PERFORMANCE OF 600MHz 5-CELL SUPERCONDUCTING CAVITIES FOR PROTOTYPE CRYOMODULE AT JAERI

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Abstract

Two 5-cell cavities (600MHz, β=0.60) were fabricated for installing into the prototype cryomodule at JAERI. Before assembling the cryomodule, pretuning, surface treatment and vertical test were carried out. Before pretuning, maximum deviations of peak field at each cell center of two cavities were 12% and 8% respectively. These deviations were improved within 1% after pretuning. Barrel polishing (BP), electro polishing (EP), heat treatment at 750 °C for 3 hours and high pressure rinsing with ultra-pure water (HPR) for 1.5 hours were applied as surface treatment. At vertical tests, maximum field strengths of 31 and 40 MV/m were achieved in 2K measurements. Quality factor of both cavities at 2K was about 1.5E10.

1 INTRODUCTION

The Japan Atomic Energy Research Institute (JAERI) and the High Energy Accelerator Research Organization (KEK) are proposing the Joint Project for High Intensity Proton Accelerator[1] by merging their original Neutron Science Project (NSP) and Japan Hadron Facility (JHF)[2]. This accelerator consists of a 600-MeV linac, a 3-GeV rapid-cycling synchrotron and a 50-GeV synchrotron. Superconducting (SC) cavities are intended to apply to the high energy part of the linac. R&D studies for the SC proton linac based on the NSP are being continued in JAERI in collaboration with KEK. In the R&D work, vertical tests of single-cell cavities, pretuning and vertical tests of 5-cell cavities have been carried out[3]. As a next step, a prototype cryomodule was designed and manufactured. This cryomodule includes two 600MHz 5-cell cavities (β=0.604). Pretuning, surface treatment and vertical tests of these cavities were carried out before installation. This paper describes the results of pretuning and vertical tests.

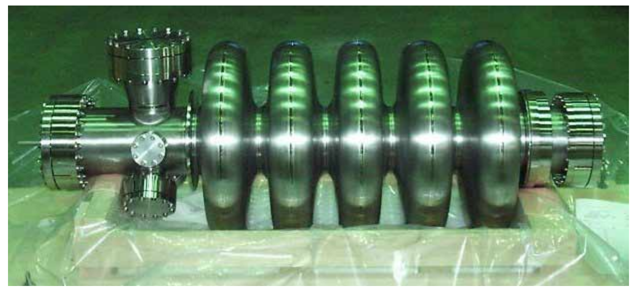

Fig. 1 600MHz 5-cell cavity (β=0.604)

2 CAVITY DESIGN

The cavity and its cross section view are shown in Fig. 1 and Fig. 2, respectively. The cavity is equipped with one input coupler port, one pickup port, two HOM coupler ports and two rings for welding Helium vessel.

Table 1 Design parameters for cavity

Resonant Frequency, [MHz]	600
E_{peak}/E_{acc}	3.45
H_{peak}/E_{acc}, [Oe/(MV/m)]	72.28
R/Q, [Ω]	154
Geometrical factor, [Ω]	166

