R&D STATUS OF THE ANNULER COUPLED STRUCTURE LINAC FOR THE JAERI/KEK JOINT PROJECT

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Abstract

Annular Coupled Structure (ACS) has been developed for the 190-400MeV coupled-cavity linac of the JAERI/KEK joint project. Design optimization of the ACS cavity has nearly been completed using 2D and 3D codes. In parallel with the numerical analyses, half-scale aluminum models were fabricated to confirm the numerical results. The cold-model tests also aim to finish the detailed design taking mass production procedures into account. Especially, the machining and the tuning procedures are examined in detail from the viewpoint of cost reduction and quality management. The results of the model tests are presented with those of other recent R&D works on ACS, which include fabrication R&D performed with full-scale models.

1 INTRODUCTION

The phase-I construction of High Intensity Proton Accelerator Facility (JAERI/KEK joint project) has been started. The plan has been discussed and proposed jointly by the High Energy Accelerator Research Organization (KEK) and the Japan Atomic Energy Research Institute (JAERI). The linac uses normal-conducting cavities up to 400MeV. An RFQ linac accelerates the beam up to 3MeV, a DTL up to 50MeV, a SDTL up to 190MeV, and an ACS up to 400MeV. An acceleration frequency from the RFQ to the SDTL is 324MHz, and the ACS is 972MHz.

In advance of the practical ACS cavity production, a half scale aluminum model was fabricated; the frequency is 1944MHz. This model aims at the evaluation of the cavity properties with low power RF and the examination of the measuring method required for the RF measurements. Refer to [1] for the cavity design in detail, and [2] for the beam dynamics. The half-scale model test and buncher cavity (first practical model of ACS) fabrication are proceeded with in parallel now. The knowledge brought with the half-scale model is reflected in the buncher production.

2 HALF-SCALE MODEL OUTLINE

The half-scale model consists of two kinds of 17-cell cavities ($\beta = 0.5581, 0.5624$). The total number of accelerating cell is up to 34. It also includes the nine cell bridge cavities and the connection cavities corresponding to each beta. Figure 1 shows the configuration of the half-cell disk.

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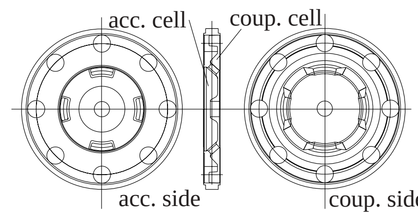

Figure 1: Configration of the half-cell disk

A half-cell disk contains a half of an accelerating cell and a coupling cell on the each side. The same configuration is used in the practical cavity. RF properties are measured with stacked some disks and end plates in piles. The end plates which make an E-symmetry plane were separated from assembling parts, so that the individual characteristics of the end plates were able to be checked, and the rigidity was improved. Figure 2 shows the whole view of the measurement setup.

It is necessary to take consideration of the deformation by stacking pressure. The measurement results were plotted against the contact pressure converted from the stacking torque.

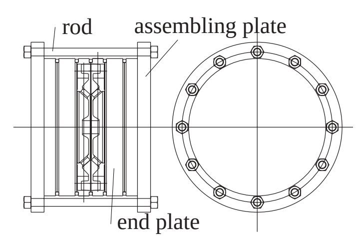

Figure 2: Whole view of the measurement setup

3 HALF-SCALE MODEL MEASUREMENT

Section 3.1 to 3.3 describe the measurement result of the axial symmetrical cavity without coupling slots. Section 3.4 mentions the individual difference of the frequency about the initial shape of models just after machining using the case of the high-beta cavity with coupling slots.

3.1 Flatness of Contact Surface

Figure 3 shows the frequency measurement results of the accelerating cell about two kinds of models. One is the low-beta (LB) model and the other is high-beta (HB) model. The main difference of two models is the flatness of the RF contact surface between a half-cell and a half-cell, or a half-cell and an end plate. The high-beta model keeps 2.5μm flatness, however the low-beta model is 12.5 μm. The surface roughness is almost same; the design roughness is $R_{max} = 3.2$. This difference mostly depends on quality control through the machining process.

