LARGE GRAIN 9-CELL CAVITIES R&D AT KEK

K.Saito# and F.Furuta: KEK, Accelerator Lab1-1 Oho, Tsukuba-shi Ibaraki-ken, 305-0801, Japan
T.Konomi: The Graduate University for Advanced Studies, Japan

Abstract

We are developing large grain/single crystal niobium material for ILC, collaborating with Tokyo Denkai. These materials are very much promising to obtain high SRF cavity performance with cost-effective production. We have fabricated two 9-cell cavities from large grain materials and made cold test to evaluate the SRF performance. In this paper, we will report cavity fabrications and preparations and cold test results.

INTRODUCTION

SRF cavity fabrication using large grain (LG) niobium material has a high potential of breakthrough on cavity cost performance. It can be fabricated very efficiently by multi-slicing large grain niobium ingots, which has been already successfully developed at KEK/Tokyo Denkai Corporation Ltd. [1]. The material property becomes more reliable and the cost should be cheaper than fine grain materials based on forging and rolling methods. To produce high gradient, BCP process will be available, which is much cost effective compared with EP. Thus, it will bring another reduction on cavity preparation.

The grain size in niobium ingots is getting larger. Heraeus in Germany and CBMM in Brazil already have produced ingots having only several grains in the effective zone of sheet material for 1.3GHz cavity. Tokyo Denkai also has started R&D to produce large grain /single crystal sheets [2]. The regular production of single crystal sheet is getting reality, which could improve the material quality and produce cavity performance more reliably.

LG 9-CELL CAVITY FABRICATION EXPERIENCES

So far, we have fabricated two LG 9-cell cavities (I9#9 and I9#10) with low loss (LL) shape as ILC R&D. In the experience of I9#9, several difficulties on cavity fabrication were found due to the nonhomogeneity of grain orientations. Some of them were feed-backed to the I9#10 cavity fabrication.

Deep Drawing and Trimming

We describe the I9#10 experience here. We used LG materials by multi-wire slicing ingot [1]. No annealing carried out for the sheets before deep drawing. Forming was looks nice but some bigger machining error was observed in the cup length (±140μm) after trimming, compared to the fine grain (±40μm). The material thickness variation on an end cup is shown in Fig.1. The original thickness is 2.8mm. The iris section is reduced about 10%, the sidewall is no changed and the equator section becomes thicker about 5%.

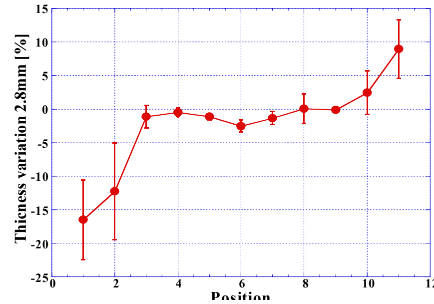

Figure 1: Thickness variation in an end cup.

kenji.saito@kek.jp

Dumbbell Electron Beam Welding (EBW)

Stiffener is changed from half rings (I9#9) to complete ring (I9#10), which makes tolerance better. It is important at CBP process later described. Iris EBW was done from inside. EBW shrinkage was measured after dumbbell EBW and was 0.171±0.04mm. We made the off set of +0.20mm at trimming for the shrinkage, which was a little too big.

Dumbbell Tuning

The dumbbells were mechanically tuned with length and plane. Fig.2 shows an example of lengths in one dumbbell measured every 45^{O}. Usually dumbbells as received are shrunk about 2mm and the plane is also tilted by the Iris EBW strains, which is seen in Fig.2 (triangles). Dumbbells were tuned up to the target length (116.61 ± 0.1mm) of RF design + a half of the equator EBW shrinkage (0.14mm, here).

Grinding at Iris Seam and Cleaning

All Iris EBW seams were ground by handy grinder. After that, they were lightly etched all the surfaces about 20μm in KEK. Dumbbells were rinsed with civil water at

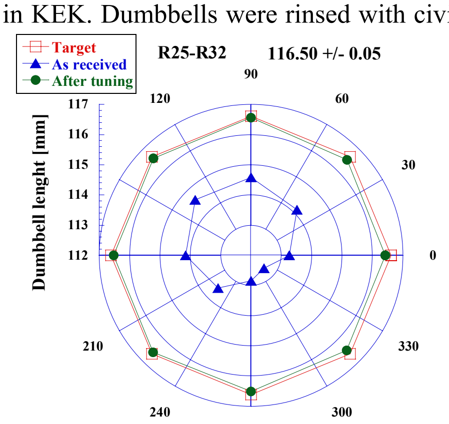

Figure 2: Dumbbell tuning result.

first after the etching, and then brought into the class 10 clean-room. They were rinsed again with Ultrasonic and DI water, dried for one night in the clean-room, then packaged in plastic bags and shipped to the EBW Company (Kuroki EBW Company).

