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Mechanical Characteristics of Nb Coated Copper Trial Superconducting Cavity for the High Intensity Proton Linac

K. Mukugi*, T. Murai*, Y. Kijima*, R. Fujimoto*, K. Tsumagari*, C. Tsukishima*, M. Arakawa*, N. Ouchi, J. Kusano, N. Akaoka, and M. Mizumoto

*Mitsubishi Electric Corporation (MELCO)
1-1-2, Wadasaki-cho, Hyogo –ku, Kobe-shi, Hyogo-ken, 652-8555, Japan
Japan Atomic Energy Research Institute (JAERI)
2-4 Shirakata Shirane, Tokai-mura, Naka-gun, Ibaraki-ken, 319-1195, Japan

Abstract

The Neutron Science Project has been proposed with the superconducting proton linac in JAERI. Because the superconducting cavities used for this linac are driven by the pulsed electromagnetic force, the mechanical stiffness and vibrational characteristics are very important. One Nb coated copper single cell cavity (β=0.805, 600 MHz) was manufactured under the R&D collaboration contract between JAERI and MELCO for trial purposes (coated by ACCEL GMBH using the European sputtering technology), and tested for the vibrational modal, and RF resonant frequency detuning characteristics by the Lorentz force.

1. Introduction

The Neutron Science Project has been proposed with the superconducting proton linac in JAERI [1]. Superconducting cavities used for the linac are driven by the pulsed electromagnetic force. Mechanical stiffness and vibrational (dumping) characteristics of the cavities are very important [2]. One Nb coated copper single cell cavity (β=0.805, 600 MHz) was manufactured and mechanically tested. Experimental and analytical modal analysis were done , and the RF resonant frequency shifts of the cavity caused by the Lorentz force were measured.

2. Cavity fabrication and setting

The details of the cavity fabrication are described in another report [3]. The cavity is made from 4 mm thickness Oxygen-Free copper, shaped by the spinning, welded by the EBW (Electron Beam Welding), and Nb coated.

The cavity shape is for 600 MHz, β=0.805 with 230 mm length of the beam pipe. Figure 1 and figure 2 show the cavity and apparatus for the vibrational modal test.

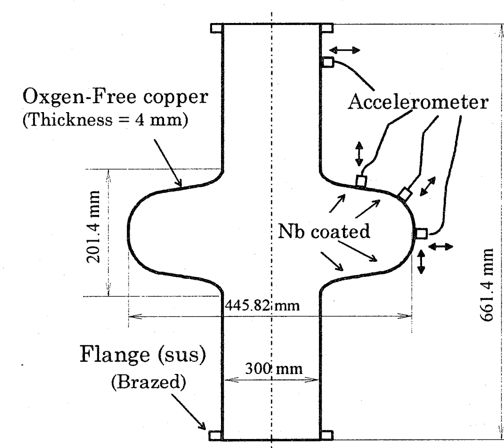

Figure 1 Cavity shape and transducers for vibrational modal test.

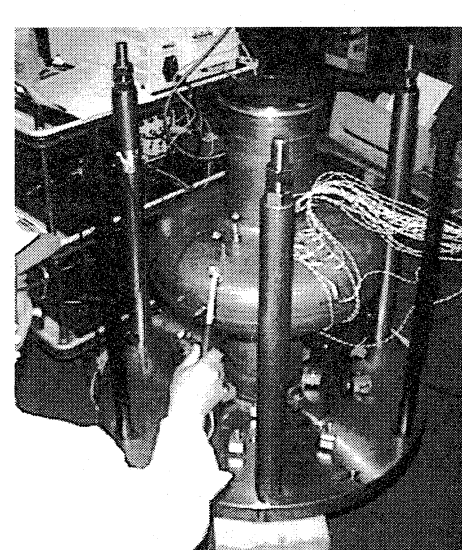

Figure 2 Cavity with modal test setup.

3. Vibrational modal test and analysis

As shown in figure 1, four accelerometers were installed. The end of the beam pipe in one side is free. The transfer functions were measured by the bump test, and analyzed for mechanical natural frequencies, modes and mechanical quality factor (Q_m). Here, the dumping ratio ζ is described as $\zeta = 1/2Q_m$.

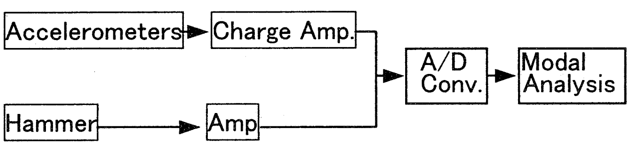

Figure 3 Experimental setup for modal test.