The low-beta model was machined first. The flatness mentioned above was not paid much attention at that time. This model had the 8MHz shift in proportion to the contact pressure from zero to 3kg/mm^2, and the pressure dependence is much larger than the high-beta model as shown in Fig. 3. This model also had other problems:
(i) the frequency of the single cell measurement was 5MHz higher than that of the half-cell;
(ii) the Q-value decreased with increasing the contact pressure.

The high-beta model was machined secondly using another factory with more careful quality control. The frequency shift decreased to 400kHz, and the Q-value increased up to 7000 simply.

Following the above results, the flatness of the low-beta model was corrected with diamond machining to confirm the cause. As a result, this correction decreased the flatness from max.20 μm to max.10 μm, and the frequency shift also decreased from 8MHz into 350kHz.

Consequently, the flatness of RF contact surface is important for the reliable measurement of this type cavity. The 1944MHz half-scale model requires the flatness less than 10 μm.

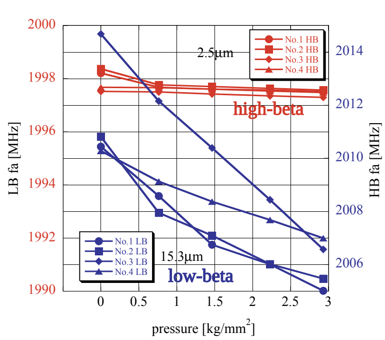

Figure 3: Effect of flatness on frequency shift

3.2 Q-value and Contact pressure

Figure 4 shows the relationship between the contact pressure and Q-value, and these figures compare before and after diamond machining at the contact surface.

The surface before diamond machining was finished with a normal lathe. After diamond machining, the saturation of Q-value is more quickly than before. Although the Q-value saturation requires about 2kg/mm^2 pressure without diamond machining, it requires only 0.5 kg/mm^2 for an accelerating cell and 1 kg/mm^2 for a coupling cell after diamond machining. Since both cells appear by turns, it

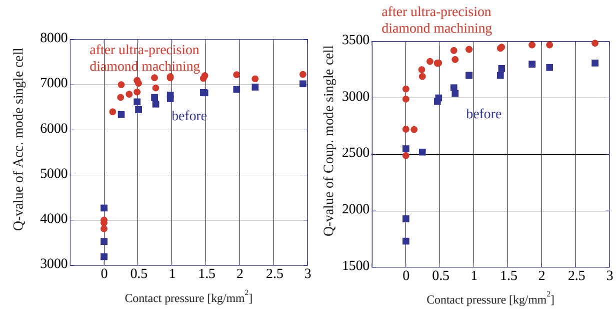

Figure 4: Q-value and Contact pressure

is thought that the whole assembling of cavities (multi-cell measurement) needs slightly larger contact pressure.

Comparing the convergence tendencies of an accelerating cell and a coupling cell, that of a coupling cell is slow, while the total area of a contact surface is almost same. This is because the coupling cell side has two contacts; the inner and outer circumference of the cell. This suggests the contact of a coupling cell should be thought with care. Furthermore, the frequency variation of a coupling cell is larger than that of an accelerating cell. (See Section 3.4)

These resluts shows diamond machining is one of the effective corrections to suppress the frequency variation in the process of fine-tuning of this models.

3.3 Frequency Measurement and Analysis

Table 1 summarizes the frequency measurement and numerical results using SUPERFISH. The measurement uses the single-cell setup and the results were corrected including the measurement environment.

Table 1: Summary of frequiecy measurement

	Measurement [MHz]	SF	Δf
Low-beta (fa)	2004.4	2005.9	-1.5
Low-beta (fc)	2156.9	2162.4	-5.5
High-beta (fa)	1998.1	1999.0	-0.9
High-beta (fc)	2148.8	2147.2	+1.6

It is thought that the frequency of the low-beta model decreased slightly because of the influences by correction machining of the own contact surface. As described above sections, frequency changes with contact pressure. These values were evaluated by extrapolation for zero pressure about the measurement results.

