COLD-MODEL TESTS OF AN ANNULAR COUPLED STRUCTURE FOR UPGRADE OF A J-PARC LINAC

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Abstract

An Annular Coupled Structure (ACS) has been developed for upgrade of a J-PARC (Japan Proton Accelerator Research Complex) linac from 180 MeV to 400 MeV. Although install area is prepared for the ACS cavities at an initial construction, it will be used as a beam-transport line temporarily. Aluminum and copper models were fabricated for RF properties confirmation based on an initial design, and for final optimization. RF measurement procedure of the ACS structure was also studied thorough the R&D process. Many items should be considered for mass production; schedule, handling parts, utilities, and so on. The measurement results of models and some fabrication status are presented.

INTRODUCTION

The phase-1 construction of High Intensity Proton Accelerator Facility (JAERI/KEK joint project) has been started. A nickname for this facility has been decided to be "J-PARC" (Japan Proton Accelerator Research Complex)[1]. 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 following are the complete design of the linac. The linac uses normal-conducting cavities up to 400MeV. An RFQ linac accelerates the beam up to 3MeV, a DTL up to 50MeV, an 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. For the detail design of the ACS, refer to the references [2, 3].

The beam energy of the linac is planned for 180 MeV at present temporarily, which is restricted from a total budget. Although the ACS is not sure to be installed at an initial operation of the phase-1, R&D for a cavity fabrication and a mass production should be finished as soon as possible. Since April 2002, the fabrication of first 972 MHz prototype module was started. This is first buncher module, consisting of two 5-cells accelerating cavities and a 5-cells bridge cavity. And then, at the last of fiscal year 2002, second buncher module and three accelerating module were ordered. Fabrication of these modules will be active from April 2004 mainly. Two 17-cells accelerating cavities and a 9-cells bridge cavity were chosen for the accelerating module. The total number of accelerating modules were reduced from 23 to 21 at present design to save a total fabrication cost. (The former design was 15-cells and 23-modules.)

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ALUMINUM MODEL TEST AND COUPLING IRIS ANALYSYS

A wave guide and a bridge cavity are coupled with an iris for matching condition of RF power. A coupling factor β was analyzed for this region and discussed.

Review of JHF L-band ACS coupling

An ACS prototype module for JHF was developed at KEK. This module was installed high power RF and confirmed the cavity is performance. Based on the this module, a coupling β was analyzed for the iris part dimensions of the JHF module with an HFSS. Figure 1 shows an analyzed model and a calculated S11 parameter. The analyzed model in Fig. 1 includes 1-cell (0.5-cell + 0.5-cell) cavity. The upper boundary plane is a magnetic boundary for a $\pi/2$ mode excitation, and the rear plane is a magnetic boundary and the bottom plane is an electric boundary because of a symmetry. Evaluated from this results, a coupling value is $\beta = 37.5$. The designed value is $\beta = 43$, supposing that a Q-value and a coupling factor are ideal between a bridge cavity and an accelerating cavity. Measured value is $\beta = 0.99$ for whole cavities [4]. This is one sample of comparing an analysis and a measurement.

For another case, 2.5-cell (2-cell + 0.5-cell) cavities case was analyzed. This analysis concludes $\beta = 12.8$. It is considered reasonable. This is because that a ratio of two cases are $37.5/12.8 = 2.93$; it is almost equal to a ratio of a stored energy. These results will be checked by model and module measurements in a fabrication process.

Half-scale model test for J-PARC

In advance of the practical ACS cavity production, a half scale aluminum model was fabricated; the frequency is 1944 MHz. 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 [5].

As mentioned in above section, a coupling β was also analyzed for a half-scale model. Several size of iris and connecting dimensions are fabricated and these measurement is underway. (See Fig. 2) For a regular accelerating section, accelerating and coupling cells have a margin for frequency tuning at initial dimensions, so that these cells have been tuned by several times of machining.

