Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

RF Conditioning Effect of PEFP SRF Prototype Cavity

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1. Introduction

For the future extension of the PEFP (Proton Engineering Frontier Project) proton linac, a study on the SRF technology has been performed including a prototype cavity development to confirm the design of the cavity and fabrication procedures and to check the RF and mechanical properties of a reduced beta elliptical cavity. The geometrical beta and resonant frequency of operating mode of prototype cavity are 0.42 and 700 MHz, respectively. The cavity is a five-cell structure as shown in Fig. 1, stiffened by double-ring structure to increase mechanical stability. The main parameters of the prototype cavity are like followings [1].

- Frequency:	700 MHz
- Cavity shape:	Elliptical
- Geometrical beta:	0.42
- Number of cells:	5
- Accelerating gradient:	8 MV/m @2.0K
- Epeak/Eacc:	3.71
- Bpeak/Eacc:	7.47 mT/(MV/m)
- r/Q:	102.3 ohm
- Cell to cell coupling:	1.41 %
- Geometrical factor:	121.68 ohm
- Cavity wall thickness:	4.3 mm
- Lorentz force detuning:	0.4 Hz/(MV/m)^2
- Stiffening structure:	Double ring structure
- Effective length:	0.45 m

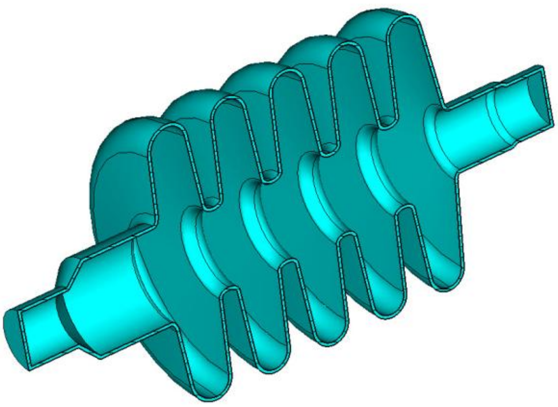

Figure 1: Five-cell prototype cavity

The cavity fabrication procedure mainly consists of the deep drawing process to make each components and the electron beam welding process to join them in one piece. We made the half cells with the deep drawing process [2].

We etched the surface of each part by using an acidic solution before every electron-beam welding process for better welding performance. The acidic solution consisted of HF, HNO_3 and H_3PO_4 with a volume ratio of 1:1:2. The etching rate was estimated to be about 2.5 μm/min, which was confirmed by several tests using specimens. After etching, each part was cleaned with DI water. Figure 4 shows the five-cell cavity with fixing jigs during the final equator welding step.

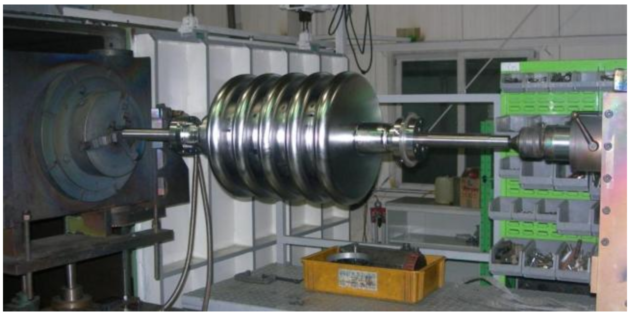

Figure 2: Electron beam welding of five-cell cavity

2. Experimental Setup

A PLL (phase locked loop) based RF system was prepared for the low temperature test of the cavity. We used a vector signal generator (E4432B, Agilent) and a phase comparator to make an RF system which can track the resonant frequency of the SRF cavity during the test. In addition, two solid state amplifiers were used to generate the RF power for the test. To combine the RF power from two solid state amplifiers, we used a split coaxial type RF power combiner which was developed in house.

A cryostat for low temperature test was fabricated. The cryostat is double-wall structure and the space between the inner chamber and outer chamber is filled with 40 layers of the super-insulation and evacuated down to 3E-07 Torr. The height of the cryostat is about 2550 mm and the outer diameter is about 840 mm.

To shield the radiation during the vertical test, the cryostat was inserted into the concrete pipe with thickness of 95 mm. In addition, the lead plates with 20 mm thickness and the concrete blocks with 400 mm width were installed outside the concrete pipe. The control room was located behind the concrete blocks. The overall experimental setup is shown in Fig. 3.

3. Results and Summary

RF power was applied in pulse mode with 250 ms pulsed width and 2 Hz repetition rate (duty factor: 50 %). From the pulse mode measurement, we obtained the unloaded Q as a function of Eacc, as shown in Fig. 3. At a low power level, the measured Q was about 2.9E+8.

