PROGRESS OF HIGH GRADIENT PERFORMANCE IN STF 9-CELL CAVITIES AT KEK

Y. Yamamoto#, H. Hayano, E. Kako, S. Noguchi, T. Shishido, K. Watanabe, KEK, Tsukuba, Japan

Abstract

Vertical tests for ILC have been carried out since 2008 at KEK-STF. Measured cavities are from MHI#5 to MHI#22, and MHI#12, #13, #17 and #21 reached the ILC specification of $0.8x10^{10}$ at 35MV/m [1]. The MHI cavity was added into the "qualified vendor" for the cavity yield. These four cavities (#12, #13, #17 and #21) had no defect on every EBW (Electron Beam Welding) seam of equator, but not iris and beampipe. On the other hand, the other cavities had a few or several defects on EBW seam. Especially, defect on the EBW seam of the equator is the worst case, and cavity performance is limited "certainly". MHI#10, #15 and #16 cavities were limited at the low gradient by this kind of defect. As for iris region, MHI#14 had large defect at the iris between cell #8 and #9, and the performance was limited by the heavy field emission with "explosive event". However, after the locally mechanical grind for this defect, the cavity performance was drastically improved with no field emission at 37MV/m. In this paper, the recent progress of the cavity performance at KEK-STF will be reported with the "detailed" defect analysis.

INTRODUCTION

The 22 9-cell cavities have been fabricated, measured and assembled for the use of STF-1 (Phase-1), S1-Global [2], Quantum Beam Project [3] and STF-2 (Phase-2) since 2008. During these five years, various measurement techniques have been developed, and used at STF. T-mapping/X-ray-mapping system [4] is important for the identification of the heating location and x-ray emission site. The optical inspection (Kyoto camera) system [5] is crucial for the observation of the defect on the inner surface of the cavity. The replica method [6] using the laser microscope is useful for the evaluation of the defect shape. In STF, the cause of the cavity performance limit and the evaluation of the problematic defect have been studied using these three techniques. Defect on the EBW bead of the equator, which is the worst case, causes the cavity performance to limit considerably. Defect on the EBW bead of the iris, which is the next worst case, causes the heavy field emission, and limits the cavity performance in some cases. In STF, various kinds of problematic defects during vertical test were observed, analyzed, and categorized. Consequently, it becomes clear that there is a correlation between the quench field and the shape of the problematic defect.

VERTICAL TEST RESULT

Figure 1 shows the result of the vertical tests for 9-cell cavities (MHI#12-#22) in STF-2. MHI#12, #13, #17 and #21 reached the ILC specification in one or two vertical tests (first and second pass). MHI#14 reached it at the third vertical test after the removal of the problematic defect by the mechanically local grinding (presented later). MHI#16 was limited by the heating at the HOM coupler at the quenching field of 33.8MV/m. The other cavities are being inspected the cause of the performance limit, mechanically local-ground, and vertical-tested. Figure 2 shows the accelerating gradient in every vertical test for MHI#1-#22. The result of MHI cavity was added to the cavity yield for ILC after MHI#12. Table 1 shows the summary of the best result in vertical tests for STF-2. The average maximum gradient from MHI#12 to MHI#22 in Table 1 is 31.9MV/m, and the total number of vertical test is 18.

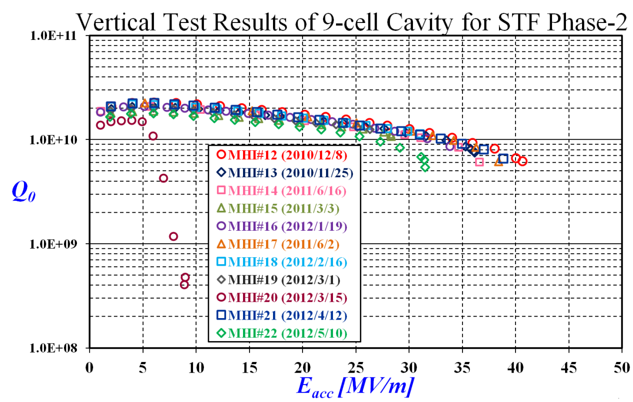

Figure 1: Best Q_0 vs. E_{acc} curves of the vertical tests for MHI#12-MHI#22 in STF-2.

