RECENT RESULT OF CAVITY INSPECTION FOR THE SUPERCONDUCTING CAVITIES AT KEK-STF

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Abstract

The inspection of inner surface of the superconducting rf cavities is essential in achieving high accelerating gradient. The camera system developed by Kyoto-KEK collaboration is a good tool to survey defect locations and to analyze a defect shapes in the inner surface of the cavities for boost accelerating gradient yield of 1.3 GHz superconducting 9-cell cavities.

The inspection of the STF (STF: Superconducting rf Test Facility) baseline cavity (MHI-05 and MHI-06) in each process (as received, after EP process and vertical test with T-map (temperature mapping), where EP stands for electro-chemical polishing) was carried out to study relations between a defect shape and a heating location of the cavities in vertical test. The full inspection of the EBW (electron beam welding) seam and next to area at equator and iris parts was carried out before vertical test.

The vertical tests of these cavities using T-map with fixed thermometer allocation were carried out at STF in KEK from December 2008 to April 2009. Non-uniform EBW seam in the equator area were found at the heating locations detected by T-map at high field. The inspection result of these cavities will be presented in this paper.

INTRODUCTION

The inspection of MHI-05 and MHI-06 [1] in each process was carried out using the Kyoto camera system [2] in KEK-STF for ILC (International Linear Collider) from June 2008. The purpose of this inspection is to search a correlation between a heating location detected by T-map and irregularity of the inner surface inspected by Kyoto camera system, and accelerating field level measured by V.T. (vertical test) when a heating has started. The goal of this study is to have reference of judgement to estimate a cavity performance by inspection at "As received". It is important for industrialization of cavity fabrication to make a suitable EBW process and the surface treatment.

THE INSPECTION OF MHI-05 AND MHI-06 BEFORE V.T.

The process of inspection after the fabrication are shown in the followings,

A) As received
B) After Pre-EP (5um) and EP-1 (20um)
C) After 2nd time EP-1 (100um)
D) After Anneal
E) After EP-2 (50um) and vertical test with T-map

The inspection of A) is important for quality control and feedback to EBW operators to boost a yield of the accelerating gradient for superconducting rf cavities.

The images of MHI-05 and areas of the inspection (Rectangular mark in the picture show a image size of the inspection.) are shown in Figure 1. The images are taken for the inspection in the following cases,

1. All EBW seams of the equator and the iris part (we call it the full inspection)
2. Only the suspicious spots or defects which are found at outside of weld area.

The images of the inner surface in comparison with as received and after EP-1 process for MHI-05 are shown in Figure 2.

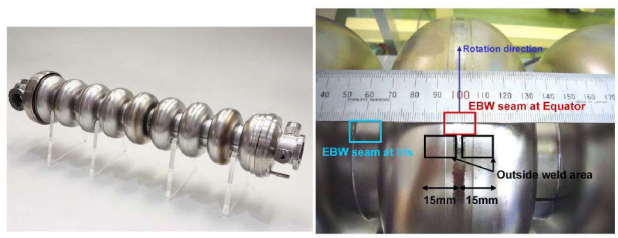

Figure 1: MHI-05 cavity and area of the inspection.

Figure 2: Images of the MHI-05 at "As received (left) and after EP-1 process (right)".

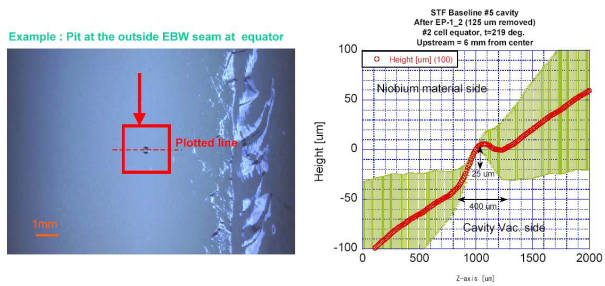

Figure 3: Example of image and shape of the suspicious spot at outside weld area measured by after EP-1 process.

Found the Suspicious Spots Before EP-2 and V.T.

The two types suspicious spots were found at outside of weld area in the inspection C) for MHI-05 and MHI-06. Then surface gradient measurement, shape analysis and marking of these spots were done. Figure 3 is image and shape of a pit type suspicious spot. The location and size of the observed suspicious spots at outside weld area is summarised in Table 1. The diameter and depth of the pit

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type spots were 200 ~ 500 μm diameter and 10 ~ 30 μm depth. The diameter and height of the bump type spot were 800 μm diameter and 50 μm height.

