PROGRESS ON RFQIII FABRICATION IN J-PARC LINAC

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Abstract

For the beam current upgrade in J-PARC linac, the fabrication of a new RFQ, which is designed for 50mA beam acceleration, has been started. The engineering design and the fabrication technologies were carefully chosen to reduce the discharge risk during the operation. For good vacuum pumping, vanes and ports are brazed for the direct pumping through slits at the tuners. Also, we tried a chemical polishing to improve the smoothness of the vane surface.

INTRODUCTION

The J-PARC accelerator comprises an injector linac, a 3-GeV Rapid-Cycling Synchrotron and a 50-GeV Main Ring. The J-PARC linear accelerator consists of an ion source, an RFQ, DTLs, separated DTLs (SDTL), and the beam transport line to the RCS synchrotron [1].

The J-PARC linac has been operating for users with the beam energy of 181 MeV. The currently operating RFQ is a four-vane type cavity used to accelerate a negative hydrogen beam from 50 keV to 3 MeV with peak current of 30mA. The RF duty factor is 3% (600 μs at50 Hz). For the quick replacement in case of the RFQ trouble, we fabricated a spare RFQ (RFQII) as a backup machine. [2, 3, 4]

The energy (to 400MeV) and current (to 50mA) upgrade of the linac is scheduled for 1MW operation at RCS. The beam dynamics of an RFQ is newly designed for beam current upgrade to 50 mA operation. [4, 5] Then, we started a fabrication of RFQIII last year.

In this paper, we present the fabrication progress of an RFQIII for J-PARC linac.

ENGENEERING DESIGN

Table 1 shows the RFQ III parameters. For the beam current upgrade, the vane length is longer than RFQII about 0.5 m. The RFQ cavity is divided into three unit tanks. Each tank (about 1.2 m long) will be integrated together on a platform after the brazing of the major and the minor vanes.

Engineering design topics are listed in Table 2. The high-power test of the RFQII has been done successfully at April 2012. Basically the mechanical design and the fabrication procedure are the same as RFQII. Followings are the points which are changed from RFQII

Drilled Hole Plugging

The drilled hole plugging technique was changed from electron beam welding to the brazing. In the fabrication of RFQII, there was a vacuum leak at the welding spot after the brazing (one of seventy-two welding points). Then we changed it to brazing along with the vane brazing in the RFQIII fabrication.

Table 1: Main Parameters of RFQIII

parameter	RFQ III
Beam current [mA]	50
Frequency [MHz]	324
Acceleration energy [MeV]	0.05 to 3
Vane length [m]	3.6
Inter-vane voltage[kV]	81
Maximum surface field [MV/m]	30.7 (1.72 Kilpatrick)
Average bore radius [mm]	3.5
Vane-tip curvature [mm]	0.75r0(2.617)

Table 2: Mechanical Design Features

Material	High-purity oxygen-free copper with HIP(Hot Isostatic Pressing)
Drilled hole plugging	RFQII : Electron beam welding RFQIII : Brazing
Annealing	600 degree C in vacuum furnace
Vane machining	Numerical-controlled machining with ball-end mill RFQIII: Introduced non-contact measurement [6]
Surface treatment	Chemical polishing (3-5μm)
Integration method	Vanes and ports are jointed in one step brazing
Unit cavities connection	RFQII : Welding for vacuum sealing, bolting for mechanical alignment RFQIII : bolting for mechanical alignment and vacuum sealing

Dry Cutting for the Fitting of End Flanges

Figure 1 shows a schematic drawing of the unit cavity components to be assembled for brazing. After the final cutting of vanes, those are assembled and machined for a flange fitting at each ends. In the RFQII, vanes were disassembled for the surface treatment to remove cutting oil, then, reassembled for brazing. In the RFQIII, to reduce costs and production period, dry-machining for a flange fitting is adopted after the surface treatment. Then we can reduce the disassemble-reassemble process.

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Additionally, the displacements by the reassembling could be removed.