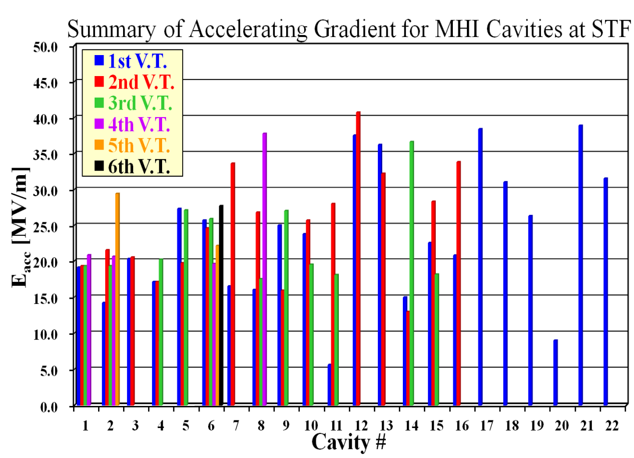

Figure 2: Accelerating gradient in vertical tests of MHI#1-MHI#22.

#yasuchika.yamamoto@kek.jp

ISBN 978-3-95450-115-1

Table 1: Summary of the Best Result in V.T.s for STF-2

Cavity	Max. E_{acc} [MV/m]	Q_0 at Max. E_{acc}	Q_0 at 35MV/m	# of V.T.s
MHI#12	40.7	6.2 x 10^9	9.3 x 10^9	2
MHI#13	36.2	7.5 x 10^9	8.6 x 10^9	2
MHI#14	36.6	6.1 x 10^9	8.4 x 10^9	3
MHI#15	28.3	1.1 x 10^{10}	-	3
MHI#16	33.8	8.6 x 10^9	-	2
MHI#17	38.4	6.1 x 10^9	8.5 x 10^9	1
MHI#18	31.0	1.1 x 10^{10}	-	1
MHI#19	26.3	1.3 x 10^{10}	-	1
MHI#20	9.0	4.8 x 10^8	-	1
MHI#21	38.9	6.6 x 10^9	9.1 x 10^9	1
MHI#22	31.5	5.4 x 10^9	-	1

Case of MHI#15 (Defect on equator bead)

The MHI#15 cavity had two defects on the equator bead (62°) at the cell #2 and slightly away from equator at the cell #5 after the light EP (20μm), and the cavity performance was actually limited by this problematic defect below 24MV/m in the first vertical test. Figure 3 shows the correlation between T-mapping and the position of the problematic defects. The heating on the equator bead at the cell #2 occurred around 23MV/m. On the other hand, the heating was observed slightly away from equator at cell #5 around 30MV/m.

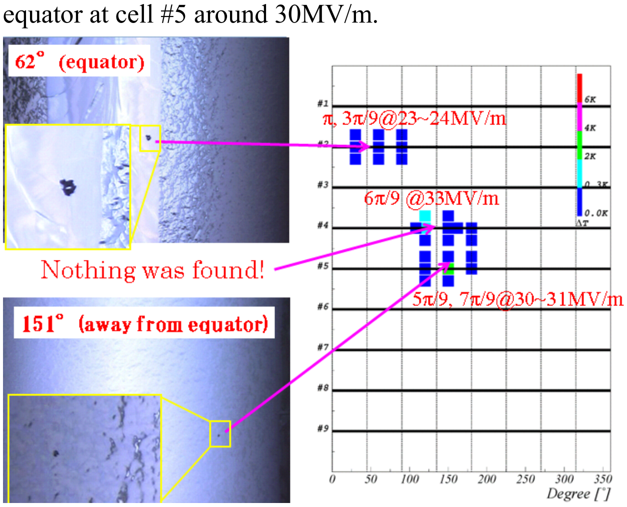

Figure 3: Correlation between T-mapping and the position of the problematic defect in MHI#15.