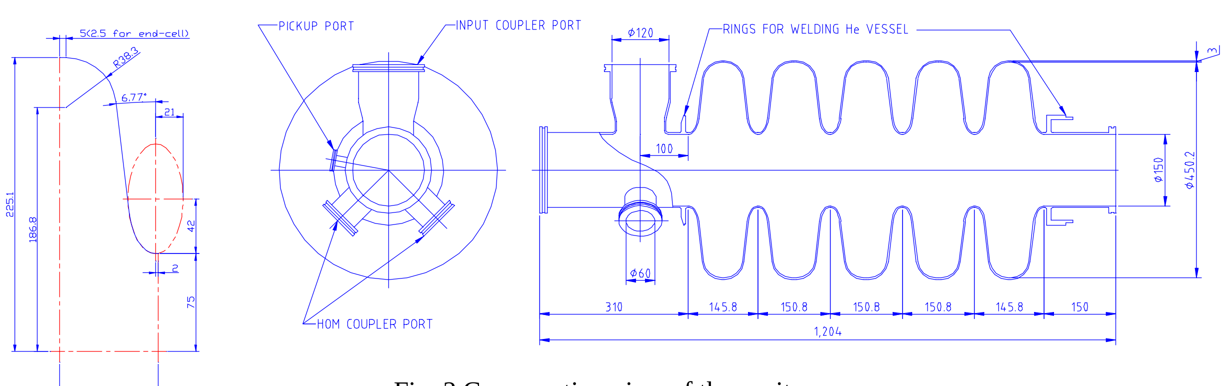

Fig. 2 Cross section view of the cavity

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Design parameters of the cavity are shown in Table 1. Resonant Frequency, E_{peak}/E_{acc}, H_{peak}/E_{acc}, R/Q and geometrical factor of the cavity are 600 MHz, 3.45, 72.28 Oe/(MV/m), 154 Ω and 166 Ω, respectively. Equator straight lengths at both end cells are adjusted to achieve flat electric field distribution on the beam axis. As the cavity material, the niobium sheets with the residual resistance ratio (RRR) of more than 200 were used which supplied by Tokyo Denkai Co., Ltd. The cavities were fabricated in Mitsubishi Electric Co. (MELCO).

3 IN WHAT ORDER SHALL WE BEGIN?

The surface treatment procedure consist in four processes; barrel polishing (BP), erector polishing (EP), heat treatment and high pressure rinsing with ultra-pure water (HPR). In this procedure, pretuning and EP were carried out each twice. Because the heat treatment causes deformation to the cavity, final pretuning (Pretuning#2) is necessary after heat treatment. Final EP (EP2) was done just before HPR in order to remove contamination that attached in the heat treatment and pretuning#2. A flowchart of pretuning and surface treatment is presented in Fig. 3.

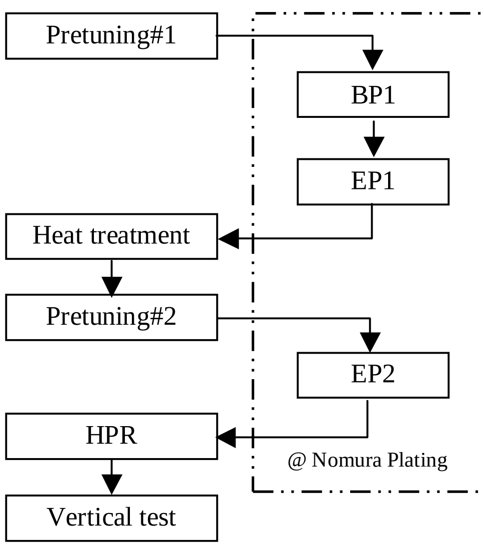

Fig.3 Flowchart of cavity processing

4 PRETUNING OF CAVITIES

Pretuning was carried out by deforming each cell. The deformation device consists of two pairs of steel plates that were machined as it fits the outside of the cell. These plates are inserted to the irises of target cell and squeeze or expand that cell by pushing it or neighbour cells. When end cell is expanded, semicircle shape plates that surround the iris are detached to push the ring for welding Helium vessel instead of the neighbour cell. The deformation device is actuated by four stepping motors through the ball screws. Four dial gauges were set at both beam tube flanges in order to measure the deformation length.

The procedure of pretuning is the same as mentioned in ref [4]. In this procedure, the deformation length needed for tuning is calculated from the field profile and the dispersion diagram of the cavity by modelling it as coupled LC oscillators. The field profile of the cavity was measured by using bead-perturbation method.

Table 2 Resonant frequency and maximum deviation of peak field

(1) J6001

	Frequency, [MHz]	Field deviation, [%]
Initial	598.48	16.0
Pretuning#1	600.04	3.3
Heat treatment	599.86	6.7
Pretuning#2	599.99	1.0

(2) J6002

	Frequency, [MHz]	Field deviation, [%]
Initial	597.73	7.8
Pretuning#1	600.09	7.1
Heat treatment	599.82	9.6
Pretuning#2	600.01	0.8