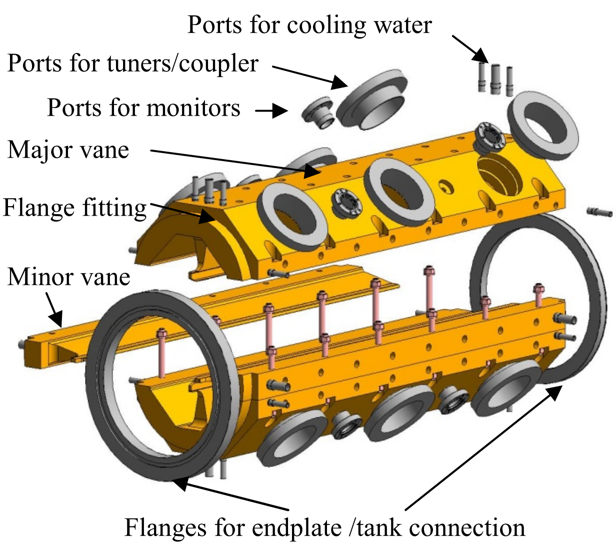

Figure 1: Assembling of vanes and other components of the unit tank for brazing.

Unit Cavities Connection

Unit cavities are bolted together with a vacuum seal and an RF conductor. This configuration is simple and decomposable easily. However, the angle error between flanges at the connection will cause the alignment errors for the straightness between unit tanks. In the experience from RFQII fabrication, the angle error of the brazed flange was less than 0.07mm/(flange diameter). Then we put the 0.1 mm gap between flanges for a margin to correct the angle error. By adjusting the gap locally within the squashing tolerance of a vacuum seal and an RF contactor, t he angle error will be compensated.

Dividing Point of the Unit Cavity

The longitudinal dividing point (i.e. the edges of the second unit cavity) of the RFQII cavity is taken at the top/bottom of the modulation. In the RFQIII, dividing point is taken at the position where the longitudinal effect for the beam bunch is small. The gaps between unit cavities are 0.3 mm.

SURFACE TREATMENTS

To reduce the discharge risk in the high electric field, the inner surface of the cavity was chemically polished after the machining. The surface treatment procedure is summarized in Table 3. Figure 2 shows a chemical-polishing major vane in the bath.

Four kinds of solutions were tested before the fabrication of RFQII. Figure 3 shows the surface conditions for solutions and polishing depths.

- Solution #3 cannot produce a smooth surface.
- A smooth surface can be obtained by the solution #4, however, outshoots are found occasionally.
- Grain-boundary appears for over-polished (more than 10 μm) with the solutions #1,2, and 3.
- Lightly-polished (less than 10 μm) surface seems well with the solutions #1 and 4.

Table 3: Surface Treatment Procedure

Process	Tools/Solutions	procedure
Cleaning	Water, methyl alcohol, MEK	wiping
Masking	Taping, caulking	Screw holes, brazing surface
Degreasing	Alkaline solution	Submerging
Acid wash	Sulfuric acid aqueous solution	Submerging
Chemical polishing	Nitric acid + Phosphoric acid + Surfactant	Polishing depth is controlled by temperature and submerging time
Acid wash	Sulfuric acid aqueous solution	Submerging
Anticorrosion	Chromate solution	Submerging
Cleaning /drying-out	Ultrapure water / drie	Running water Air blow

Figure 2: Major vane is submerging in solution #1.

Figure 4 shows the surface roughness for the cases of before polishing, 3μm polished, and 10μm polished by the solution #4.

