STATUS OF SUPERCONDUCTING CAVITY AND CRYOMODULE DEVELOPMENT AT MHI

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Abstract

MHI's activities for superconducting accelerator are reported. MHI have supplied several 9-cell cavities for STF (R&D of ILC project at KEK) and have been considering production method for stable quality and cost reduction. And we had fabricated and installed cryomodules for STF and ERL R&D. These activities are reported in detail.

INTRODUCTION

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-26 reached Eacc= 35.2MV/m on average. This average Eacc achieves the ILC target, 35MV/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 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	2005-2014	9	26	MHI-1 to MHI-26
		2013-	9	4	MHI-27 to MHI-30 (under fabrication)
ERL		2009-2010	2	3	For injector of KEK c-ERL project
		2010-2011	9	2	For main ring of KEK c-ERL project
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）

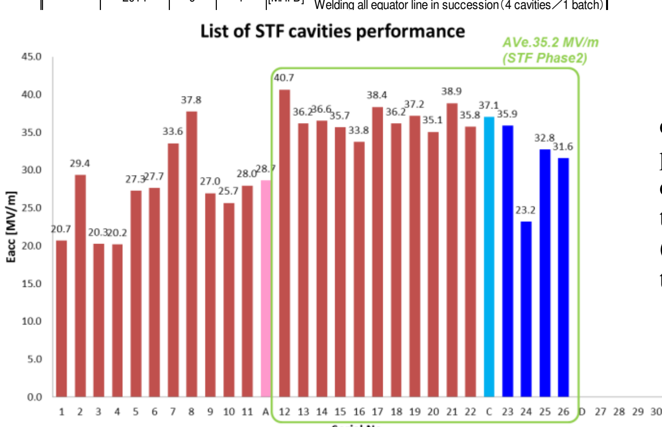
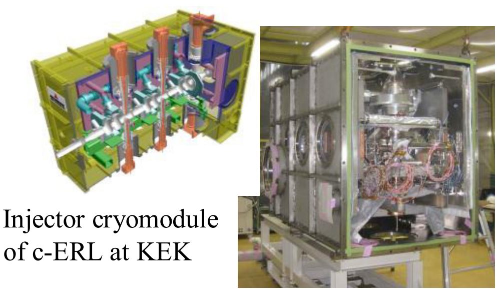
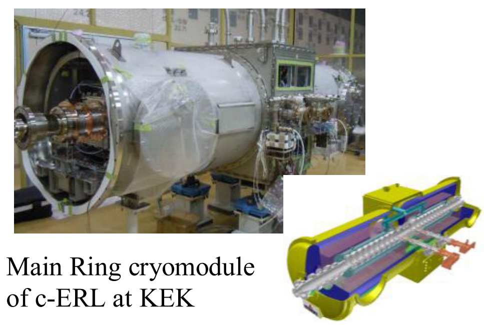


Figure 1: List of STF cavities performance.



(a) Injector cryomodule of c-ERL at KEK



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

Figure 2: Cryomodules

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, ASTEM Gr-2 Nb (No treatment) was adopted. MHI has fabricated R&D cavity (MHI-D) using niobium flanges. Hereafter we will check the effect of cavity performance.

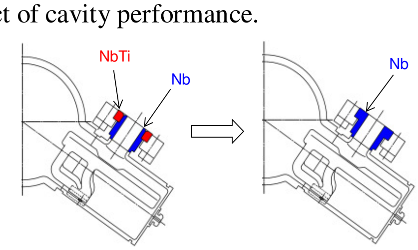


Figure 3: Cavity flange

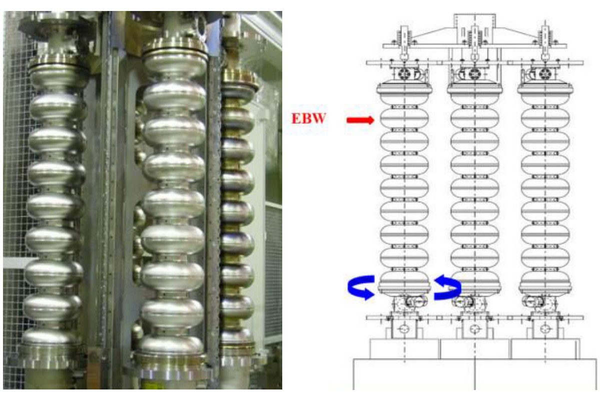
Welding Method

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. MHI -25 and MHI-26 cavities were set together and weld in one batch.