End Group Fabrication

Parallel to the dumbbell fabrication, a set of end groups was EBW assembled in a small EBW company (SFC Techno Center). I9#10 is the bare shape, which has no input coupler and HOM coupler on the beam tubes. Even such a simple structure, end groups consist of many small parts. Small EBW machine is much flexible for the assembly. So we have been used properly EBW companies in end group assembly and 9-cell cavity one. After completing them, they were lightly etched at KEK and shipped to Kuroki EBW Company similar to the dumbbells.

EBW Assembly of 9-Cell Cavity

In the 9-cell cavity EBW assembly, a big difference from the last ones is inner EBW at all equators. The welding was really done mainly from inside and partially from outside. We used a large EBW machine at Kuroki to do it: Mitsubishi low voltage machine as seen in Fig.3. The beam direction was tilted about 36^{O} from the vertical at the inner welding. Fig.4 compares the welding seam between the inner and outer EBWs on large grain cells. The inner EBW has very sharp and smooth boundaries.

The final EBW between the both end cup Iris and end of beam tube was done from the outside, which are no way to weld from inside.

Figure 3: Inner EBW at equator in a large EBW chamber.

The equator EBW shrinkage was measured because the trimming configuration was changed for the inner EBW. The value is 0.51 ± 0.14mm and rather large from our estimation (0.28mm) which had been off set in the trimming.

Inspection and Field Flatness Tuning

After the successful leak tight check at Kuroki, KEK made geometrical measurement, inner surface inspection, measurement of field flatness as received cavity, and mechanical tuning. The design cavity length is 1244.00mm. The cavity length as received was 1237.10mm and short 6.90mm. 4.79mm of the 6.90mm can be explained by the wrong EBW shrinkage off set at equator (-2.07mm totally), the wrong EBW shrinkage off set at Iris (+0.30mm totally), and the EBW re-strains at equators (-3.02mm totally). The remained –2.1mm is explained by the measured EBW strains (-3.36mm totally) in the end cups within a measurement error, which we had never considered before. The π-mode frequency as received was 1302.220MHz, while the design is 1301.813 MHz before preparations. Field flatness of the π-mode was 20.5%. The end cells seemed to be rather deformed.

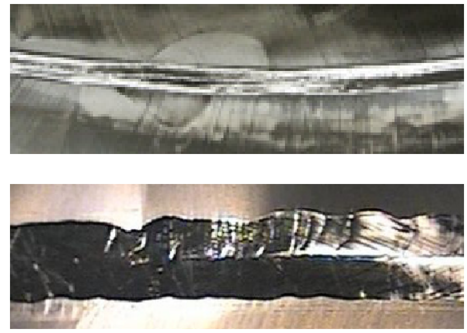

Figure 4: Comparison of EBW seams between the inner (top) and outer (bottom) EBWs at equators on large grain cavity.

The flatness was corrected up to 96.5% by mechanical tuning, where both end cells were almost tuned. The cavity length became 1239.5 mm but still short by 4.5mm. Flatness tuning recovered the cavity length by 2.40mm, which is close to the shrinkage 2.1mm by the EBW stains in end cups. The tuning did not change the lengths of equator to equator, which means the errors -2.07mm and –2.72mm mentioned above stay no changed after the tuning. Finally the missing value in the cavity length after flatness tuning is –0.29mm=4.5-(2.07+2.72), which is well within a measurement error.

The π-mode frequency was 1302.668MHz after the tuning, which was high by 0.855MHz. Banana structure, which was often observed in the last Ichiro cavities, was not seen this time. The modified trimming configuration was effective.

The inner surfaces were inspected with CCD camera. Equator EBW seams are presented in Fig.5 on most stable and most unstable ones.

NEW CAVITY PREPARATIONS

The detail of cavity preparation recipe of WG5-KEK is seen in the reference [3]. Here the benefits found in the recent R&D are described.

Figure 5: Equator EBW seams of I9#10 cavity. Top is most stable one and bottom is most unstable one.

Centrifugal Barrel Polishing (CBP)

We routinely take mechanical grinding by CBP in order to remove EBW defects, which is our unique process. I9#10 was also made CBP. It is worth to compare the defect removal by CBP in I9#9 and I9#10. Both are bare LL LG 9-cell cavity. I9#9 took outer EBW at equator sections, while I9#10 took inner EBW as mentioned above. Fig.6 compares number of the remained visual defects on RF surfaces vs. CBP material removal. A benefit of the inner EBW is clear. Inner EBW much reduces the number of EBW defects and the defect depth.

