

DEVELOPMENT FOR MASS PRODUCTION OF SUPERCONDUCTING CAVITY BY MHI

T. Yanagisawa[#], H. Hara, K. Kanaoka, K. Okihira, K. Sennyu, Mitsubishi Heavy Industries, Ltd.,
 Mihara, Hiroshima, Japan

Abstract

MHI's activities for superconducting accelerator are reported. MHI has supplied several 9-cell cavities for STF (R&D of ILC project at KEK) and have been considering production method for stable quality, cost reduction and mass production. Furthermore MHI had produced another shape cavities and cryomodules for several R&D projects. These activities are reported in detail.

INTRODUCTION

Mitsubishi Heavy Industries (MHI) has supplied a 1.3GHz superconducting cavity for the STF project (STF is a project at KEK to build and operate a test linac with high-gradient superconducting cavities, as a prototype of the main linac systems for ILC.) for several years [1] [2]. The cavities from MHI-12 to MHI-30 reached $E_{acc} = 33.9 \text{ MV/m}$ on average. This average E_{acc} approaches the ILC target, 35 MV/m . (see Table 1 and Figure 1) And we have developed new techniques for improvement of productivity and for cost reduction for ILC.

On the other hand, MHI has supplied other shape cavities and the cryomodules for KEK's superconducting projects including STF [3]. (see Figure 2) The details of cavity manufacturing techniques and cryomodule for STF are described below.

Table 1: Cavity Production List

| Project | Customer | Production year | Cell-number | Quantity | Remarks |
|---------|----------|-----------------|-------------|----------|--|
| STF | KEK | 2005-2015 | 9 | 30 | MHI-1 to MHI-30 |
| | | 2009-2010 | 2 | 3 | For injector of KEK c-ERL project |
| | | 2010-2011 | 9 | 2 | For main ring of KEK c-ERL project |
| | | 2013-2014 | 1.5 | 1 | For Superconducting RF electron gun of ERL R&D |
| ILC R&D | MHI | 2009 | 9 | 1 | [MHI-A] Deep drawing for HOM cup LBW for stiffener and flange |
| | | 2010 | 2 | 1 | [MHI-B] Seamless dumbbell, Auto buffing |
| | | 2012 | 9 | 1 | [MHI-C] LBW for baseplate Welding all equator line in succession |
| | | 2014 | 9 | 1 | [MHI-D] Nb Gr-2 flange Welding all equator line in succession(4 cavities/1 batch) |

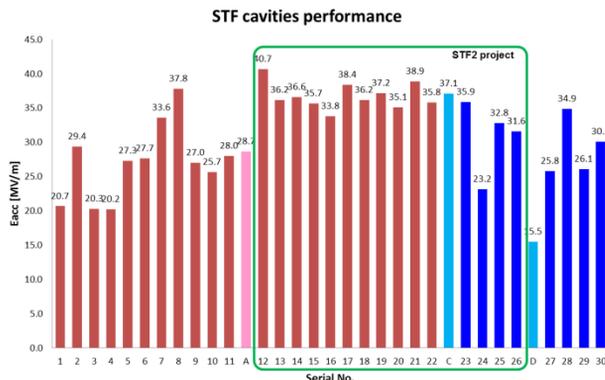
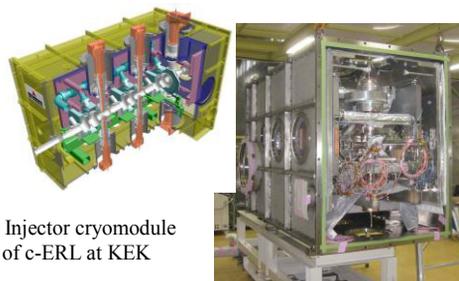
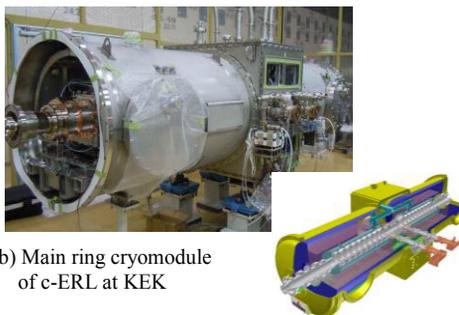


Figure 1: Performance of STF cavities.



(a) Injector cryomodule of c-ERL at KEK



(b) Main ring cryomodule of c-ERL at KEK

Figure 2: Cryomodules for c-ERL at KEK.

MANUFACTURING TECHNIQUES OF CAVITY

Nb Gr-2 Flange

The flanges of Cavity are generally made by Nb-Ti alloy because of the welding quality with niobium and the hardness for vacuum seal. MHI has developed to use the Niobium for cavity flanges. (see Figure 3) This way causes the reduction of number of parts and number of welding.

MHI tested three kind of niobium made by Heraeus.

- ASTM Gr-2 Nb with surface hardening treatment
- ASTM Gr-2 Nb (No treatment)
- RRR300 Nb with surface hardening treatment

After the annealing same as cavity and the thermal cycle test using liquid Nitrogen, three material flanges passed the helium leakage test. From point of view of commercial availability, ASTM Gr-2 Nb (No treatment) was adopted.