Case of MHI#14 (Defect on iris bead)

In the inner surface inspection by Kyoto camera after the first vertical test of MHI#14, large bump defect was observed at the bead edge of the iris between cell #8 and cell #9. During the vertical test, the heating by the field emission and the heavy x-ray emission were observed around this defect by the T-mapping and X-ray-mapping system, which had a good correlation each other. Figure 4 shows the correlation between T-mapping and the position of the problematic defects. The angle for the heating location in the Figure 4 is about 100° and 280°, which is opposite each other. This is the clear feature of the field emission.

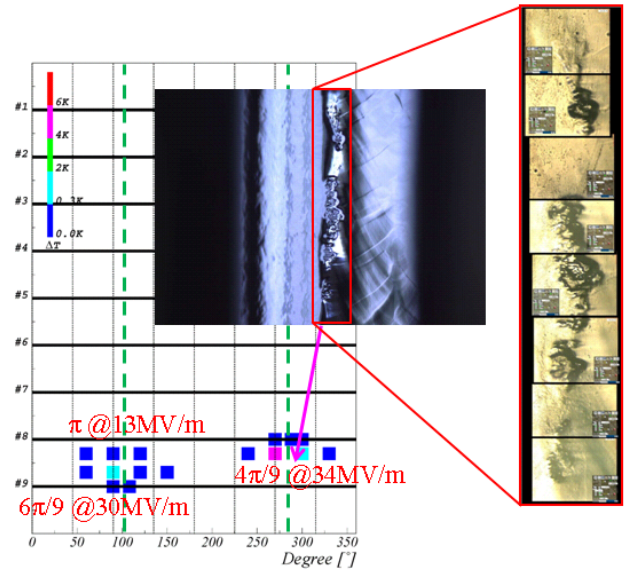

Figure 4: Correlation between T-mapping and the position of the problematic defect in MHI#14.

Effect of Mechanically Local Grind for Defect

For removal of problematic defect, the mechanically local grinding machine is normally used at STF, because it is not removed by EP at all. It takes a few days for the removal at present. However, the effect is remarkable, and the cavity performance is drastically improved. Table 2 shows the effect of the mechanically local grind carried out at STF. Figure 5 shows the status of the mechanically local grind. This method is a key technology to improve the cavity performance as shown in Table 2.

Table 2: Effect of Mechanically Local Grind at STF

Cavity	Change of Max. E_{acc} [MV/m]	Problematic location
MHI#8	16 → 27	Equator at cell #2
MHI#14	13 → 37	Iris between cell #8-#9
MHI#15	23 → 33	Equator at cell #2
MHI#16	21 → 34	Equator at cell #1

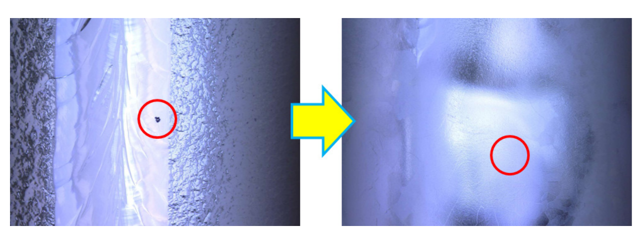

Figure 5: The status of the mechanically local grind.

PROBLEMATIC DEFECT ANALYSIS

Problematic defects observed at STF are separated into three categories, on EBW bead of equator, at bead edge of equator and several cm away from equator (iris and beampipe are excluded). The worst case is a defect on bead of equator, which limits the cavity performance certainly. Therefore, this kind of defect should be removed mechanically by the local grind machine, because it is not removed by Electro-Polishing. Table 3 shows the summary of the problematic defect observed at STF including TOS#2. The shape of the defect is usually analyzed by using the laser microscope after the replica production at STF. "Caldera" [7] in column of Shape means the shape of the problematic defect is not merely a pit or bump, but more complicated.

