STUDY ON FABRICATION OF SUPERCONDUCTING RF 9-CELL CAVITY FOR ILC AT KEK

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Abstract

We constructed 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-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 International Linear Collier (ILC) from 2009 using this facility. The study is focusing on the cost reduction with keeping high performance of cavity, and the goal is the establishment of mass-production procedure for ILC. This article reports the current status of the studies in this facility.

INTRODUCTION

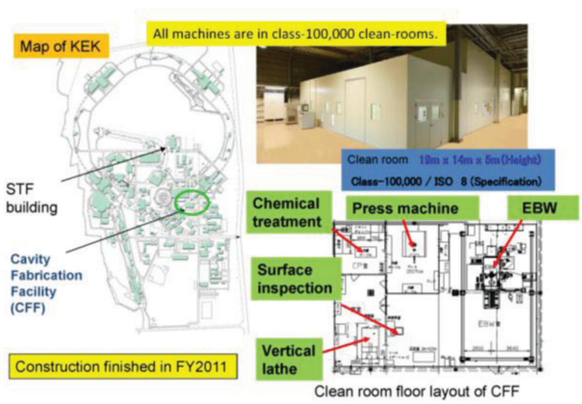

Figure 1: Construction of Cavity Fabrication Facility (CFF) at KEK. The layout of equipment in the clean-room of CFF.

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 35 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 around 80%, but the study is not enough yet. Moreover, in order to realize the ILC, the cost reduction is still a challenging problem.

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 already started fabricating 9-cell cavities in CFF. 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* curve 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 cell#2 and field emission.

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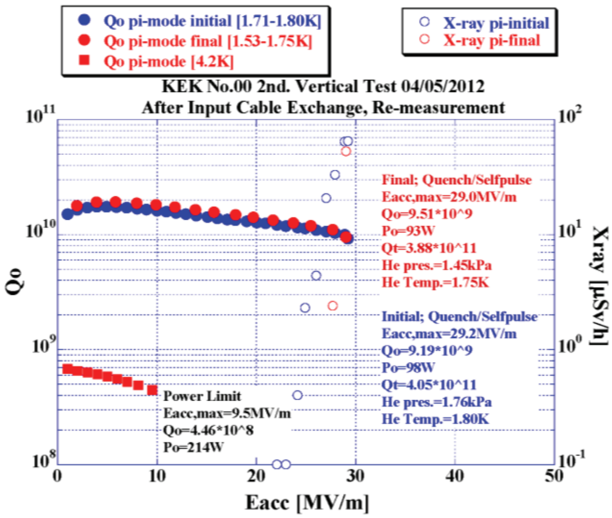

Figure 2: The result of vertical test for the KEK-00 cavity.

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.

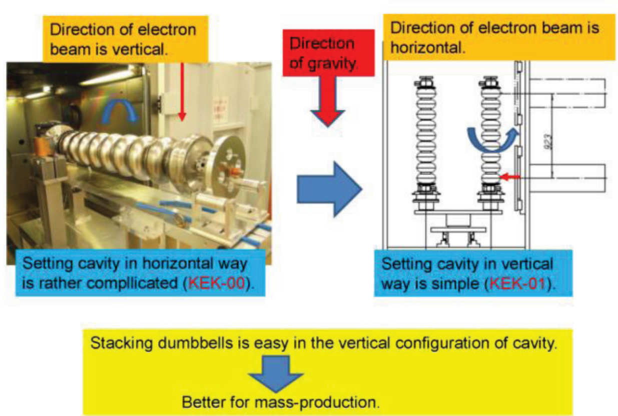

Figure 3: Configuration choice of cavity setting and electron-gun position for the optimization of mass-production.

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.

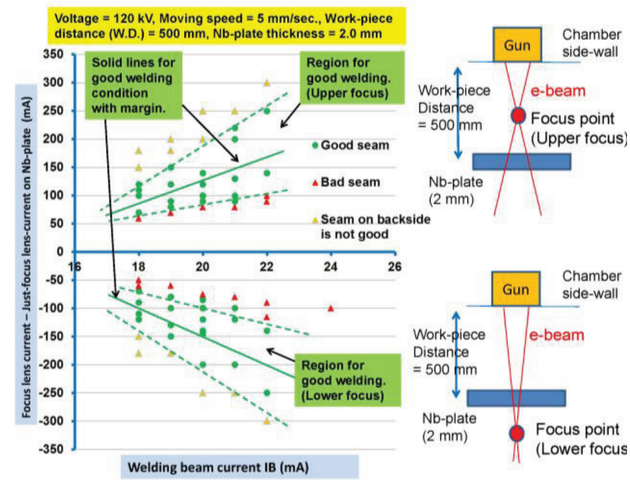

Figure 4: Focus-lens current vs. welding electron-beam current for the good and bad welding conditions with the Nb plate of 2-mm thickness.

