RESULT OF MHI 2-CELL SEAMLESS DUMB-BELL CAVITY VERTICAL TEST

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Abstract

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, seamless dumb-bell cavity was one of them. We had fabricated a 2 cell seamless dumb-bell cavity for cost reduction and measured RF performance in collaboration with JLab, KEK and MHI. Surface treatment recipe for ILC was applied for MHI 2-cell cavity and vertical test was performed at JLab. The cavity reached Eacc=32.4MV/m after BCP and EP. Details of the result are reported.

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]. In a recent Vertical Test at KEK, some cavities reached Eacc= 31.5MV/m in first VT, and MHI-12 was also over 40MV/m. At the moment 19 new cavities for STF the Phase2 project involving MHI-12 and conforming to the high pressure gas safety law in Japan have been manufactured and 4 cavities are under testing (see Table 1 and Figure 1). On the other hand, we have developed new techniques for improvement of productivity and for cost reduction for ILC. The MHI-B as the first proto-type cavity using seamless dumb-bell cavity was fabricated and vertical tests were carried out at JLab. The details of MHI-B cavity are described below.

Table 1: Production list

Project	Customer	Production year	Cell number	Quantity	E_{acc} max at VT (MV/m)	Q_0 at operating (final) Eacc	Remark
STF Phase1	KEK	2005	9	4	29.4	2×10^{10}	MHI-1～4
ERL R&D		2006	1	2	31	9×10^{9}	
		2007	9	1	25	5×10^{9}	
		2007	2	1	43.7	3.4×10^{9}	pick up antenna
		2008	2	1	40.9	3.3×10^{9}	
		2009	9	1	28	7×10^{9}	
cERL		2009～2010	2	3	33.4	6.1×10^{9}	
		2010～2011	9	2	25	1.2×10^{10}	@20MV/m
STF Phase1.5		2007	9	2	27.7	5×10^{9}	MHI-5,6
		2008		3	37.8	4.8×10^{9}	MHI-7～9
		2009		2	28	5.1×10^{9}	MHI-10,11
STF Phase2		2010～2014	9	15	40.7	6.2×10^{9}	MHI-12～
		2013～		4	under testing		MHI27～
ILC R&D (MHI R&D)	–	2009	9	1	28.7	1×10^{10}	MHI-A
		2011	2	1	32.4	9×10^{9}	MHI-B
		2012	9	1	37.1	5.2×10^{9}	MHI-C
		2014	9	1	under testing		MHI-D

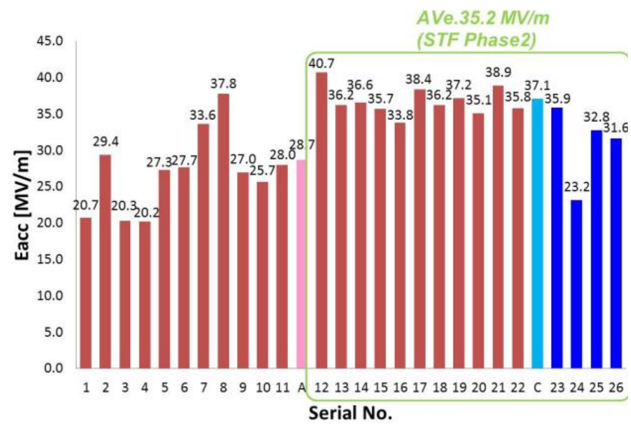


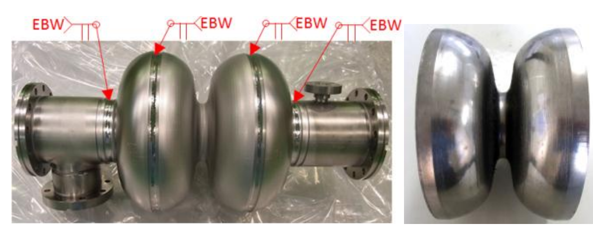
Figure 1: List of STF cavities performance.