Table 3: Summary of the observed problematic defect

Cavity	V.T. #	Cell #	Angle	Shape
MHI#5	3rd	5	155	Bump
MHI#5	3rd	6	320	Pit
MHI#8	1st	2	172	Pit
MHI#9	3rd	2	222	Bump
MHI#10	1st	1	354	Caldera
MHI#10	2nd	1	353	Caldera
MHI#10	3rd	1	356	Caldera
MHI#10	3rd	4	123	Pit
MHI#15	1st	2	62	Caldera
MHI#15	2nd	9	353	Caldera
MHI#15	1st & 2nd	5	150	Bump
MHI#16	1st	1	94	Bump
TOS#2	1st	7	173	Pit
TOS#2	1st	8	90	Bump

Figure 6 shows the correlation between the quench field and the size/depth/height of the problematic defect, which was observed around the heating location during the vertical test. The black and blue fitting lines are shown for

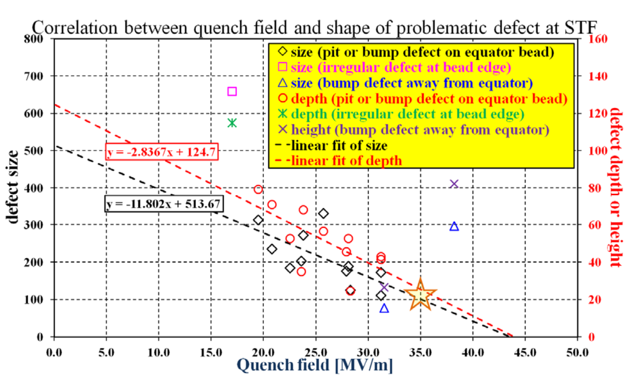

Figure 6: The correlation between the quench field and the problematic defect shape.

the size and the depth of the problematic defect on equator bead, respectively. From these two lines, it is clear that the size of the problematic defect should be below 100μm, and the depth below 30μm, around 35MV/m of the accelerating gradient, as shown by the "star" mark in Figure 6. This information is important for the cavity fabrication, especially searching optimum parameters of EBW.

SUMMARY

In STF, many vertical tests have been carried out since 2008. MHI was added to the "Qualified vendor" in 2010 and totally four cavities (MHI#12, #13, #17 and #21) reached the ILC specification. The mechanically local grind is the key technique for the improvement of the cavity performance. The replica production is done for the problematic defect observed by the Kyoto camera, and the shape of the problematic defect is analyzed in detail. There is a clear correlation between the quench field and the defect shape. This information is important for the cavity fabrication, especially the search for the optimum parameter in EBW.

ACKNOWLEDGEMENTS

The authors are indebted to K. Sennyu and H. Hara (MHI, Mitsubishi Heavy Industries), T. Ota, T. Tosaka and M. Takasaki (TOSHIBA Corporation) for the fabrication of the STF cavities and H. Umezawa (TOKYO DENKAI Co., LTD). Special thanks are given to K. Nakamura, F. Tsukada and T. Kitajima (Assist Engineering Co.), M. Sawabe at KEK for the surface preparation of these cavities, T. Okada and M. Iitake (k-VAC), T. Yanagimachi, S. Imada and M. Asano (NAT) for the preparation of the vertical test.

REFERENCES

[1] ILC Reference Design Report (http://www.linearcollider.org/about/Publications/Reference-Design-Report)

[2] Y. Yamamoto et al., SRF11, Chicago, U.S., Jul 2011, THIOA01.

[3] Y. Yamamoto et al., IPAC12, New Orleans, U.S., May 2012, WEPPC014, in this conference.

[4] Y. Yamamoto et al., TTC Meeting 2011, Milano, Italy, Feb 2011. (https://agenda.infn.it/conferenceDisplay.py?confId=3087)

[5] Y. Iwashita et al., Phys. Rev. ST Accel. Beams 11, 093501 (2008).

[6] H. Hayano et al., TTC Meeting 2010, FNAL, U.S., Apr 2010. (https://conferences.fnal.gov/ttc10/index.html)

[7] Y. Yamamoto et al., LINAC10, Tsukuba, Japan, Sep 2010, THP018.

ISBN 978-3-95450-115-1