FIELD FLATNESS DEGRADATION PROBLEMS AND CURE

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Abstract

Field flatness of ICHIRO 9-cell cavities was often degraded <70% after vertical test (VT) though it was tuned >96% before surface preparations. In order to find which process degrades the flatness, we checked it at each step of procedures. We improved cavity jig and fitting method. Now the degradations of flatness are less than <1% during jig fittings, transportations, handlings, rinsing and vertical tests. Electropolishing (EP) still degrades flatness about 5%. To cure this, we tried pre-tuning again after EP, and then cavity was HPR rinsed and measured. The maximum field gradient of pi-mode achieved 33.7MV/m. Flatness of 94% was confirmed after the VT. Re pre-tuning seems have no problem for cavity performance. The flatness of >96% is in hand now.

INTRODUCTION

We have continued high gradient R&D of ICHIRO 9-cell cavities at KEK [1,2,3]. For a multi cell cavity, one of the important issue is field flatness. In order to measure correctrly accelerating gradient at VT for a multi cell cavity, the each cell should be has equal field strength; high field fltaness. Field flatness is mechanically adjusted by squeezing or stretching individual cells: pre-tuning. 9-cell cavities were usually tuned more than 96% before EP. We sometimes had an inconsistency in measurement results. Figure 1 shows one example. The maximum field gradient at pi-mode achieved 23MV/m, but in pass-band measurements, each cell achieved more than 30MV/m. After the VT, we found the flatness was degraded from 96% to 68%. The difference is too much even considered the measurement error. We have considered the inconsistency was due to the flatness degradation. In this paper, we will describe what makes degradation and how to cure it.

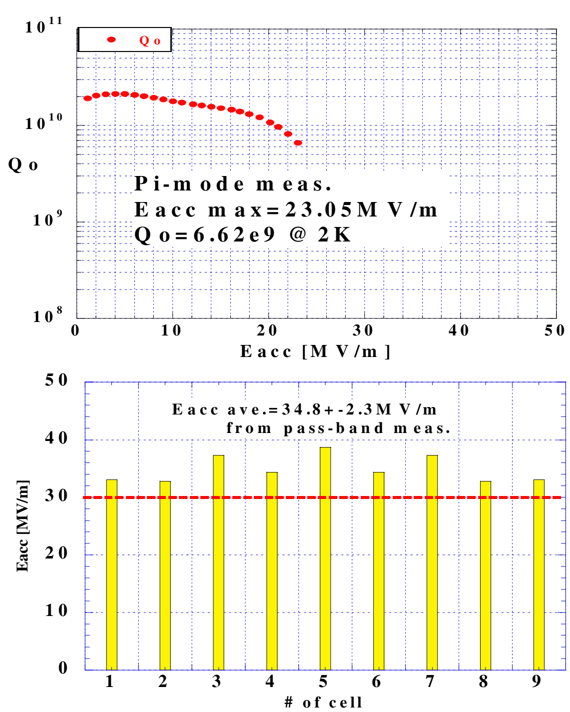

Figure 1: VT results of ICHIRO 9-cell #5, Qo vs. Eacc plot (top), analysis of pass-band measurements (bottom).

FIELD FLATNESS

Flatness of multi cell cavity is defined by the equation (1).

$$field\ \ flatness[\%]=\left(1-\frac{E_{c\max}-E_{c\min}}{\frac{1}{N}\sum E_{ci}}\right)\times 100\% \qquad (1)$$

E_{ci} is the peak axial electric field of ith cell. E_{cmax}, (E_{cmin}) is the maximum (minimum) filed among N cells. N is a number of cell. When E_{ci} are equal, flatness is 100%. For ILC, field flatness of more than 96% is required. Flatness measurement is done by network analyzer using the bead-pull method [4]. Run the small metal bead on the cavity axis with a fixed velocity, the frequency shift (δf) of pi-mode with each cell are measured as the phase shift (δP) by a network analyzer. δP is in proportion to δf, δf is linearly proportional to E^2. The equation (1) can be rewritten as equation (2) by replacing E_{ci} with δP_{ci} square. We used equation (2) for flatness measurements. Figure 2 and 3 show our flatness measurement set up image and pre-tuning machine respectively.

$$field\ \ flatness[\%]=\left(1-\frac{\sqrt{dP_{\max}}-\sqrt{dP_{\min}}}{\frac{1}{N}\sum_{i=1}^{N}\sqrt{dP_{ii}}}\right)\times 100\% \qquad (2)$$