It is necessary to analyze stress distribution about cavity deformation for evaluating the frequency measurement error in detail.

3.4 Frequency Distribution by Machining Error

The frequency was measured with a single half-cell to estimate how the machining error of a normal lathe would come out in RF measurement. A half-cell disk includes a half accelerating cell and a half coupling cell. It is equivalent to two (half) cells cavity; both cells are terminated by end plates. The measurement recorded three modes from lowest mode f_1 to third mode f_3. In the mode of f_1 and f_2, an accelerating cell side is excited mainly, and a coupling cell side is excited mainly in mode f_3.

Figure 5 shows the frequency distribution of 28 half-cells in the form of a histogram.

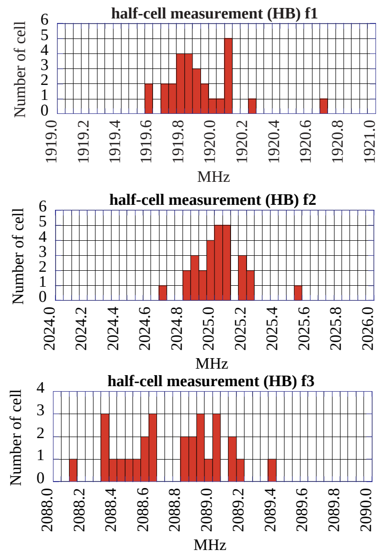

Figure 5: Frequency distribution of 28 half-cells (high-beta model)

The distribution of f_3 is about ±600kHz. It is larger than that of f_1 and f_2 whose range of about ±200kHz. It can be understood that the end plate influence of the coupling cell side appears in mode f_3 as mentioned in Section 3.2 .

It is expected that the ultra-precision diamond machining of the last finish in the practical cavity production can reduce the error distribution. These data are the base of error estimation in mass production.

In this half-scale model, the frequency will be adjusted into ±100kHz.

4 FULL-SCALE MODEL

4.1 Buncher fabrication

The buncher fabrication is now in the trial machining stage using an aluminum or cupper disk. The study items of real-scale machining are the coupling slot finishing and total accuracy. The magnetic flax is concentrated in coupling slot region, so that the surface finishing is important to reduce the surface loss. The technical issues have been optimized. The smooth surface is achieved with a five-axes machining-centre.

4.2 RF measurements

The measurement technique in the full-scale model is not easy using same procedure of the half-scale model. The flatness of contact surface is key issue for this type cavity. It is slightly difficult to keep the accuracy of flatness less than 10μm in the normal machining of the large diameter (460mm). For an experiment example, the end plate finished with a normal lathe could not close the contact surface completely, and the electromagnetic field leaked out. Thus, surrounding situations shifted the frequency easily.

Figure 6: Trial machining of the aluminum model on a machining-centre

The contact surface of end plate was corrected with diamond machining for the improvement. At the present status, however, assembling parts are temporary; it requires the adjustment of the stacking pressure and position for every measurement. The assembling system for real-scale model should be developed for more reliable and quick measurement.

5 SUMMARY

The half-cell model measurement was finished at single-cell setup. The fundamental measurement procedure and accuracy requirements were confirmed. The multi-cell measurement and frequency tuning are continued.

The technical problems have been solved for the machining of buncher fabrication. The real-scale RF measurement leaves room for improvement. We are planning the measurement procedure through the assembling of the buncher cavity.

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6 REFERENCES

[1] N. Hayashizaki et al. "Structure Design of the Annular Coupled Structure Linac for the JAERI/KEK Joint Project", in these proceedings

[2] M. Ikegami et al., "Beam Dynamics Design of the Annular-Coupled-Structure linac and its Beam Matching Section for the KEK/JAERI Joint Project", in these proceedings