STUDIES OF FABRICATION PROCEDURE OF 9-CELL SRF CAVITY FOR ILC MASS-PRODUCTION AT KEK

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Abstract

We had been constructing a new facility for the fabrication of superconducting RF cavity at KEK from 2009 to 2011. In the facility, we have installed a deep-drawing machine, a half-cup trimming machine, an electron-beam welding machine, and a chemical etching room in one place. We started the studies on the fabrication of 9-cell cavity for International Linear Collier (ILC) using this facility. The studies are focusing on the cost reduction with keeping high performance of cavity, and the goal is the establishment of mass-production procedure for ILC. We already finished the fabrication of two 9-cell cavities in this facility. This article reports the current status of the studies.

INTRODUCTION

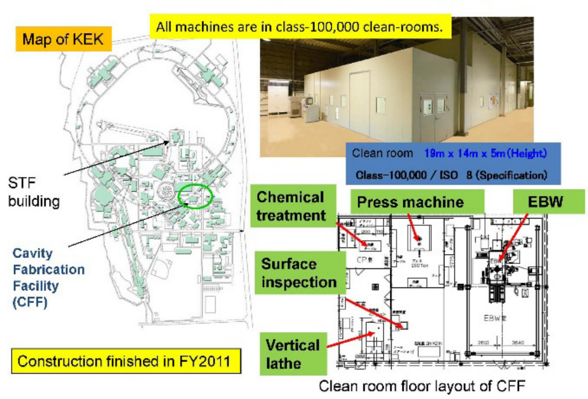

Figure 1: Construction of Cavity Fabrication Facility (CFF) at KEK. The layout of equipment in the clean-room of CFF.

In the construction of International Linear Collider (ILC), the number of 9-cell cavities to be installed is about 16,000. If we assume the yield rate of the cavity production to be 90%, the number of 9-cell cavities to be fabricated becomes about 17,600, where the acceptance gradient of fabricated cavity is 28 MV/m in the vertical test [1]. In the recent studies of ILC cavity-production around the world, the yield rate of cavity is reaching more than 80%, but the study is not enough yet. Moreover, in order to realize the ILC, the cost reduction is still a challenging issue.

In such a situation, we constructed a new facility for the fabrication of superconducting RF cavity at KEK from 2009 to 2011, which is called Cavity Fabrication Facility (CFF). The location of this facility at KEK and the layout of equipment in the facility are shown in Figure 1. In CFF, we have installed a deep-drawing machine, a half-cell trimming machine, an Electron-Beam Welding (EBW) machine, and a chemical etching room in one place. We started the study on the fabrication of 9-cell cavity for ILC from 2009 using this facility.

PURPOSE OF CFF

The purpose of CFF is to establish the mass-production procedure for ILC with realizing reasonable cost reduction and also with keeping high performance and high yield rate of cavity. The studies in the facility is efficient because all necessary equipment for the fabrication of cavity is located in one place, and in addition, we have surface-treatment facility and vertical test facility in Superconducting accelerator Test Facility (STF) building at KEK (see Figure 1) to have quick feed-back of cavity performance after the fabrication. The results of study in CFF are open to the other laboratories and also industry in the world. This policy might accelerate the establishment of mass-production procedure for the ILC.

FABRICATION OF CAVITIES IN CFF

We started fabricating 9-cell cavities in CFF from 2009. The 9-cell cavity without HOM coupler which is called KEK00 was fabricated, where the center-cells were welded by an EBW machine in a job-shop and the end-groups were welded in CFF [2]. KEK00 cavity has been continuously vertical-tested at KEK. Figure 2 shows the *Q-E* curves of the second vertical test that was performed in April 2012. The maximum field gradient E_{acc} reached 29 MV/m. The field gradient was limited by quench at quench at cell#2 and field emission.

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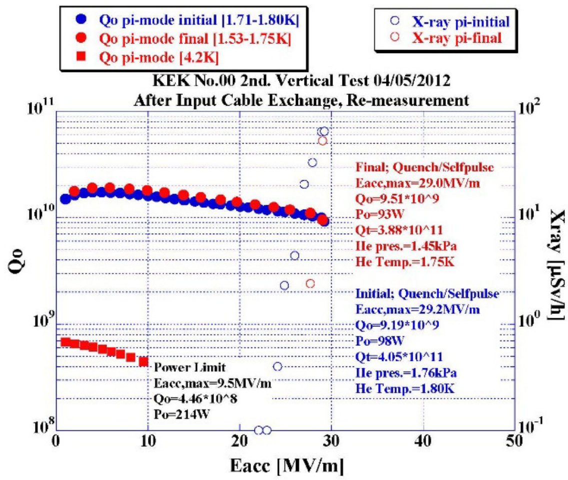

Figure 2: The result of vertical test for the KEK00 cavity without HOM coupler.