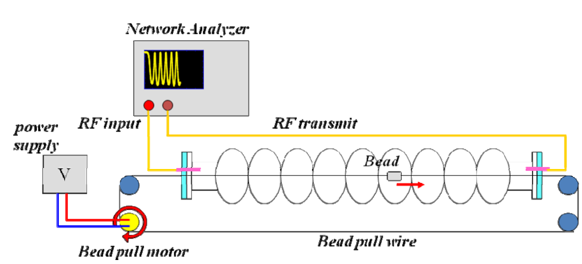

Figure 2: Image of flatness measurements,

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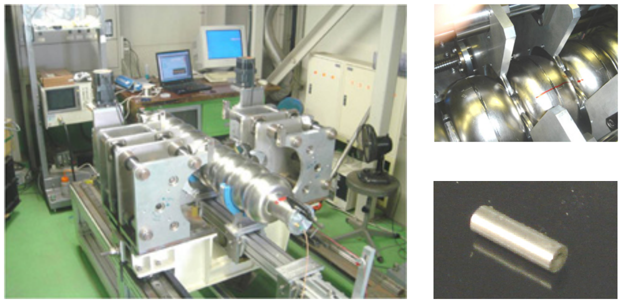

Figure 3: pre-tuning machine.

DEGRADATION AND CURE

To find out which process makes the flatness degradation, we checked it in each step. Table 1 shows the results of flatness in individual process. At the "Previous", we didn't check flatness between pre-tuning and the VT. We found the cavity support jig fitting degraded the flatness more than 60 % in the worst case. The jig made stress to cavity. This stress brought the cavity a deformation resulting in flatness degradation. We modified the jig to make it stress free and also improved the jig fitting procedures. The cavity transported with dressing the jig to Nomura Plating. This jig also use afterwards of EP: HPR, baking, evacuation and VT. At present, no degradation happens by the jig.

At EP process, dressing of EP jigs has no effect on field flatness. Rotating cavity, put and dump water to cavity in vertical position also have no degradation. Only EP itself made degradation about 5%. No systematic degradation was seen in those. We are under investigation about this.

To cure the degradation by EP, we decided to re pre-tune cavity after EP. Usually this process is not preferred due to additional contaminations on the SRF surface. However we expect HPR rinsing can remove such contaminations after the re pre-tuning. This re pre-tuning process is the challenging. So far we take following procedures after the re pre-tuning, HPR, drying in the class 10 clean room, assembly, baking, evacuation and VT. So far we have not serious degradation in those processes.

At current preparation recipe, we have replaced degreasing by ethanol rinsing and wiping with degreaser [5]. We confirmed these preparations made no flatness degradation.

Table 1: Flatness measurement at each process

Process	Flatness [%]	
	Previous	Present
Pre-tuning	>96%	>96%
Cavity jig fitting	30~88%	>96%
Transportation	No check	>96%
EP set-up	No check	>96%
EP+1st rinsing	No check	90~94%
Re pre-tuning	-	>96%
Degreasing	No check	90~94%
HPR + assemble	No check	>96%
Baking + evacuation	No check	>96%
VT	30~88%	>96%

PILOT STUDY OF RE PRE-TUNING

We used ICHIRO 9-cell #5 for re pre-tuning test. This cavity was limited 18MV/m by field emission. The flatness was 93% after the VT. We tuned this cavity again up to 97%. Then HPR (2hrs), assembly, evacuation and measurement were done. Unfortunately we gave the cavity a shock during HPR setting, the flatness was degraded to 94%. This re pre-tuned cavity achieved maximum field gradient of 33.7MV/m with Qo value of 6.8e9 at pi-mode (Fig. 3). In the pass-band measurements, 3rd or 7th cell were limited at 33.7MV/m, other cells achieved higher gradient than that (Fig. 3). The pass-band results showed the field limitation of pi-mode was at 3rd, 7th, or the both cell. After the VT, the flatness of 94% was confirmed.

We got several important points from the results. First one is no flatness degradation happened by VT. For the statistics, we did the tight loop test for the flatness.

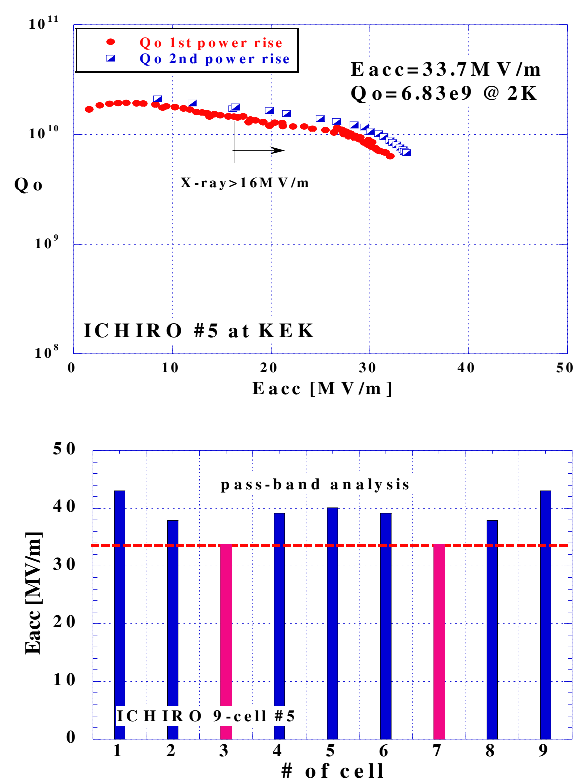

Figure 3: VT results of ICHIRO 9-cell #5 after re pre-tuning, Qo vs. Eacc plot (top), analysis for pass-band measurements (bottom).