Figure 3: Overall experimental setup

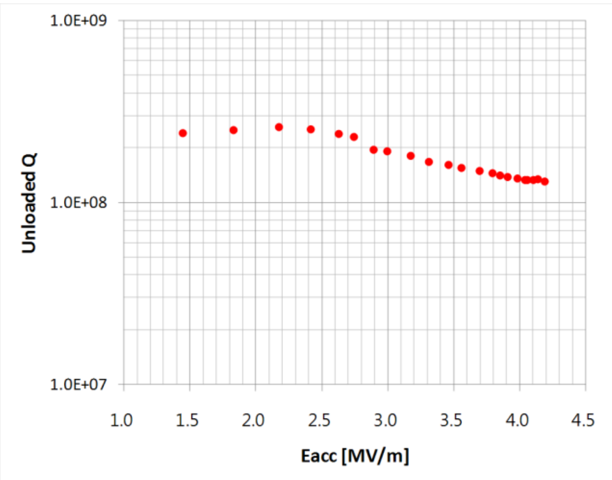

Figure 4: Unloaded Q and Eacc for the prototype cavity

The BCS resistance at 700 MHz and 4.2 K is about 155 nΩ, and the magnetic resistance is about 126 nΩ at the earth's magnetic field level of 500 mG [3]. If we assume that the additional residual resistance is about 50 nΩ, the total surface resistance is about 330 nΩ, which results in an unloaded Q of about 3.8E+8. From the measured Q, the surface resistance of the cavity is estimated to be about 425 nΩ.

When the accelerating gradient is about 2.7 MV/m, which amounts to a 10 MV/m peak field, the Q value starts to decrease with noticeable increases in radiation level. This decrease may be due to field emission. The maximum accelerating gradient was 4.2 MV/m with RF power of 330 W, which was limited by the available RF power. During the test, we could observe the conditioning effect by noticing the increase of the Eacc and Q value at the same RF input power level as shown in Fig. 5 and Fig. 6. For example, the initial accelerating field with 300 W RF power was about 3.7 MV/m. But after one hour conditioning, the accelerating field was increased to 3.9 MV/m at the same RF power level. The accelerating gradient reached 4.0 MV/m after additional one hour conditioning. However, the conditioning is considered to be not sufficient due to the limited test time. With enough RF power and sufficient high-power conditioning, we expect the cavity to meet the design accelerating gradient of 8 MV/m.

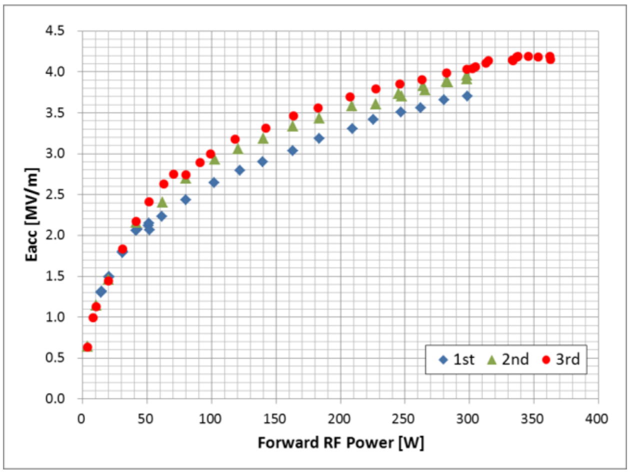

Figure 5: Eacc vs. Forward RF power

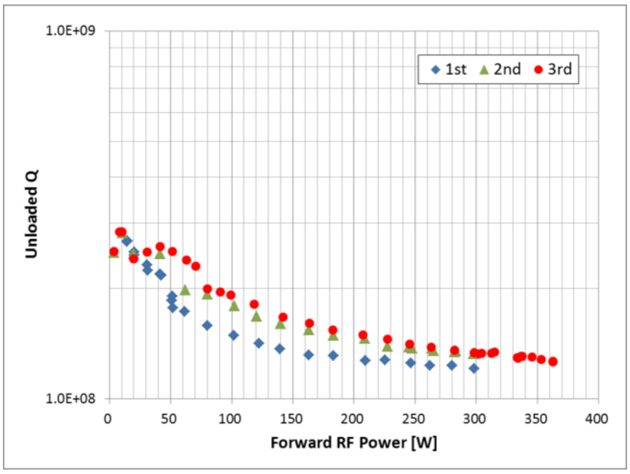

Figure 6: Unloaded Q vs. Forward RF power

Acknowledgements

This work is supported by the Ministry of Education, Science and Technology of the Korean Government.

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