Vibrational modes of 2-dimensional and 3-dimensional models were also calculated using ABAQUS 5.7 finite element code.

Table 1 shows the vibrational modes obtained from experiments and calculations.

Table 1 Vibrational modes

Mode	1	2	3	4	5	6	7
Experimental	50, 65	158	218	375	863	1906	2650
Calculation	70	177	286	326	1236	2143	3036

Figure 4 shows the measured Q_m values. Q_m varies from 23 to 114 which are around the TESLA's results (Q_m=115 at 175 Hz) [4].

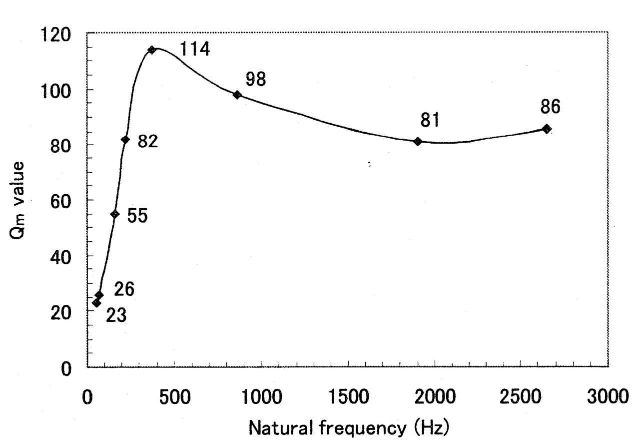

Figure 4 Measured Q_m values.

One example of the measured power spectrum is shown in Figure 5.

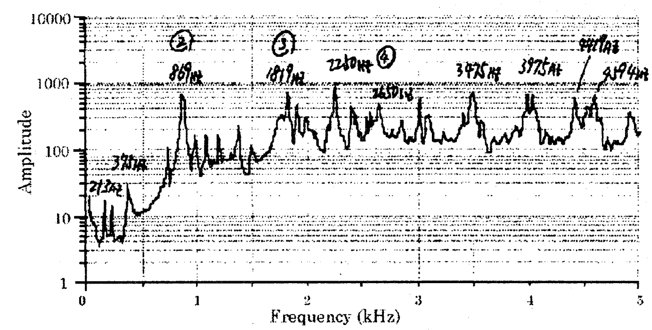

Figure 5 One example of power spectrum.

Figure 6 shows the calculated vibrationl modes, mode 1 and mode 3 of 3-dimensional model.

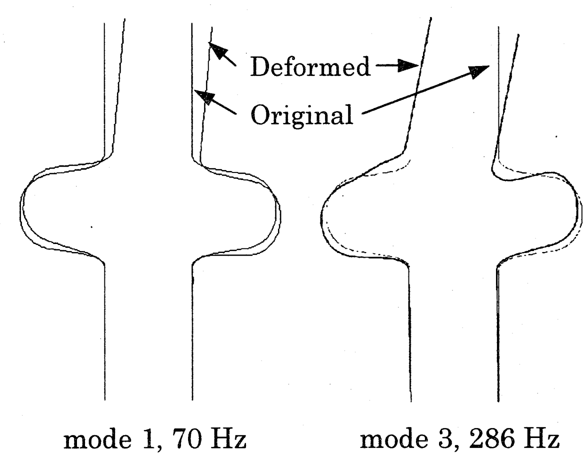

Figure 6 Calculated vibrational modes.
(3-dimensional model analysis)

Figure 7 shows the calculated vibrationl modes, mode 5 and mode 6 of 2-dimensional model.

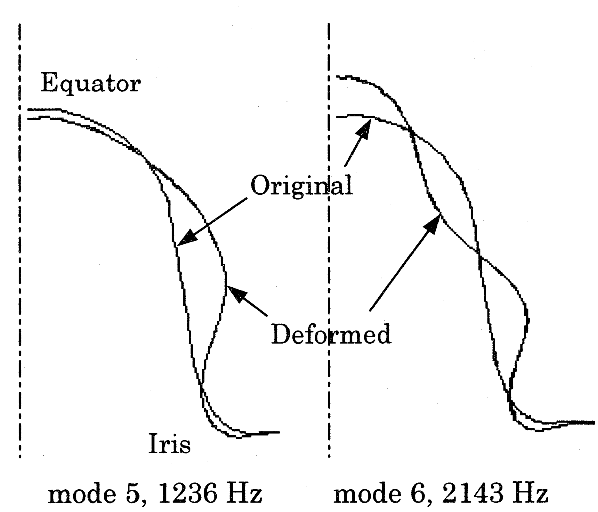

Figure 7 Calculated vibrationl modes.
(2-dimensional model analysis)

3. Lorentz force detuning

RF resonant frequency shifts of the cavity caused by the Lorentz force were measured in the RF performance test, and compared with calculated ones (Table 2). Lorentz force detunings were also calculated using the Superfish code combined with the ABAQUS code. The cavity support is same as that of the modal test.