We have interested in the following things,

1. When were these suspicious spots made?
2. Are these suspicious spots become heating source?

Table 1: location and size of the suspicious spots in MHI-05 and MHI-06

No.	MHI-05 : Equator area						No.	MHI-06 : Equator area					
	cell	Angle [deg.]	Diameter [um]	Size [um]	Type	Location		cell	Angle [deg.]	Diameter [um]	Size [um]	Type	Location
1	1	88	200	12	Pit	Outside weld area	1	#2	116	350	20	Pit	Outside weld area
2	1	200	800	50	Bump	Outside weld area	2	#2	164	300	10	Pit	Outside weld area
3	2	219	400	25	Pit	Outside weld area	3	#2	200	500	20	Pit	Outside weld area
4	2	248	300	25	Pit	Outside weld area	4	#3	10	400	30	Pit	Outside weld area
5	2	323	250	10	Pit	Outside weld area	5	#3	95	300	15	Pit	Outside weld area
6	3	100	300	15	Pit	Outside weld area	6	#3	287	350	15	Pit	Outside weld area
7	4	110	300	10	Pit	Outside weld area	7	#3	353	300	15	Pit	Outside weld area
8	4	196	300	10	Pit	Outside weld area	8	#4	103	400	30	Pit	Outside weld area
9	5	139	400	10	Pit	Outside weld area	9	#5	10	250	10	Pit	Outside weld area
10	5	303	400	10	Pit	Outside weld area	10	#6	115	250	10	Pit	Outside weld area
11	6	253	250	15	Pit	Outside weld area	11	#7	45	200	15	Pit	Outside weld area
12	7	184	250	15	Pit	Outside weld area	12	#7	66	300	15	Pit	Outside weld area
13	9	190	400	25	Pit	Outside weld area	13	#8	216	300	12	Pit	Outside weld area
14	9	240	400	25	Pit	Outside weld area	14	#8	232	300	12	Pit	Outside weld area
15	9	353	300	10	Pit	Outside weld area	15	#8	285	300	10	Pit	Outside weld area

When Were Those Suspicious Spots Made?

The inspection of three dumbbells for MHI-07 cavity was carried out to search that "When were suspicious spots made?". The setup of the inspection is shown in Figure 4. The result of this inspection is shown in Figure 5. The spots were observed on the surface even in the dumbbells stage. The spots do not occur in neither the surface treatment nor EBW process. The locations of the spots were within 15 mm from a joint point of equator.

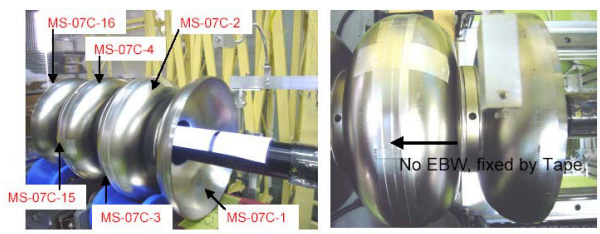


Figure 4: The setup of the inspection for three dumbbells of the MHI-07.

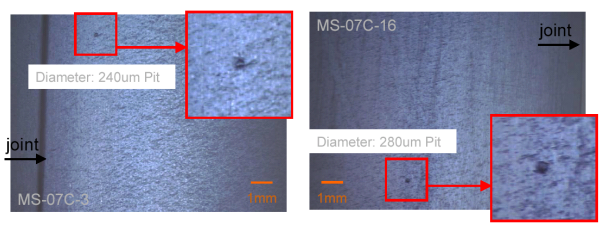


Figure 5: Observed the suspicious spots in the stage of the Dumbbells (before EBW)

RESULT OF THE V.T. WITH T-MAP FOR MHI-05 AND MHI-06

Two vertical tests with T-map for each MHI-05 and MHI-06 were carried out in December 2008 to March 2009 [3], [4]. The heating locations of both cavities detected by T-map at high field are shown in Figure 6. The heating location detected by T-map, the cause of limitation and result of the inner surface inspection are summarised in Table 2. In the first V.T. of MHI-05 and MHI-06, the reason of limitation for the cavity performance was field emission. In the second V.T. of MHI-05, the heating locations at high field were #3 cell equator, #5 cell equator and #6 cell equator. In the fourth V.T. of MHI-06, the heating locations at high field were #5 cell equator. The heating of the suspicious spots (see Table 1.) of both cavities were not detected by T-map at ~ 39.9 MV/m in the pass-band measurement. The observed suspicious spots in MHI-05 and MHI-06 are not reason of