Following KEK00, KEK01 cavity with HOM couplers has been fabricated, for which all manufacturing processes including Electron Beam Welding (EBW) have been performed in CFF and the welding methods were tried to be optimized for mass-production. One example of optimization of EBW process for KEK01 cavity is shown in Figure 3. In the fabrication of KEK00 cavity, the electron-gun of EBW machine was set on the ceiling of EBW machine and then the direction of electron-beam was vertical with the horizontal posture of cavity. On the other hand, in the fabrication of KEK01 cavity, the electron-gun is set on the side-wall of EBW machine with the upright posture of cavity. If considering about the direction of gravity, stacking dumbbells before EBW process is simpler in the latter configuration, and then it might be better choice for the mass-production.

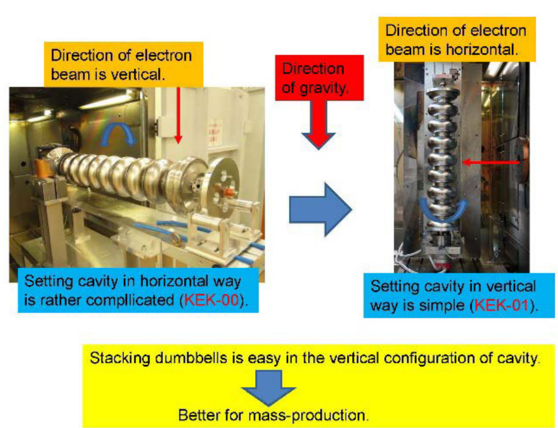

Figure 3: Configuration choice of cavity setting and electron-gun position for the optimization of mass-production.

Before the fabrication of KEK01, rigorous parameter studies were done with Nb plates. One example-plot of the study is shown in Figure 4 in which the good and bad welding conditions are plotted in the 2-dimensional parameter-space of the focus-lens current (focus-intensity of welding electron-beam) and the welding electron-beam current for the welding of 2mm-thick Nb plates in the side-gun configuration. In this plot, the green circles denote the good conditions, and the red and yellow triangles denote bad conditions. Such parameter search was done by changing the welding beam-voltage, focus-lens current, beam-current, working-piece distance from gun, working-piece moving speed, and Nb-plate thickness.

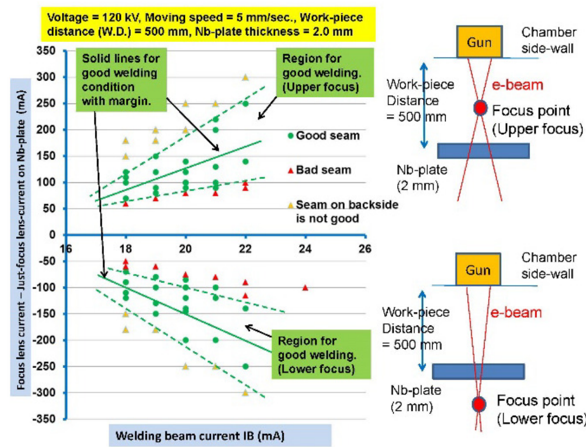

Figure 4: Focus-lens current vs. welding electron-beam current for the good and bad welding conditions with the Nb plate of 2-mm thickness.

In addition, one must consider about the 3-dimensional shape of working-pieces because it affects the heat capacity and then the welding results. In order to optimize the welding parameter at the iris of dumbbell, welding parameter search was done using a Nb pipe which has the same diameter as the iris. The same method was taken for searching the welding parameter at the equator of cell.

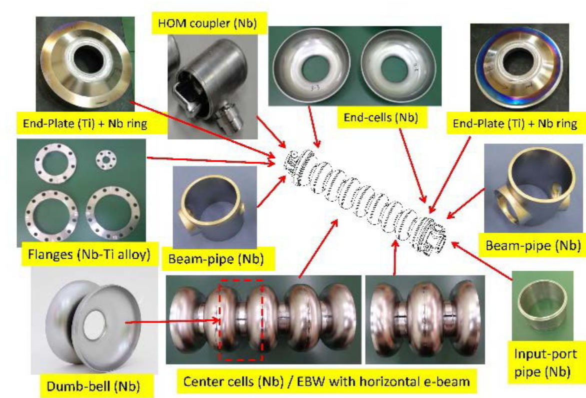

Figure 5: The assembly parts in the fabrication of KEK01 cavity with HOM couplers.