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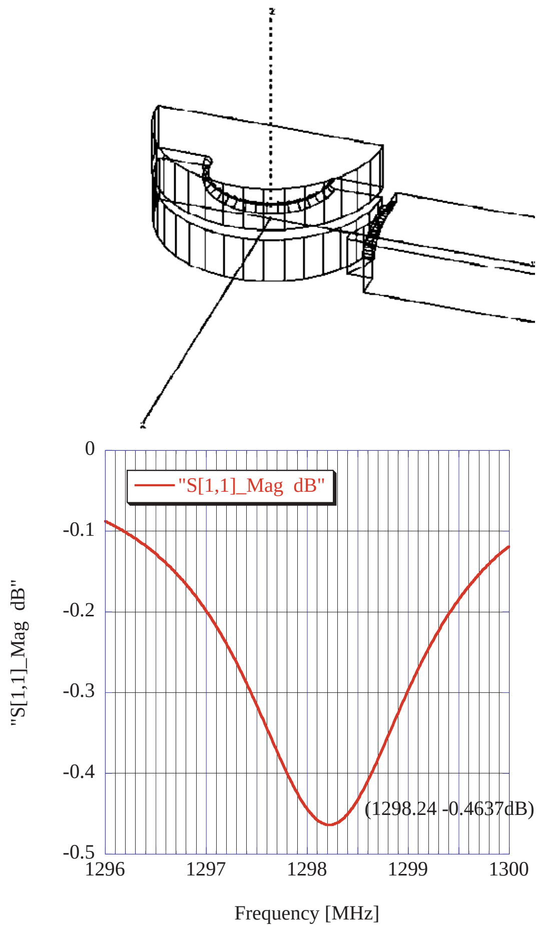

Figure 1: The analyzed model shape and the calculated S11 parameter with an HFSS

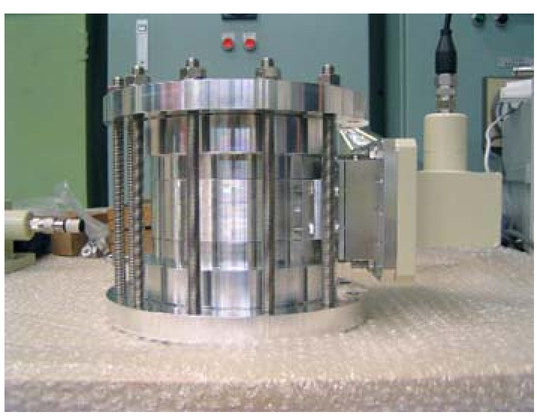

Figure 2: Half-scale aluminum model of connection part between a bridge cell and a wave guide

PROTOTYPE MODULE

Machining of half-cell disks

Many half-cell disks are layered and brazed for assembling an ACS cavity. Figure 3 shows the configuration of a half-cell disk. Flatness of a composition surface is important for brazing. An OFC half-cell disk is machined as follows:
1) machined with 5-10 millimeter margin at a material factory,
2) machined with 1 mm margin and then annealed,
3) machined with 0.5 mm, 0.18 mm, 0.08 mm margin step by step,
4) four coupling slots are drilled on a machining-centre,
5) finished with ultraprecision machining for the design shape.

It is better to minimize the margin for ultraprecision machining. This is because that small volume of machining saves damage for a cutting tool, thus it brings stable quality of machining. It is slightly difficult to keep the accuracy of flatness less than 10μm in the normal machining of the large diameter (460mm). Therefore, the final margin for diamond machining is depend on an error of normal machining.