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 pip which has the same diameter as the iris. The same method was taken for searching the welding parameter at the equator of cell.

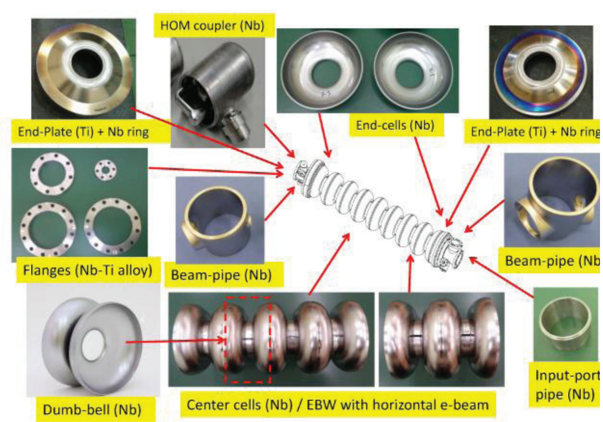

Figure 5: The status of fabrication for the KEK01 cavity with HOM couplers.

Figure 5 shows the status of fabrication for 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-production. The

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

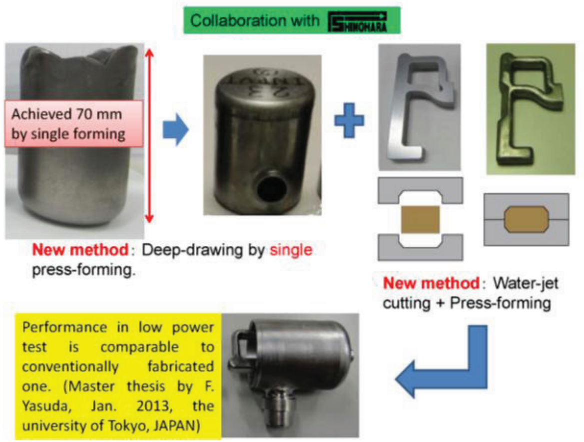

Figure 6: The new fabrication-methods for the HOM coupler for KEK01 cavity.

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].

R&D OF MASS-PRODUCTION FIXTURES FOR EBW PROCESS

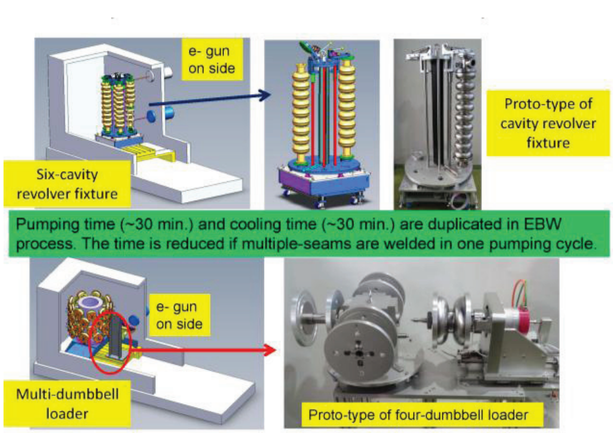

Figure 7: R&D of fixtures of EBW process for the mass-production of cavity.

In parallel to the fabrication of cavities, we are also trying to design and to make the fixtures for EBW process which are suitable for the mass-production of cavity. In the EBW process, the working-pieces are set into the machine chamber, and then the air inside the chamber is pumped out to have a reasonably low pressure for EBW process. It takes about 30 minutes for pumping. After the welding process, the welded pieces must be cooled down in the chamber with keeping low pressure because if the welded pieces at high temperature are put into the air, the surface of welded pieces might get the oxidation layer and then it degrades superconducting performance. To avoid this situation, it takes another 30 minutes for cooling before breaking the low pressure of chamber. To reduce these pumping and cooling time in the EBW process, multiple working-pieces might be loaded in the chamber and multiple EBW processes can be done in between the first pumping and last cooling processes. The fixtures shown in Figure 7 are designed to reduce the duplicated pumping and cooling time in EBW process where multiple cavities and dumbbells are loaded in the chamber at once. As seen in the Figure, we already made some proto-types for the concept of fixtures.

SUMMARY

In order to realize the mass-production technology of ILC for about 17,600 cavities, 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 is on-going in CFF. Studies on mass-production are on-going in parallel to the fabrication of cavity. For KEK01 cavity, the fabrication-methods of HOM outer- and inner-conductors are newly developed and simplified. Multi-cavity and multi-dumbbell fixture/loader are designed for EBW process for mass-production and some proto-types were made.

ACKNOWLEDGMENT

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