Figure 5 shows the assembly parts in the fabrication of 9-cell cavity KEK01 with HOM couplers. All parts were manufactured and welded in CFF. In particular, the multiple-dumbbells were welded in the upright posture with horizontal electron-beam to be optimized for mass-

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production. The details of studies on the search of EBW parameter is found elsewhere [3]

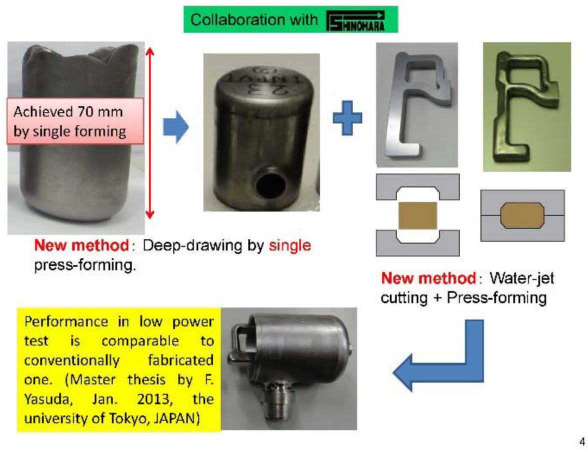

Figure 6: The new fabrication-methods for the HOM coupler for KEK01 cavity.

The fabrication process of end-group for the 9-cell cavity is the cost-driver because the shape of HOM coupler is complicated. The conventional fabrication-method for the outer-conductor of HOM coupler is multiple-step deep-drawing with annealing. We realized the deep-drawing of the outer-conductor of HOM coupler with single press-forming in collaboration with industry (see Figure 6). Currently, the conventional fabrication-method for the inner-conductor of HOM coupler is machining. We realized the fabrication of inner-conductor of HOM coupler with water-jet cutting and press-forming as shown in Figure 6. These newly developed fabrication-methods are cost-effective due to the simpler fabrication-processes. The performance of newly fabricated HOM couplers in a low power test at room temperature is confirmed to be comparable to that of conventionally fabricated one [4].

FIRST VERTICAL TEST OF KEK01 CAVITY

The fabrication of KEK01 cavity finished in March 2014. The preparation of inner surface of KEK01 cavity was done with the KEK-standard recipe. The bulk Electro-Polishing (EP) was done where the removal thickness was 100 um. Following the bulk-EP, degassing/annealing was done at 750 degree C for 3 hours. The removal thickness of final EP process was 20 um. After final EP process, detergent rinse (FM-20 2%, 50 degree C, 15 min.), low pressure water rinse and brushing at end-groups followed. High Pressure Rinse (HPR) was done with no flange being dressed on the cavity for 1.5 hours and HPR was done with flanges being dressed for 3.5 hours. After assembly of cavity in class-10 clean-room, in-situ baking at 140 degree C was done for 44 hours. The first vertical test of KEK01 cavity was done on 1st May 2014. The *Q-E* curves of the test are shown in Figure 7. In the final rise, the maximum field gradient E_{acc} reached 36 MV/m at the Q value of 6.1 x 10^9. The limitation was quench at cell#1.

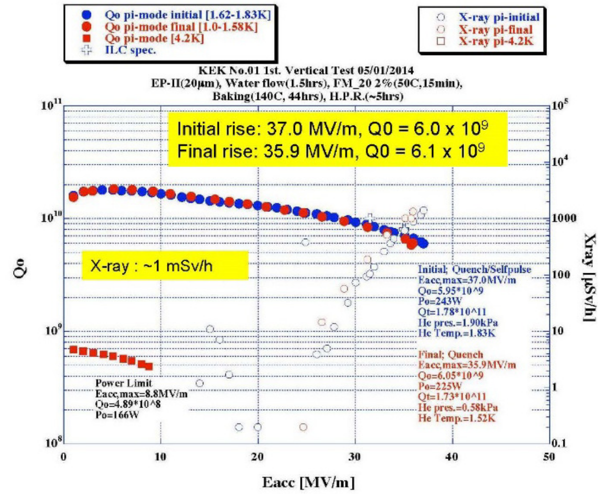

Figure 7: The results of 1st vertical test of KEK01 cavity.

SUMMARY

In order to study the mass-production technology of ILC, we constructed Cavity Fabrication Facility (CFF) at KEK and the installation of all equipment finished in 2011. The maximum acceleration gradient of KEK00 cavity without HOM coupler which was fabricated in a job-shop and in CFF reached 29 MV/m in vertical test. Fabrication of KEK01 cavity with HOM couplers was done entirely in CFF and the fabrication-methods were more optimized for mass-production. The fabrication of KEK01 finished in March 2014 and the KEK-standard recipe of surface preparation was applied to it. The maximum filed gradient of KEK01 cavity in the 1st vertical test reached 36 MV/m at the Q value of 6.1 x 10^9.

ACKNOWLEDGMENT

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