Calculated frequency shift is smaller than that of measured, about 30%-40%. This is considered due to the decreased thickness in the manufacturing process. The measured minimum thickness of the cavity was about 3 mm.

Table 2 Lorentz force detuning

	$\Delta f/E_{sp}^2$ (Hz/(MV/m)^2)
Calculated	-3.06
Measured	-4.28~-5.19
Cal/Meas ratio	0.71~0.59

3. Conclusions

(1) In the vibrational modal test, main mechanical resonant modes were recognized in comparison with calculated ones. Mechanical quality factors Q_m of the cavity were around 100.

(2) In Lorentz forced detuning measurement and calculation, calculated detuning was smaller than that of measured, about 30%-40%.

Further intensive studies of mechanical vibrational properties and the dynamic behavior of the resonant frequency of cavities under the pulsed Lorentz forces are needed.

4. References

[1] M. Mizumoto, et al., "A High Intensity Proton Linac Development for Neutron Science Research Program", Proc. of the 1996 International Linac Conference, Geneva, Switzerland, (1996)

[2] K. Mukugi et al., "Structural Analysis and Simulation of Superconducting Cavities for High Intensity Proton Linac", Proc. of the 23rd Linear Accelerator Meeting in Japan, Tsukuba, 1998, p.301

[3] Y. Kijima et al., "RF Performance of Nb coated Copper Trial Superconducting Cavity for High Intensity Proton Linac", these proceedings.

[4] T. Schilcher, "Vector Sum Control of Pulsed Accelerating Fields in Lorentz Forced Detuned Superconducting Cavities", TESLA 98-20, August 1998

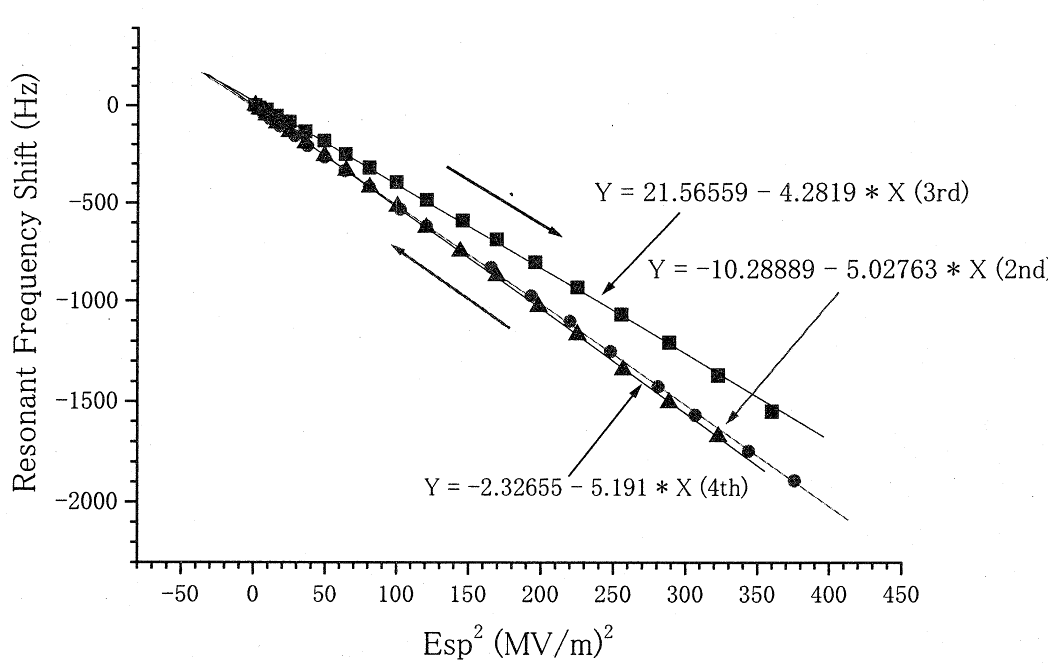

Figure 8 Measured Lorentz force detunig.