Second is re pre-tuning did not make severe contaminations or damage on EP surface. It seems no effect on cavity performance so far. The third one is we got well consistency between pi-mode and pass-band measurement on the field limitation. To get high reliable data, flatness should be kept as higher as 94%.

We make it rule for 9-cell preparation to do re pre-tuning cavity when the flatness degrades less than 95% after EP.

TIGHT LOOP TEST FOR FLATNESS

We checked the reliability of flatness preservation by repeating HPR+VT without re pre-tuning. Cavity was tuned up to 98% at first. Then, HPR + vertical test + flatness measurement were repeated 5times. In these tight loop test, cavity jig was not disassembled. Figure 4 shows the results. Flatness was kept more than 96% during this tihgt loop. We confirmed that cavity processes of HPR rinsing, evacuation, thermal cycles of VT make no degradation on flatness. In these measurements, we also checkd the flatness dependence on the cavity position, horizontal and vertical. The degradation on cavity position was less than 1%.

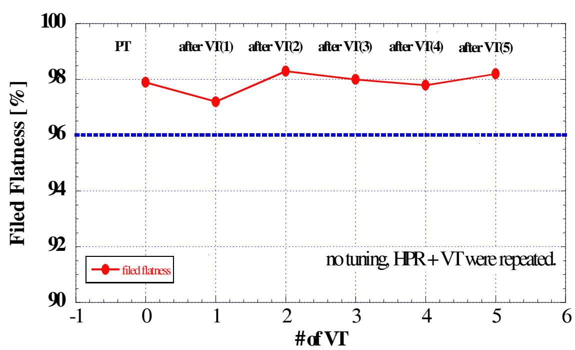

Figure 4: Tight loop test on field flatness

STATISTICS OF FLATNESS

Figure 5 shows the statistics of flatness so far collected on 9-cell cavities. Left graph is the flatness comparison of before and after EP. It was fitted by gaussian. Before EP, pre-tuned flatness were about 97%. After EP, the flatness was 92±4%. Right one is the comparison before and after VT. No significant degradation were seen. Almost cavity were pre-tuned again after EP.

CONCLUSIONS

We found the flatness degradation problems during cavity handlings and processes. This problem affected data quality. One of reason for degradation was, very primiteve, the cavity jig stress. We modified the jig and solved degradation caused by jig. On the other big reason is EP process. EP makes flatness degradation about 5% or more. We have been investigating why EP process degrades flatness and how to prevent it. To cure this, we did re pre-tuning after EP. It is working well so far. Cavity performance has achieved about 34MV/m. Good consistency between pi-mode and pass-band measurements was obtained. This makes data quality higher and tells us correctry which cell limits a gradient. Exposing electropolished SRF surface to normal enviroment during pre-tuning seems to not so worse on performance. Other processes: transportation, rinsing, baking, evacuation, and VT make no degradation. Flatness controll of >96% is in hand now.

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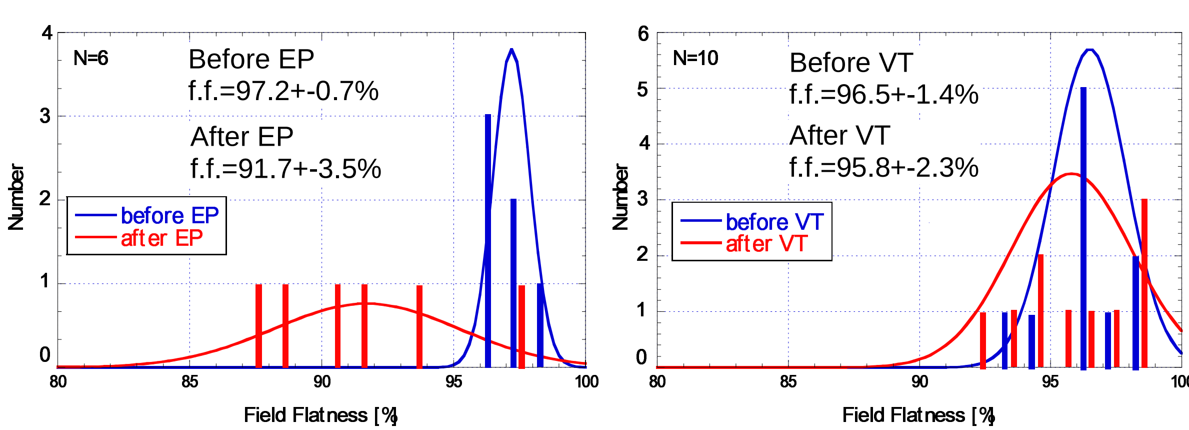

Figure 5: Comparison of flatness before (blue line) and after (red line) process. Left one is for EP, right one is for VT (right).