CONSTRUCTION OF THE BASELINE SC CAVITY SYSTEM FOR STF AT KEK

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Abstract

The STF-Baseline superconducting cavity system, which includes four TESLA-type 9-cell cavities, input couplers and frequency tuners, has been developed for the future ILC project. A main improvement in the cavity system is a very stiff design in a He vessel and a cavity tuning system, which can relax a cavity deformation due to Lorentz force. Vertical tests of four 9-cell cavities have been carried out repeatedly, and the attained accelerating gradients have reached to 20 ~ 29 MV/m with Qo values higher than $1x10^{10}$. Peculiar phenomena, like increasing of Qo values with higher Eacc or very slow degradation of Qo values, were observed in the vertical tests. RF processing of input couplers was successfully carried out up to 1.0 MW with a 1.5 msec and 5 Hz operation .

INTRODUCTION

Construction of STF (Superconducting RF Test Facility) is being carried out at KEK. The main purpose of STF is to develop the cryomodule including high performance cavities and to establish the industrial design of a Main-Linac unit for ILC (International Linear Collider). One of the important tasks is to carry out high power tests of the STF cryomodule, which includes four TESLA-type STF-Baseline 9-cell cavities and four Low-Loss-type High-Gradient 9-cell cavities. Stable pulsed operation with beam and reliability as a total system with sc cavities will be confirmed in STF Phase-1. Presently, assembly of the 6 m cryomodule including one of four STF-Baseline cavities had completed for the initial test, called STF Phase-0.5. Design, fabrication, component tests and assembly of the STF-Baseline cavity system are described in this paper.

CAVITY PACKAGE

A sc cavity system consists of a 9-cell niobium cavity with titanium endplates, an input coupler with cold and warm rf windows, two HOM couplers, a mechanical tuner with a piezo element, a He vessel and a magnetic shield.

STF-Baseline 9-cell cavities

The specific feature of the STF-Baseline cavity, as shown in Fig. 1, is an improved stiffness of the total cavity supporting system consisting of endplates, a cylinder and a tuning mechanism [1]. Comparison with the TESLA cavity is shown in Table 1. Added modifications are summarised as follows:

- Improved support stiffness by thick titanium endplates.
- Enlarged diameter of beam pipes to compensate a weakened input coupling due to a thick endplate.
- Enlarged diameter of an input port to make an usable rf window larger to raise up a power capability.
- Re-optimisation of cell shape to decrease a ratio of a surface peak magnetic field and an accelerating field.
- Over-coupling of an input coupler for making a band width widen to assure more stable operation.

As a result of the improved cavity supporting system, the stiffness has increased from 22 to 72 kN/mm. Therefore, suppression of the Lorentz detuning from -500 to -150 Hz is expected in operation at 31.5 MV/m. Confirmation of this improved effect is the most interesting experiment in high power tests of the cryomodule.

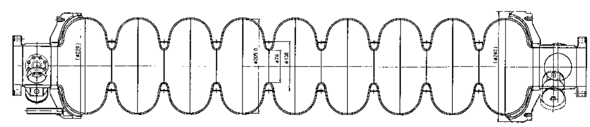

Figure 1: The STF Baseline 9-cell Cavity.

Table 1: Comparison of the main cavity parameters.

Cavity	TESLA	STF-Baseline
Cell Taper	76.7 °	80. °
Φ Beam pipe	78 mm	84 mm
Φ Input port	40 mm	60 mm
Esp / Eacc	1.98	2.17
Hsp / Eacc	42.6 Oe/MV/m	41.0 Oe/MV/m
R / Q	1036 Ω	1016 Ω
Input Coupling	3.0×10^6	2.0×10^6
Support Stiffness	22 kN/mm	72 kN/mm
Lorentz Detuning at 31.5 MV/m	- 500 Hz in a flat top	- 150 Hz in a flat top

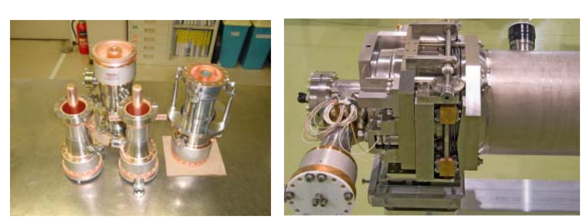

Figure 2: Input couplers and a slide-jack tuner system.

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Input Couplers

An input coupler, which consists of a cold and a warm couplers, has two Tristan-type coaxial disk rf windows, as shown in Fig. 2, (Left). There is no tuning mechanism for varying coupling for simplicity and cost reduction. Four input couplers were fabricated, and the high power test was carried out in the test stand with a 5 MW pulsed klystron. Rf processing up to 1.0 MW in a 1.5 msec and 5 Hz operation (1.9 MW in a short pulse) was successfully performed without any troubles.

HOM Couplers

Two types of HOM couplers (I-type and L-type), which were based on the TESLA design, were fabricated. Their filter shapes were optimised so as to have a different 2nd stop band in each other.

Frequency Tuner

A slide-jack tuner system with a piezo element (see Fig.2, Right) was developed for the STF-Baseline cavities. A stepping motor is put outside of the cryomodule, so that exchange of the motor is very easy when a trouble occurred. A piezo element is attached at the replaceable location without disassembling of the cryomodule.

CAVITY PERFORMANCES

Making clear the performance level of four 9-cell cavities, which were fabricated by "a Japanese company" and were prepared by "existent infrastructures at KEK", is the most important purpose in the whole vertical test.

Surface Preparations

After the initial rf measurements and dimension check, the 1st step of the standard surface treatments is

- Barrel polishing of about 100 µm.
- Initial electro-polishing (EP-I) of 100 µm.
- Annealing for hydrogen degassing at 750 °C for 3 h.

