STATUS OF SUPERCONDUCTING CAVITY DEVELOPEMT FOR ILC AT MHI

K. Sennyu[A)], H. Hara[A)],H. Hitomi[A)], T. Yanagisawa[A)], K. Kanaoka[A)], M. Matsuoka[B)]
[A)] Mitsubishi Heavy Industries, Ltd., Kobe, Hyogo, 652-8585, Japan
[B)]Mitsubishi Heavy Industries, Ltd., Tokyo, 108-8215, Japan

Abstract

MHI has supplied 1.3GHz superconducting cavities for the Energy Recovery Linac (ERL) project and the International Linear Collider (ILC) R&D project (STF: Superconducting RF Test Facility in KEK) to KEK in Japan for several years. [1] We are improving the technology to design and fabricate the superconducting cavities for ILC R&D step by step. The status of superconducting cavity development for ILC at MHI is described in this paper.

INTRODUCTION

As shown in Table 1, we have manufactured a 1.3 GHz superconducting cavity and accumulated much technology and know-how about manufacturing cavities for several years.

As shown in Fig. 1, the vertical test of 5 superconducting cavities for the STF Phase 1.5(S1-Global) project was carried out. [2][3] The welding conditions were improved in order to improve the cavity's performance compared with the cavity for STF Phase 1.0. [4] In a recent vertical test, some cavities reached E_{acc}= 31.5MV/m, which are the specifications for ILC. Some efforts and preparations to improve their performance were done by KEK. [5][6]

So it was proved that MHI has technology to manufacture superconducting cavities.

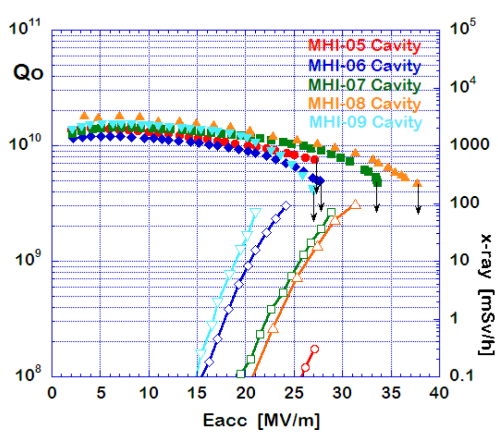


Figure 1: Q-E curve in the recent vertical test for STF 1.5 cavities (MHI #5- #9).

ACTIVITIES FOR ILC

Now we are manufacturing 11 cavities for the STF 2.0 project and carrying out the R&D to improve the productivity of cavities while guaranteeing their performance for ILC. New techniques for improving productivity were considered and we tried to use them in the manufacturing cavity.

Table 1: Production list of the superconducting cavity by MHI

Project	Customer	Production year	Cell-number	Quantity	E_{acc} max at vertical test (MV/m)	Q_0 at operating (final) E_{acc}	Remarks
STF Phase1	KEK	2005	9	4	20.2 to 29.4	2×10^{10}	
ERL R&D		2006	1	2	31	9×10^{9}	
		2007	9	1	15	2×10^{9}	
		2007	2	1	43.7	3.4×10^{9}	w/o HOM pick up antenna
		2008	2	1	40.9	3.3×10^{9}	
		2009	9	1	before testing		
STF Phase1.5		2007	9	2	31.1	7.5×10^{9}	
		2008		3	37.7	4.8×10^{9}	
		2009		2	under testing		
STF Phase2		2010	9	11	under manufacturing		
ILC R&D	MHI	2009		1	before testing		

FABRICATING CAVITIES WITH NEW TECHNIQUES

We developed new techniques to improve the productivity and fabricated one cavity with them as a prototype (MHI-#A). Producing a cavity requires the use of two main techniques. One is a manufacturing method using deep drawing for an HOM coupler, and the other is a technique using laser beam welding (LBW) to produce a dumbbell and beam tube.

By adopting these new techniques, we reduced the manufacturing costs and manufacturing times of the cavity to less than 70% of those of the present procedure. Details of the new techniques are shown below.

Figure 2: 1.3GHz superconducting 9-cell cavity with new techniques. (MHI-#A).

Deep drawing for HOM Coupler

The outer conductor of an HOM coupler was formed by deep drawing from a niobium sheet and bulge forming in place of machining as shown Fig. 3. A nipple to tune the notch frequency was fixed by electron beam welding (EBW) on the top of the outer conductor.

The smoothness of the inner surface after deep drawing was the same as the surface of the material. So finishing of the inner surface was not necessary.

(a) (b)

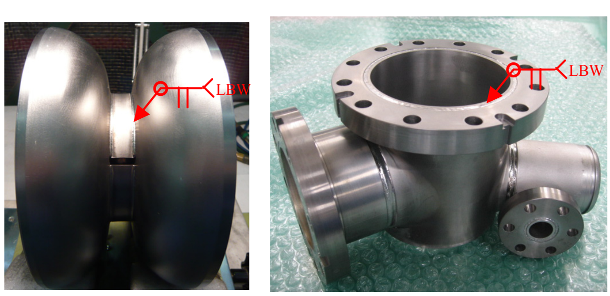
Figure 3: (a) Machining for outside after bulge forming and deep drawing, (b) Welding a nipple.

LBW for dumbbells and beam tubes

Joints with flanges and beam tubes, and joints with a stiffener and half-cell used LBW in place of EBW as shown in Fig.4. LBW has the advantage of a shorter cooling time after welding in comparison with EBW and the equipment needed is cheaper.

Because the quality of the welding bead was equivalent to EBW and the inner surface of the cell was also polished by electro-polishing (EP), we assumed that LBW could be used in a product.