This machine can set the four cavities 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. Welding has succeeded. This method will cause improvement of productivity.

1 cavity/batch 2 cavities/batch

(a) Old



4 cavity/batch

(b) New

Figure 4: Welding of Cavity

DEVEROPMENT OF CRYOMODULE

MHI has developed the cryomodule for STF. (see Figure 5) This module 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.

Figure 5: Cryomodule for STF

Vacuum Vessel

The outside of the cryomodule is a vacuum vessel. The vacuum vessel of CM-1 module is about 13m long. We divide the vessel into three parts because of portability, productivity and utilization of existent assembly jigs.

Three parts were assembled in turn. We made plural support points on the components which would be installed. And we made the jigs for hanging and guide rail inside of vessel (see Figures 6+7). During the assembly of vacuum vessel parts, we changed the support point with the moving of vessel.

The connections of the vacuum vessel parts are flanges. The leakage test point increased but it was successfully finished.

Figure 6: Assembly of Vacuum vessel

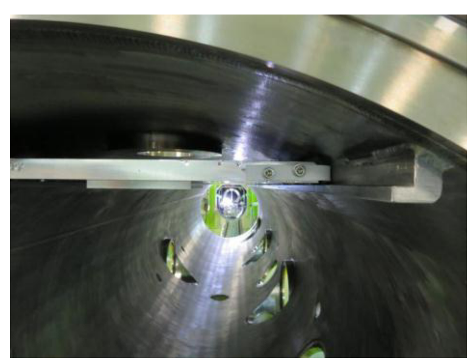


Figure 7: Assembly of Vacuum vessel

ISBN 978-3-95450-142-7

Flange Connection of Pipes

The cryomodule has many pipes, for example liquid helium supply, Gas helium return and Liquid nitrogen line. MHI designed that all connections of pipes were flanges and metal gaskets (see Figure 8) because the design of cryomodule had to be considered the disassembly.

Figure 8: Connection flanges of pipes

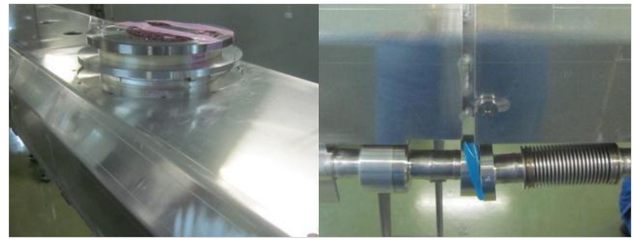
Thermal Shield

The cryomodule has the thermal shield for protection of thermal invasion from outer side to low temperature area. The thermal shield is supported by the part which is named "support post".

In the conventional design, the connection point between the thermal shield and support post can slide because of absorption of thermal contraction. And thermal connection is guaranteed by using movable cable.

MHI's designed that the thermal shield is divided and each divided thermal shield is fixed to each support post. The connection between divided thermal shields has the slide function and bellows. (see Figure 9) These functions absorb thermal contraction.

MHI design might increase protection ability of thermal invasion at support post.



(a) Support post & Thermal shield (b) Connection part

Figure 9: Thermal shield

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 cavities 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.

ACKNOWLEDGMENT

Special thanks to S. Yamaguchi, E. Kako, H. Nakai, T. Shishido, Y. Yamamoto, K. hara at KEK for these cavities and cryomodule development.

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