FABRICATION OF MHI-B CAVITY (R&D)

MHI-B cavity was manufactured to establish seamless dumb-bell [2][3] as shown figure 2. This cavity was performed several testing at JLab to inspect the influences to cavity performance by seamless dumb-bell.

Feature of MHI-B

- Number of cell is two.
- No welding seam on iris (seamless dumb-bell).
- Finishing for inner surface of dumb-bell is automatic buffing by robot.
- Cell's design is the same as STF cavity



(a) (b)

Figure 2: (a) Over view of MHI-B cavity, (b) Seamless dumb-bell.

Seamless Dumb-Bell

Figure 3 shows the flow of forming for seamless dumb-bell. The quality of inner surface of dumb-bell depends on the condition of the seamless pipe. The seamless pipe was made by deep drawing.

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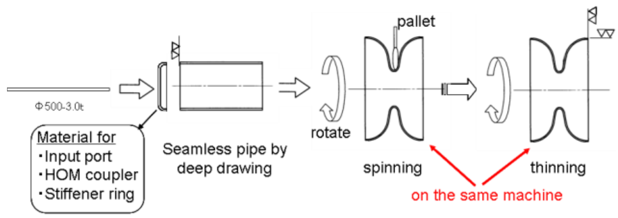

Figure 3: Flow of seamless dumb-bell.

SURFACE TREATMENT AT JLAB

MHI-B cavity was delivered to Jefferson Laboratory on Jan 2013. First inner surface optical inspection of the cavity in as-received condition was carried out by high resolution inspection machine [4] shown in Fig.4.

Figure 4: High resolution inspection machine at JLab.

At JLab, sveral surface treatments were carried out as below.

1. BCP etching
   After first inner inspection, BCP (buffered chemical etching) was carried out. There were third times BCP etching. 50μm removal from innner surface by first eching, 140μm removal by second ething, 30μm removal by third BCP ething.
2. EP etching
   EP (electron polishing) was carried out. 30μm removal from innner surface.
3. Heat treatment
   Heat treated at 800 degree for 2 hours in a vacuum furnace for hydrogen removal and stress relaxation.
4. HPR (high pressure rinsing), clean room assembly, pump down and leak checing.
5. Low temperature baking at 120 degree for 48 hours.

Figure 5 shows the results of inner surface inspection at seamless iris before and after surface treatment above. Before surface treatment, seamless iris had some linear features shown in Fig.5(a). After 50μm BCP etching, linear features became clear (Fig.5(b)) but after 140μm BCP etching, linear features became weakened (Fig.5(c)) and after 30μm EP etching, linear features removed (Fig.5(d)).

Inspections before and after BCP etching (Fig.5(a)-(c)) were carried out at JLab and after EP (Fig.5(d)) was at KEK by Kyoto camera [5] shown in Fig.6.

It is considered that these linear features was caused by spining, but able to remove by BCP and EP etching.

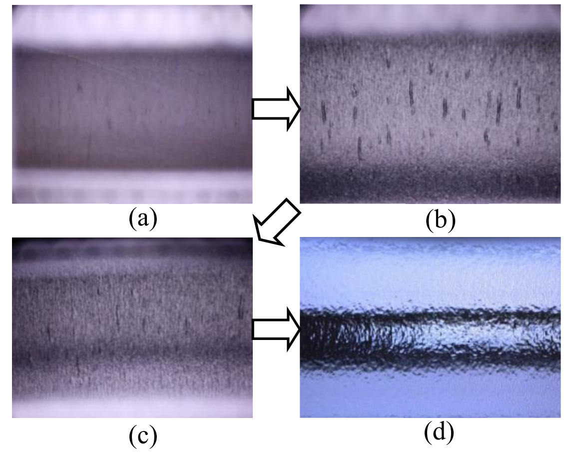

Figure 5: Inspection result at seamless iris.
(a) Before surface treatment. (b) After 50μm BCP
(c) After 140μm BCP. (d) After 30μm EP

Figure 6: Inspection by Kyoto camera at KEK.