It will be necessary to verify the prototype cavity's performance in a vertical test.



(a) (b)

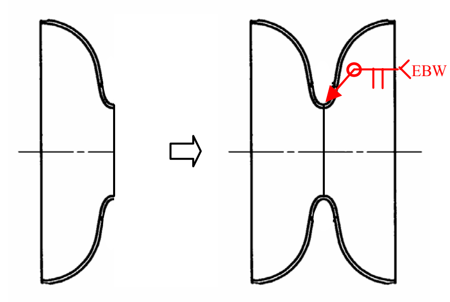
Figure 4: (a) Welding stiffener and dumbbell, (b) Welding beam tube and flange.

R&D ON MANUFACTURING DUMBBELLS

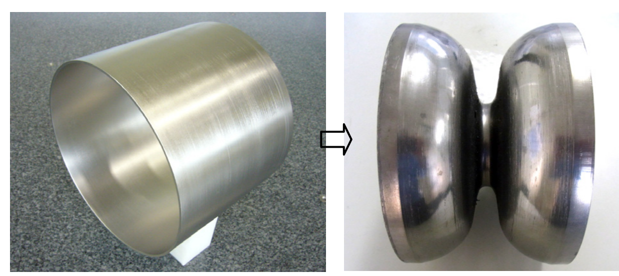
The dumbbell was assembled from a joint with two cells which were formed in a bowl shape by pressing them from a niobium sheet (fig. 5 (a) and (b)).

We tried to form a dumbbell using the technique of spinning fabrication from a seamless pipe (Fig.5(c) and (d)). The seamless pipe was obtained by deep drawing from a niobium sheet in place of spinning fabrication.

The quality of the inner surface became sufficient for the product to be usable with some slight finishing as shown in Fig. 6.



(a) (b)



(c) (d)

Figure 5: (a) Half-cell, (b) Dumbbell, (c) Seamless pipe, (d) Dumbbell made from pipe formed by spinning.

(a) (b)

Figure 6: Inner surface of seamless dumbbell (a) Made from seamless pipe formed by spinning [7] (b) Made from seamless pipe formed by deep drawing.

STF PHASE 2.0

Now 11 new cavities that have conformed to high-pressure gas safety laws in Japan are being manufactured for the STF Phase 2.0 project.

In order to conform to the law, we are designing cavities based on analysis of their strength and considering how to inspect their cavity quality. We are advancing the applications of the high-pressure gas safety laws.

The problems with manufacturing for STF phase 2.0 are as follows:

Quality control of niobium material

In order to reduce cracks and dirt on niobium material as much as possible, it is necessary to clarify how they are generated and control the causes.

Stable quality

There are many mistakes in manufacturing in the end-group with comparatively large number of manufacturing processes. Their productivity is also low because they are conveyed to different places according to the location of the production facility.

So it is necessary to optimize the manufacturing process and to improve the productivity including transportation to ensure a stable quality.

Helium jacket

Because variations in the cavity length arise when the weld shrinks, the full length of a jacket cannot be exactly determined. Moreover, the clearance between a cavity and a jacket is small.

Frequency tuner

It is necessary to improve the accuracy of attaching a tuner.

FUTURE PLAN

- In order to make sure that the new techniques do not have problems in terms of cavity performance, the prototype cavity (MHI-#A) will be tested in a vertical test at KEK. After that, we will adopt the new techniques in producing regular products.
- The inspection should be simple while guaranteeing quality and safety. So we should re-examine the items of inspection, frequency, judgement standard and method.
- It takes a long time to manually finish the inner surface of the cell to remove small defects or pits. Finishing should be done automatically with a robotic finisher. We have finished conducting a basic test on that and we are now considering developing a product.
- In order to improve productivity and reduce manufacturing costs, we are considering whether or not to re-examine the manufacturing procedure.

CONCLUSION

- We have supplied some 1.3GHz superconducting cavities for STF projects at KEK for a number of years. We have improved the technology to design and fabricate superconducting cavities for ILC.
- 11 cavities for the STF Phase 2 project that conform to high-pressure gas safety laws in Japan are being manufactured.
- We used new techniques to manufacture a prototype cavity aiming to improve productivity.
- We formed a seamless dumbbell with a spinning fabrication technique. The quality of the seamless dumbbell was sufficient for use as a product.

AKNOWLEDGMENT

Special thanks to S. Noguchi, E. Kako, Y. Yamamoto, T. Shishido, K. Watanabe, M. Satoh at KEK for this paper.

REFERENCES

[1] K. Sennyu, et al., "Design and Fabrication of Superconducting Cavities for Industrialization", 13th SRF2007, Beijing, China, (2007), WEP48

[2] E. Kako, et al , "Recent Vertical Test Results of KEK Cavities", ILC10, Beijing, China (2010)

[3] Y. Yamamoto, et.al.,"Summary of Vertical Tests for S1-Global Project in KEK-STF", IPAC'10, Kyoto, Japan (2010)

[4] E. Kako, et al., "Cryomodule Tests of Four Tesla-like Cavities in the STF Phase-1.0 for ILC", PAC09, Vancouver, Canada, (2009), TU3RAI04

[5] K. Watanabe, et al., "Techniques of Superconducting Cavity for Improvement Cavity Performance at KEK-STF", IPAC'10, Kyoto, Japan (2010)

[6] E. Kako, et al., "Preparation Status of Cryomodule Tests of Tesla-like Cavities in S1-Global Project at KEK" , IPAC'10, Kyoto, Japan (2010)

[7] K. Sennyu, et al., "Status of the Superconducting Cavity Development for ILC at MHI", 12th EPAC'08,Genoa, Italy, (2008), MOPD009