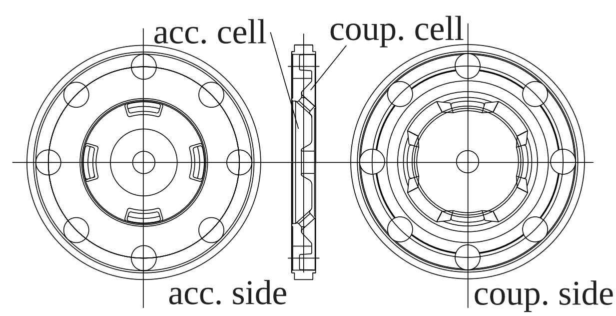

Figure 3: Configuration of the half-cell disk

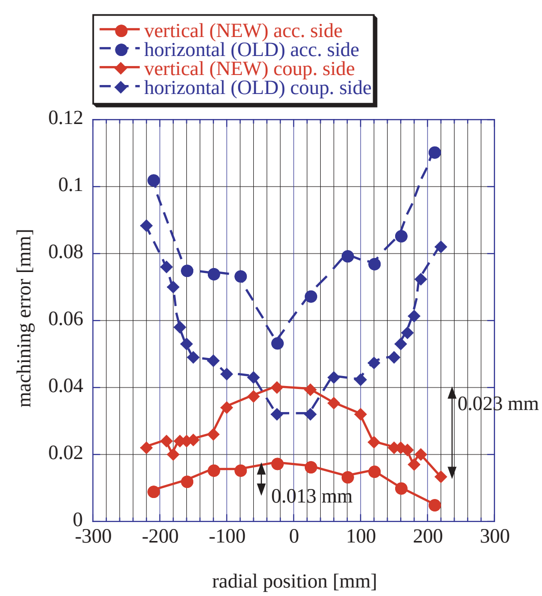

Figure 4: Machining error of a horizontal turning machine vs. a vertical turning machine

Figure 4 shows An example of a machining error with a normal turning machine is showed in Fig. 4 which compares a horizontal type turning machine (a rotating axis is

horizontal) and a vertical type turning machine (a rotating axis is vertical). Some reasons of the machining error are:
1) temperature control of a turning machine,
2) temperature control of machined object,
3) heat effect caused by machining .
Especially, it is considered that the error between a center and a circumference part are caused from the increase of the object temperature. The new vertical turning machine takes care of all above points; placed air conditioned area, temperature controlled cutting oil, and high-rotating speed reduces heating effect. Therefore, the new vertical turning machine can reduce a machining error drastically.

Figure 5: Vertical turning machine

Wave guide flange and RF window

An wave guide flange for a vacuum region and RF window have been developed. The wave guide is WR975. A rectangular flanges were fabricated and tested with several thicknesses of gaskets. (See Fig 6) These flanges are vacuum tight and they are adopt for ACS modules and RF windows.

The RF window is a pillbox type and a diameter of a ceramic window is 285mm. First prototype window is under fabrication. Although it is ensured 0.4 MPa of resist pressure for cooling water, a water cooling system of the linac recommends up to 1MPa strongly. A sleeve design around a ceramic for an accelerating modules will be revised to keep toughness up to 1MPa. This prototype window will be used for measurement of RF properties and a high-power test at a test stand.

SUMMARY

The half and full-cell models are corrected and measured continuously. The fundamental measurement procedure and accuracy requirements for measurement tools have been developed.

The technical problems have been solved for the machining of half-cell disk. The real-scale RF measurement con-

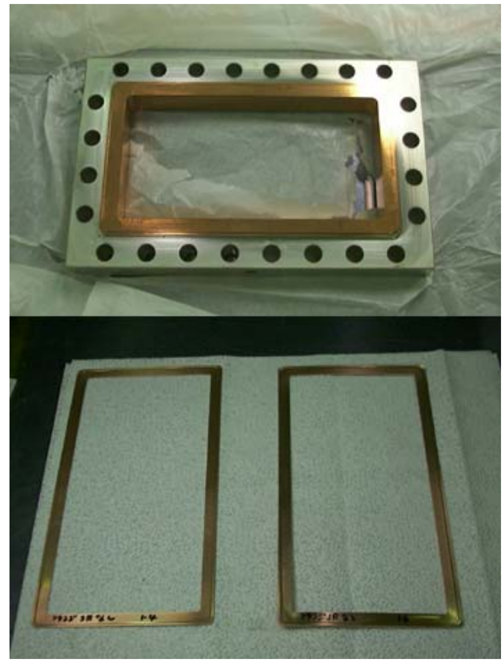

Figure 6: Rectangular flange and gaskets for vacuum waveguide WR975

tinues for improving a tuning process. We are planning the measurement procedure through the assembling of the buncher cavity.

Fabrications and R&D schedule are as follows. The first buncher fabrication is scheduled to finish in February 2004. An high-power test of this buncher is planned for a next step. From April 2004, the second buncher and accelerating modules are started. The second buncher has the same design as first one. Trial machining and tuning R&D are proceeded to next β energy of modules.

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