VERTICAL TEST AT JLAB

Between and after surface treatment process, vertical test (cryogenic RF test at 2K) of MHI-B cavity at JLab was performed 6 times. Figure 7 shows the setting for MHI-B cavity VT. Details of all VT are described below.

Figure 7: Setting for MHI-B cavity VT

1. First VT
   After third BCP etching and heat treatment at 800 degree and HPR, first VT was performed and found resonant frequency of pi mode at 2K : 1303.867MHz. But VT was failed due to transmitted probe antenna at wrong place.
2. Second VT
   After re-assembly second VT was performed and resulted cavity reaching 8.9 MV/m with $Q_0 = 8*10^9$ without X-ray, limited by quench.
3. Third VT
   Quench location identification with thermometry boards and second sound sensors was perfomed (Eacc and Q_0 were same as second VT). But no distinguish defect was found at predicted point (around the equator) by optical inspection.

4. Fourth VT
   After 30µm EP and HPR, fourth VT was performed but limited by field emission at 8 MV/m during final power rise with highest gradient of 11 MV/m with $Q_0 = 1.3*10^{10}$ during initial power rise.
5. Fifth VT
   Fifth VT after additional HPR was administratively limited at 26 MV/m with $Q_0 = 1*10^{10}$.
6. Sixth VT
   Sixth VT after 120 degree baking was limited by quench at 32.4 MV/m at $Q_0 = 8.9*10^9$ shown in Fig.8.

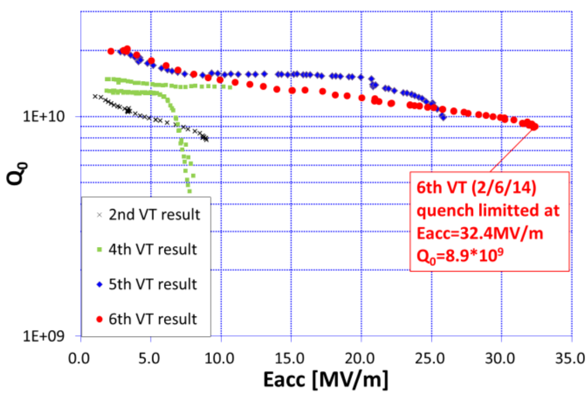

Figure 8: VT result of MHI-B cavity at JLab

All VT results are summarized in Table 2. Eacc of MHI-B cavity reached 32.4 MV/m. This result shows that seamless dumb-bell is a promising alternative dumb-bell fabrication process for lowering ILC cavity fabrication cost.

The next step we need to analyse the cost in mass production and fabricate a 9-cell cavity by seamless dumb-bell and perform RF test in future.

Table 2: Actions carried out at JLab.

No.	Processing	VT result	notes
1	･1st inner inspection ･1st BCP:50micron ･2nd inner inspection ･2nd BCP:140micron(total) ･3rd inner inspection ･Heat treatment in vacuum furnace :800℃x2H ･Final BCP:30micron ･HPR	faild	VT was failed due to probe antenna at wrong place
2	･Probe location correction ･HPR	Eacc = 8.9MV/m $Q_0 = 7.9\times10^9$	Limited by quench
3	･Inspection of inner surface at predicted quench location. ･No outstanding feature observed.	Eacc = 8.9MV/m $Q_0 = 7.9\times10^9$	Same as that from second VT
4	･EP:30micron ･HPR	Eacc =10.7MV/m $Q_0 = 1.3\times10^{10}$	Limited by field emission
5	･HPR	Eacc = 26MV/m $Q_0 = 1\times10^{10}$	Limited by RF cable limit
6	･Baking:120℃x48H.	Eacc =32.4MV/m $Q_0 = 9\times10^9$	Limited by quench

CONCLUSION

- MHI had fabricated MHI-B cavity to establish 2-cell seamless dumb-bell for improvement of productivity and for cost reduction.
- Surface treatments (BCP, EP, heat treatment) and vertical tests for MHI-B cavity at JLab were carried out in collaboration with JLab and KEK.
- Accelerating gradient of MHI-B cavity reached 32.4 MV/m.

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