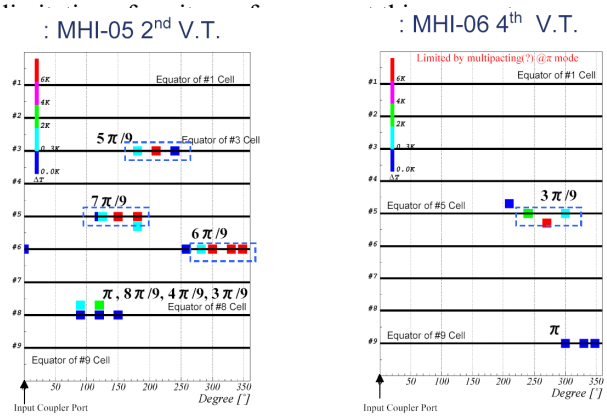


Figure 6: Heating location detected by T-map in V.T. (heating location at high field is indicated with blue doted line-box)

Table 2: Summary of the heating location in V.T. and result of inspection after V.T. for MHI-05 and MHI-06

Cavity	# of V.T.	Eacc [MV/m] @ Mode Cause of limitation	Heating location	Result of inspection (after V.T. with T-map)
MHI-05	1st	27.3 @ Pi-mode Field emission ?	#5 cell equator, t=60~150deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.
	2nd	19.7 @ Pi, 8/9, 4/9, 3/9 Defect ? Quench	#8 cell equator, t=90~150deg.	No defect in outside weld area.
		25.6 (max 32.9) @ 5/9 Quench	#3 cell equator, t=180~240deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.
		29.2 @ 7/9 Quench	#5 cell equator, t=120~180deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.
		32.9 @ 6/9 Quench	#6 cell equator, t=270~360deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.
MHI-06	1st	25.7 @ Pi-mode Field emission ?	#7 cell equator, t=150~180deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.
		35.4 @ 3/9 Quench	#5 cell equator, t=200~300deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.
	4th	19.6 @ Pi, 8/9, 7/9, 6/9, 5/9, 4/9. Defect ? Quench	#9 cell equator, t=300~350deg.	No defect in outside weld area.
		39.9 @ 3/9 Quench	#5 cell equator, t=200~300deg.	Unstable : Width of the EBW seam is narrow. No defect in outside weld area.

Inspection of the Heating Location Detected by T-Map after V.T.

Figure 7 and Figure 8 are example of the inner surface inspection of MHI-05 at heating location in comparison with after V.T. and as received. One of the conditions of heating location was non-uniform EBW seam area (Non-uniform means narrow seam area at equator). The EBW seams of the heating locations detected by T-map at high field were similar condition. The result why heating happens in these non-uniform EBW seam area is not yet understood. The inspection for heating area found at pi-mode between 30 mm form the joint of the equator were

done to make sure. However, any defect was not found this inspection area.

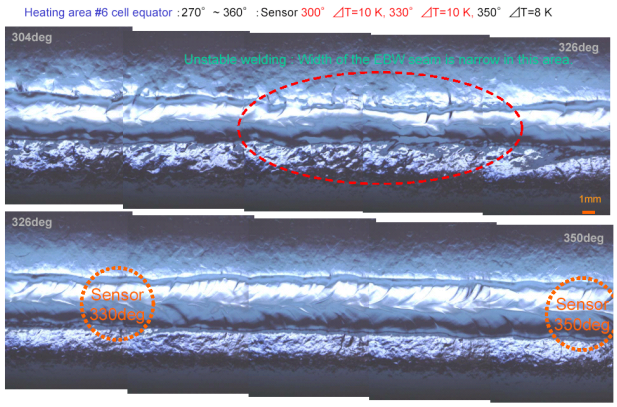


Figure 7: The images of the EBW seam in cell #6 equator (angle: 304 to 350 degree) of MHI-05 (Condition is after V.T.). The heating was occurred at 32.9 MV/m in 6π/9 mode. The orange circle is the location of thermo-sensor. Red doted line-circle is non-uniform EBW seam area.