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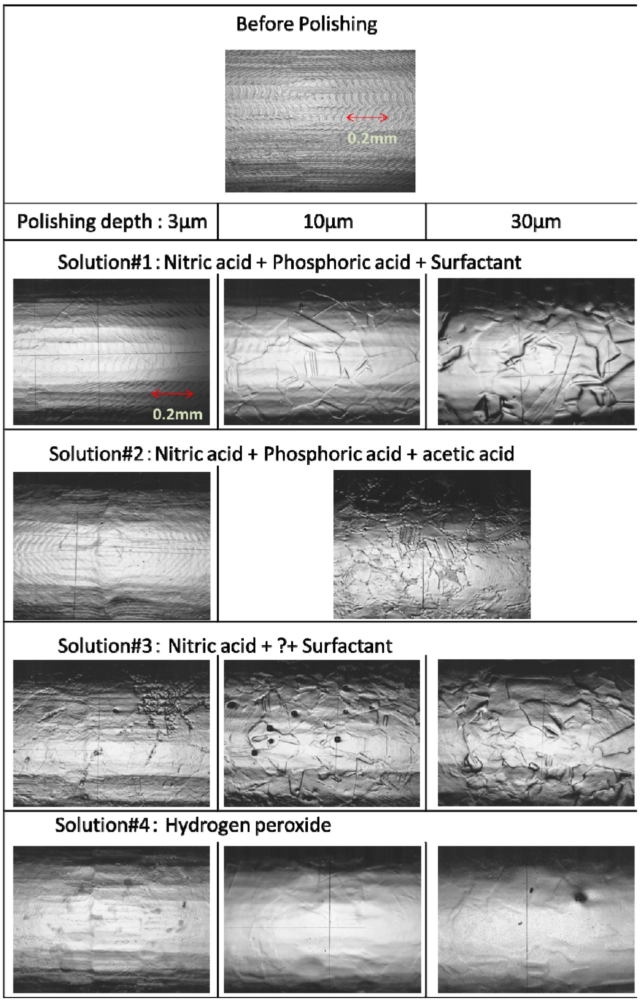

Figure 3: Close-up view of polished surface. Test pieces are machined with the same condition of the vane.

- Calculated average roughness (Ra) improved by the light polishing. The difference between 3µm and 10µm is small.
- Maximum height (Ry) decreased from 1.8µm to 1.2µm by 3µm polishing. Another 7µm polishing, the effect is 0.28µm.

Based on these examinations, we chose the solution #1 and 5µm polishing for the surface treatment.

PROGRESS OF RFQIII FABRICATION

Final machining and surface treatment for first and second units have been finished. The brazing of the first unit is in process. The machining of vanes for third unit is in the finishing step.

SCHEDULE

The third unit will be brazed this November. After the assembling, the RF tuning will be done at end of this year. The high-power test is scheduled next spring. The RFQIII will be installed in the accelerator tunnel at the shutdown period in 2013 after the off-line beam test with ion source and diagnostic beam line on the ground.

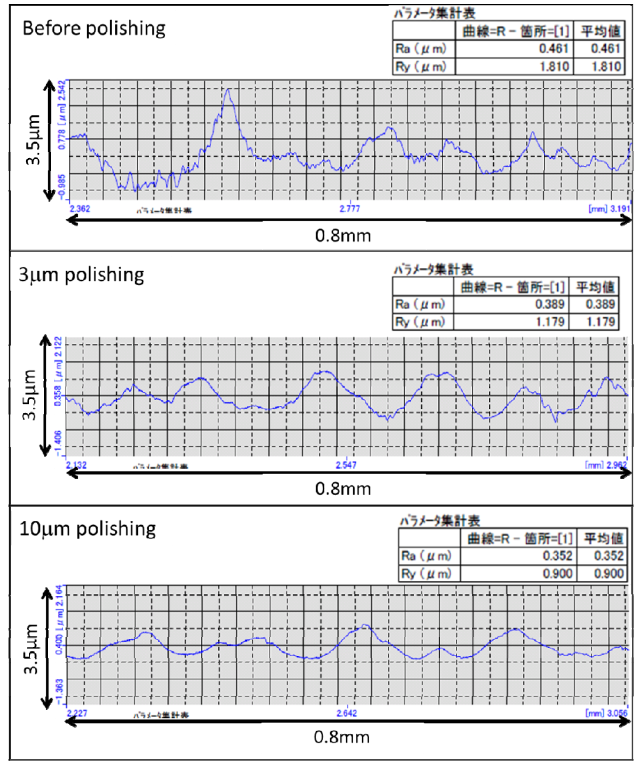

Figure 4: Surface roughness before/after the polishing. Test pieces are machined with the same condition with the vane tip.

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