Unfortunately, I9#10 had a big trouble during CBP and stopped further steps, which will be reported later in this paper. Hereafter, we switch to the I9#9 cavity results.

Development of HBCP

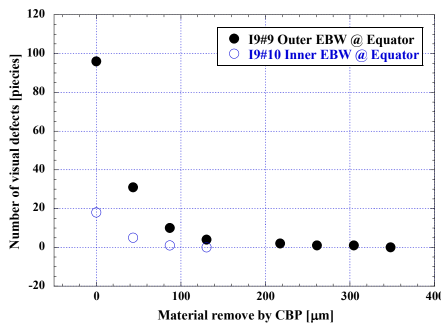

Figure 6: Comparison of defect distribution on the surface between inner and outer EBWs.

So far, LG cavities are being tested with buffered chemical polishing (BCP) to see the effectiveness. I9#9 has been tested four times, however the maximum gradient was limited at 27MV/m in the best case. By a LG single cell cavity study [4], we have understood equal material removal in each cell on 9-cell cavity is very important for cavity performance as well as the field flatness reservation. Our former BCP method produced unequal material removes in each cell (Fig.7, triangles). We have developed horizontal BCP system to improve this problem. The detail will be presented somewhere. As seen in Fig.7, by this system variation of the material removal has been improved 29% to 10%. Field flatness is also reserved before/after the HBCP at the 95% or higher. The finished surface is very shinny on the LG cavities like electropolishing.

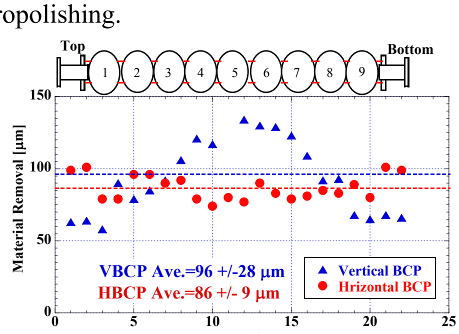

Figure 7: Comparison of material removal between the old and HBCP methods.

Fig.8 shows a comparison of equator EBW seams between fine grain (FG) and LG cavity cells. We have found a curious thing on the LG cavity. LG material has no heat-affected metallography dislike FG material, where often EBW defect locates and limits the cavity performance.

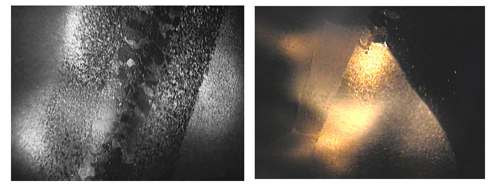

Figure 8: Different metallography seen at the EBW seam between fine (left) and large grain (right) Nb materials.

VERTICAL TEST

Fig.9 summarizes the two test results on I9#9 cavity. One was measured after the procedure: CBP(120μm)+ Light BCP(20μm) +Annealing(750^{O}C for 3hrs)+ BCP(160μm) by old method + Degreasing +HPR(10hrs) +Baking(120^{O}C for 48hrs). The other is by the procedure: HBCP(89μm)+ Degreasing + HPR(10hrs) +Baking (120^{O}C for 48hrs). HBCP is expected to improve the gradient but the both results are very similar. So far, the benefit of the HBCP is not seen on the result. We have a plan to make more tests.

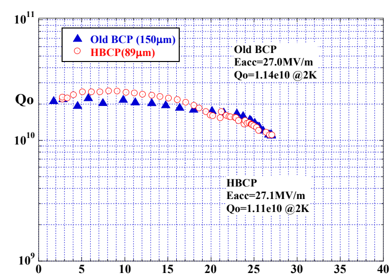

Figure 9: Vertical test results on I9#9.

TROUBLE ON I9#10 CAVITY

At the 5th CBP with rough stones, cracks happened at one end cup of I9#10. It is thought to be by the poor support on the beam pipe in the CBP jig. The cavity has been cut at the equator of the end cell. End group parts are ready to re-weld. The cavity will be repaired and tested soon.

SUMMARY

Inner EBW can rather overcome the EBW defect problem. The cavity length and frequency as received will be controlled very well by the right EBW shrinkage estimation and taking account the restrain by the equator EBW. Horizontal BCP needs the further study.

REFERENCES

[1] K.Saito et al., SRF2009, Proc. p.467-472, THOAAU05.
[2] H.Umezawa et al., in this conference, MOPEB073.
[3] F.Furuta et al., in this conference, WEPE005.
[4] F.Furuta et al., in this conference, WEPE004.