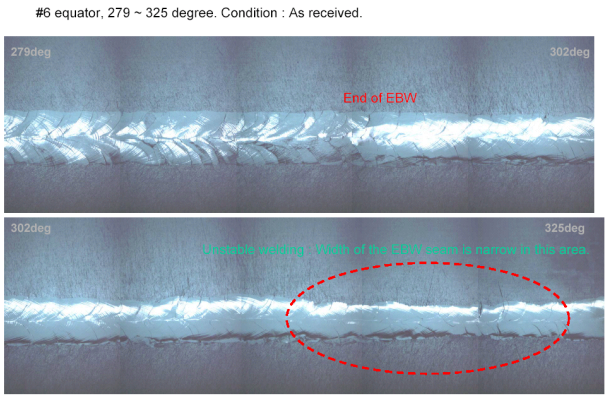


Figure 8: The images of the EBW seam in cell #6 equator (angle: 279 to 325 degree) of the MHI-05. (Condition is "As received".) Red doted line-circle is non-uniform EBW seam area.

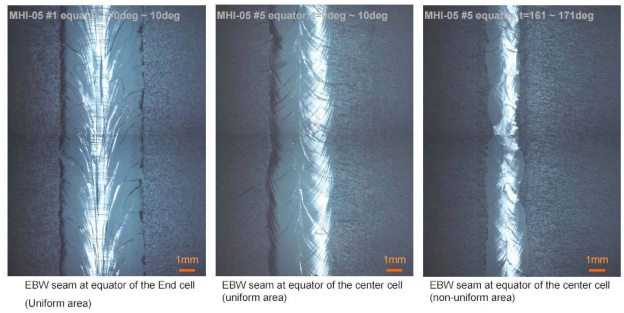
IMPROVEMENT OF EBW SEAM FOR NEW MHI CAVITIES

The EBW seam of MHI-05 and MHI-06 had both of the uniform area and the non-uniform area at around the EBW seam of the equators (see Figure 9 a). The non-uniform area of EBW seam has a possibility for a reason of the limitation to achieve a high accelerating gradient.

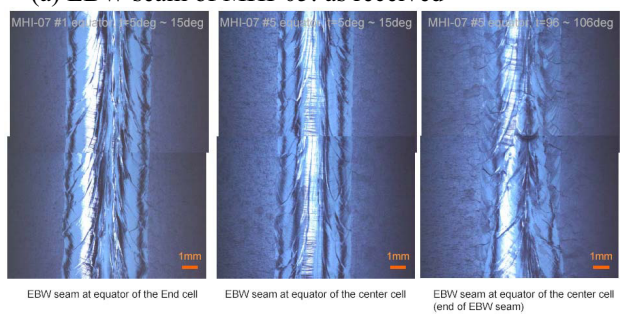
Possible reason of the non-uniform EBW seam is seemed as the material thickness error of the equator joint. EBW parameters were studied for fabricated new MHI cavities (MHI-07, MHI-08 and MHI-09) [1] to obtain a good and uniform EBW seam.

As a result, the EBW seams of MHI-07, MHI-08 and MHI-09 are improved (see Figure 9 b) by the new EBW parameter. The qualities of EBW seam for three cavities are the same. Figure 9 (a) and (b) are the images of the typical EBW seams in comparison with previous MHI-05 and improved MHI-07.

The MHI-07, MHI-08 and MHI-09 are currently under bulk EP process and anneal process. After these treatments, the surface inspection will be done for these cavities with surface gradient measurement, shape analysis and marking of suspicious spot. The vertical tests of MHI-07, MHI-08 and MHI-09 are scheduled to finish until October 2009.



(a) EBW seam of MHI-05: as received



(b) EBW seam of MHI-07: as received

Figure 9: Comparison with MHI-05 and MHI-07 (EBW improved) at as received.

SUMMARY AND PLAN

The surface inspection of five MHI cavities was done from June 2008 to May 2009. The heating locations of MHI-5 and MHI-06 at V.T. were one of the non-uniform EBW seam area of the equators. The heating of the suspicious spots (see Table 1.) of both cavities were not detected by T-map at high field. The vertical tests with T-map for improved EBW seams of MHI-07, MHI-08 and MHI-09 are scheduled to finish until October 2009.

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