MHI has fabricated R&D cavity (MHI-D) using niobium flanges. During vertical test at 2K, there is no leak from niobium flanges. The E_{acc} (π -mode) of MHI-D was 15.5 MV/m , however the Max E_{acc} of each cell reached 36.6 MV/m by another mode measurement. MHI confirmed that the niobium flange can be applicable to the superconducting cavities.

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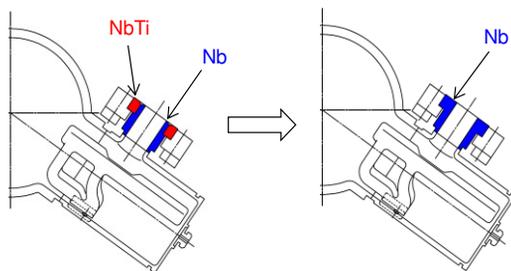


Figure 3: Nb Gr-2 flange of cavity.

Welding Method

MHI has the EBW machine which is enough to weld the 9-cell cavity by vertical position. (see Figure 4) This machine can weld all seams of equator in one batch.

This machine can set the four cavities in one batch. MHI -25 and MHI-26 cavities were set together and weld in one batch. MHI-D cavity was set together with three dummy cavities and was welded by the same procedure of four cavities welding in one batch. Thereafter, MHI-27 to MHI 30 cavities were welded in one batch. Welding has succeeded. Vertical test results of these cavities are shown in Fig. 1.

This method will cause improvement of productivity.

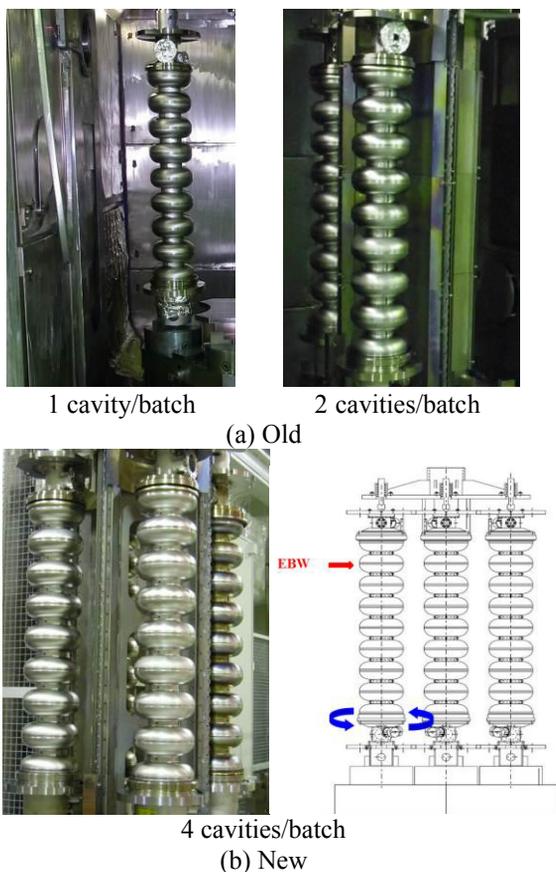


Figure 4: Welding of cavity.

CAVITIES FOR OTHER PROJECT

MHI has supplied other type superconducting cavities for several projects. Figure 5 is the 1.5-cell cavity for the superconducting RF gun of ERL R&D in KEK. Frequency of this cavity is 1.3GHz. This cavity is under vertical test at KEK.

MHI has produced the TESLA(Euro-XFEL)-shape cavity. Two TESLA-shape cavities were supplied for KEK R&D in 2014. (see Fig. 6)



Figure 5: 1.5-cell cavity for superconducting RF gun.



Figure 6: TESLA-shape cavities.

CRYOMODULES

MHI has developed various cryomodules for superconducting RF cavity project.

STF2 cryomodule (see Fig. 7) is composed of two parts, "CM-1" and "CM-2a". CM-1 module stored eight 9-cell cavities and was designed as the standard module of ILC. CM-2a module stored four 9-cell cavities. For some restrictions of this project, MHI has modified from standard design and developed original jigs and procedures [4]. Cool-down test was finished successfully in 2014. This cryomodule is under preparation of RF power test.

MHI has supplied two type cryomodule for cERL (Compact Energy Recovery Linac) project at KEK. Injector cryomodule (see Fig. 2(a)) stored three 2-cell cavities produced by MHI. The shape of vacuum vessel is cubic and this cryomodule has characteristic thermal shield. Main linac cryomodule (see Fig. 2(b)) stored two 9-cell cavities produced by MHI. Two types of cryomodules were installed to the cERL beam line in 2012.

Three cryomodules were governed by high pressure gas safety act at Japan.



(a) Cold mass of STF2 cryomodule



(b) Assembly



(c) After installation

Figure 7: STF2 cryomodule.

CONCLUSION

- MHI has supplied several superconducting cavities and have improved the quality of cavity step by step and almost achieved the ILC spec.
- MHI has supplied several cryomodules for superconducting RF project using the MHI's original design.
- MHI keeps proposing and verifying various improvements steadily in according with general principle of cost reduction for realizing ILC as an industry.

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