Cross section of the samples (right).

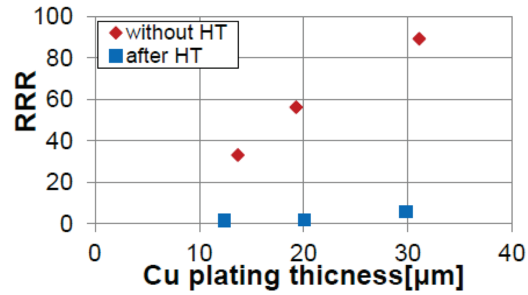

Figure 8: Result of the measurement.

DEVELOPMENT OF FABRICATION METHOD FOR MASS-PRODUCTION

In future, the mass production of the superconducting cavities will be required for the main linac of ERL. MHI has planned to have the factory to manufacture 200 cavities in 3 years. From now on, the activities of mass production performed by MHI will be introduced.

MHI's Development Histories of the Cavity Fabrication Methods

Table 1 shows our development histories of the cavity fabrication methods. Our technical developments are shown as below: [3][4][5]

- Welding process for stiffener from EBW to LBW.
- Welding process for baseplate EBW and LBW.
- Number of the cavity for final welding per 1 chamber from 1 cavity to 4 cavities.
- Seamless dumbbell applied to 2-cell cavity.
- Unification monitor port and flange

Table 1: Development Histories for Mass-production

Phase	Cavity No.	Welding process for stiffener	Welding process for baseplate	Number of the cavity for final welding per 1 chamber	New process
R&D	MHI-A 9-cell	LBW	EBW	1	
	MHI-B 2-cell	-	-	1	Seamless dumbbell
	MHI-C 9-cell	LBW	LBW	1	9seam/ 1batch
	MHI-D 9-cell	LBW	EBW	1 +3 dummy	Unification of monitor port and flange
STF 2-a	#23-26	LBW	EBW	2	Using retainer ring for monitor port
STF 2-b	#27-30	LBW	EBW	2	

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LBW for the Welding Process for Stiffener

Figure 9 shows the laser welding machine which is applied to the welding of the stiffener rings. Laser generated by the oscillator is switched by the beam switch and directed to the welding station through the fiber. This laser welding machine can be used for the welding in this station and also other stations continuously [3][4][5].

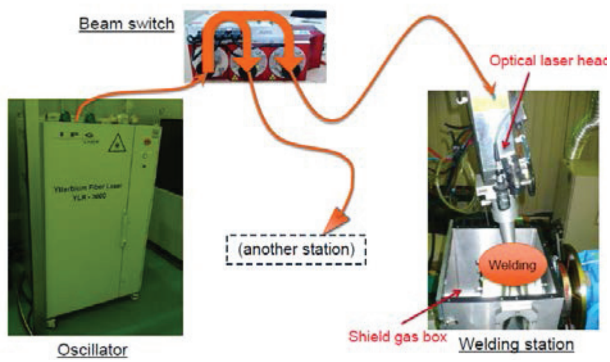

Figure 9: Composition of LBW machine.

Seamless Dumbbell

Figure 10 shows the process of the manufacture of the seamless dumbbell. The seamless pipe is made by deep drawing from a Niobium sheet and cut both end. We use spinning for the forming but not use hydroforming. We can process from "Set of the pipe" to "Turning for stiffener" without grip-changing. We fabricated the 2-call superconducting cavity called MHI-B by using the seamless dumbbell, and performed the vertical test in JLab in collaboration with JLab and KEK. This cavity reached 32.4[MV/m] [3][4][5].

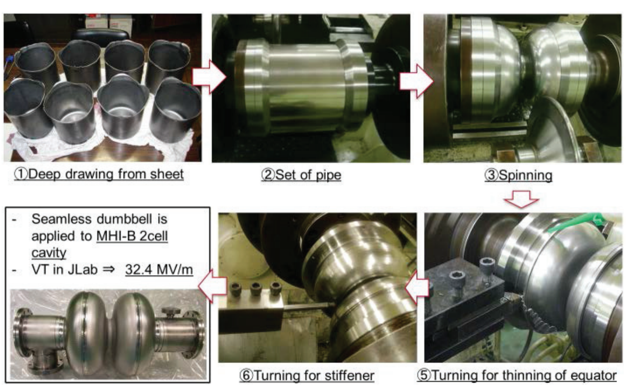

Figure 10: Process of the manufacture of the seamless dumbbell.

Unification of Monitor Port and Flange

Figure 11 shows the superconducting cavity called MHI-D. We succeeded to reduce 3 parts and 3 welding line by the combination of pick up port and flange. We changed the materials for pick up port from Niobium Titanium alloy and pure Niobium to ASTM Gr-2 Niobium. We performed the leak test for it at 2K and confirmed there was no leak [4][5].

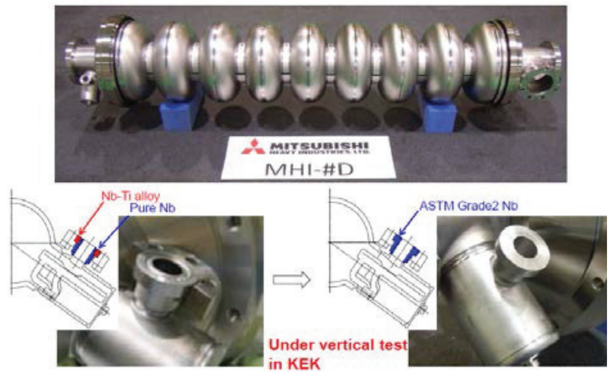

Figure 11: Result of the measurement.

Batch Process

MHI has the EBW machine which can contain four 9-cell cavities by vertical position and weld them in one batch. We succeeded in welding all seams of equator of four cavities in one batch (see Fig. 12). One of these cavities reached 34.9[MV/m] by the vertical test in KEK [4][5].

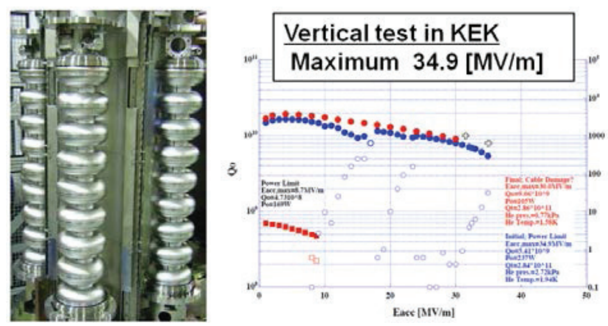

Figure 12: Batch process.

SUMMARY

- MHI fabricated "Injector module", "Main accelerator module" for KEK cERL
- MHI has improved mass-production method shown as below.
  - Laser beam welding
  - Seamless dumbbell
  - Changing the material of HOM coupler
- MHI is currently developing "SRF electron gun", "Coupler" now.

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