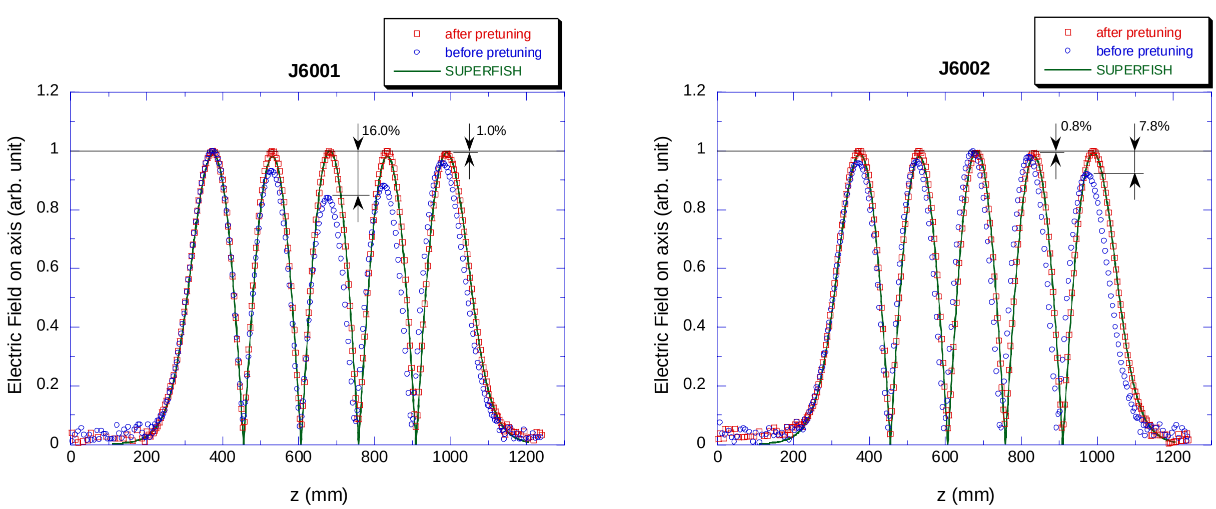

Fig. 4 Field distribution on beam axis

The resonant frequencies and maximum deviations of peak field at each process are summarized in Table 2. Figure 4 shows the relative electric field distributions on beam axis for each cavity before and after pretuning. The calculated result by the SUPERFISH code is also presented in Fig. 4. Before pretuning, maximum deviations of the peak field at each cell center of two cavities were 16% and 8% respectively. After pretuning, these deviations were improved within 1% and the agreement of the measured data with the calculated one is quite well. Errors of resonant frequency were also improved from –1.5 MHz to -6 kHz and from –2.3 MHz to +11 kHz respectively.

5 VERTICAL TEST

Barrel polishing (BP), electro polishing (EP1 and EP2), heat treatment at 750°C for 3 hours and high pressure rinsing with ultra-pure water (HPR) at 8-9 MPa for 1.5 hours were applied before vertical test. Average removal thickness in BP, EP1 and EP2 were 30 µm, 100 µm and 30 µm, respectively. After assembly, the cavity was evacuated by a turbo pump at 110-130 °C for two days and a pressure of less than 1.3×10^{-7} Pa was reached.

The cavity was pre-cooled by liquid nitrogen through one night. After all the liquid nitrogen evaporated, the cavity was refrigerated to 4.2K by liquid helium and pump-down to 2K. During pump-down to 2K, the temperature dependences of the surface resistance were measured. Residual surface resistance of 10.1 nΩ and 9.4 nΩ were measured.

Figure 5 shows the result of the vertical test. Maximum field strength of 31.1 and 39.7 MV/m were achieved in 2K measurements. The limitation of the field was thermal quench. These field strengths exceed design value of 16 MV/m.

6 SUMMARY

Two 5-cell cavities (600MHz, β=0.60) were fabricated for installing into the prototype cryomodule at JAERI. Before pretuning, maximum deviations of peak field at each cell center of two cavities were 16% and 8% respectively. These deviations were improved within 1% after pretuning. Barrel polishing, EP1, EP2, heat treatment at 750°C for 3 hours and HPR at 8-9 MPa for 1.5 hours were applied before vertical test. Average removal thickness in BP, EP1 and EP2 were 30 µm, 100 µm and 30 µm, respectively. Maximum field strength of 31.1 and 39.7 MV/m were achieved in 2K measurements. These field strengths exceed design value of 16 MV/m.

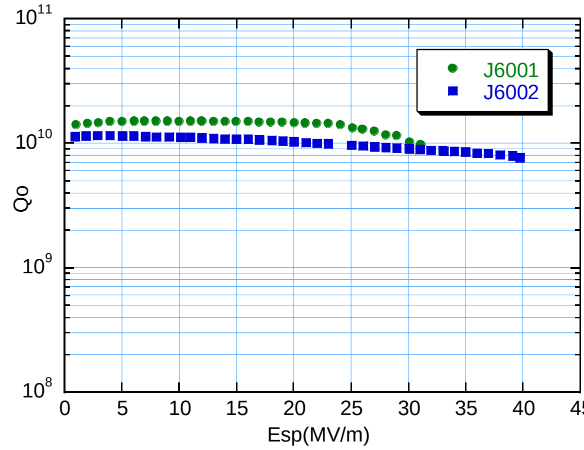

Fig. 5 Results of the vertical test

7 REFERENCE

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