Pre-tuning for adjusting the frequency (1297.4 MHz) and the field flatness (>98%) was performed. After that, a procedure for the final surface treatments is

- Final electro-polishing (EP-II) of 50 µm.
- Hot water rinsing with ultrasonic bath at 50 °C for 1h.
- High pressure rinsing (HPR) with 8 MPa for 6 ~16 h.
- Baking at 120 °C for 40 h.
- (Optionally, HF or H_2O_2 rinsing for 1 h after EP-II).

Additional EP-II of 20~30 µm was repeated in the successive tests. After one series of initial vertical tests, the 2nd barrel polishing was carried out to increase the surface removal, especially at the equator EBW seam. The average total surface removal came finally to ~500 µm.

Vertical Test Results

Not only Qo-Eacc curve and x-ray radiation level, but also Eacc,max in each cell determined by passband modes measurements and search for a heating cell due to quench detected by thermometry, are important to understand the cavity performance in detail. Results of 14 tests on four

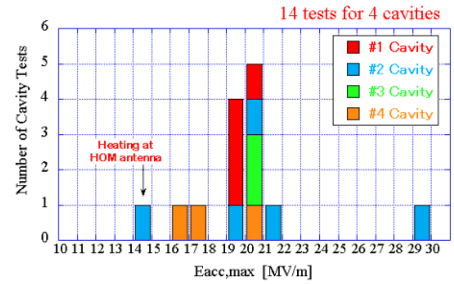

Figure 3: Distribution of the achieved maximum accelerating field (Eacc,max).

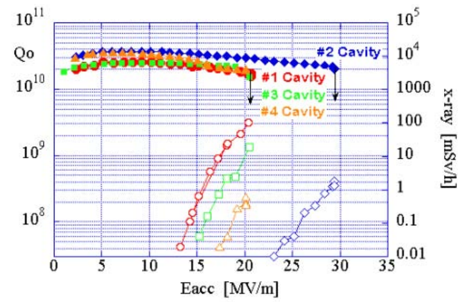

Figure 4: Qo vs. Eacc curves and x-ray radiation level in the final performance on four STF-Baseline cavities.

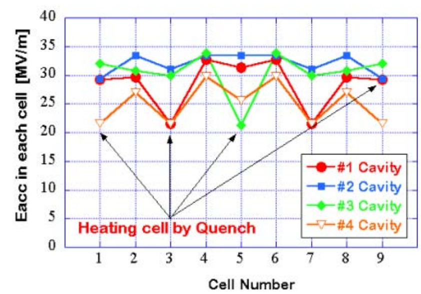

Figure 5: Achievable Eacc in each cell for four cavities.

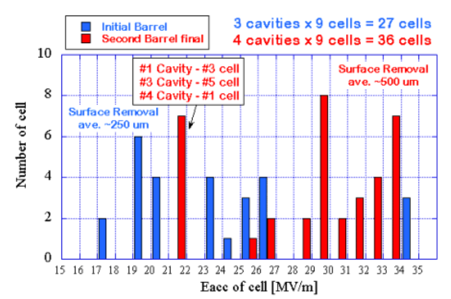

Figure 6: Distribution of the achievable Eacc in each cell before and after the 2nd barrel polishing.

9-cell cavities are summarised in Fig. 3. The average Eacc,max is 20.3 MV/m, and the limitation was due to quench in all tests, except one case (heating at HOM antenna). The final performances of 4 cavities are shown in Fig. 4. The obtained Eacc,max was 29.4 MV/m in the #2 cavity, and the others are 20.8, 20.5 and 20.2 MV/m, where Qo values higher than 1×10^{10} was obtained in all cavities. The achievable Eacc in individual cells and the cell limiting the Eacc,max by thermal quench was shown in Fig. 5. Comparison of the achievable Eacc in each cell between before/after the 2nd barrel polishing is shown in Fig. 6. The distribution of the Eacc has clearly shifted to the higher fields after the 2nd barrel polishing, but only one cell among nine cells still stays around 20 MV/m in three cavities. Therefore, elimination of these cells with a poor performance is necessary to achieve higher gradient in the 9-cell cavities, since the nine-cell performance is determined by only one cell with the lowest Eacc. So, it is considered that further strict quality control is needed both in the cavity fabrication and in the surface preparation. For the next step, improvement of welding procedure and clean environment at a company, and construction of new infrastructure for surface treatments at STF are indispensable to achieve reproducibly higher cavity performance.

Excitation of Another Passband Mode

A strange phenomenon, which Qo value goes up with higher Eacc as shown in Fig. 7, was observed in all cavities after the 2nd barrel polishing. Transition from normal to abnormal state was observed very slowly, (10~60 sec). In this period, the monitored, reflected and transmitted rf power have gradually increased, in spite of the constant input rf power. In the normal state, the Eacc,max was limited by quench at 21 MV/m, which decay time is ~1 msec. In the abnormal state, however, the Eacc,max was finally limited by uncontrollable PLL (phase-lock loop). Occurrence of this phenomenon shifted to higher Eacc by changing the coupling of an input coupler to over-coupling. The frequency spectrum in each monitored rf power was checked, so that excitation of the $8\pi/9$ mode was observed in the reflected and transmitted power, although the incident power was only fundamental π mode. One potential explanation is that field emission current might be possible to excite a parasitic mode.

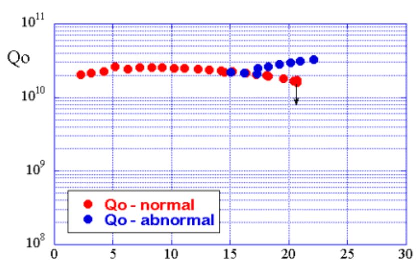

Figure 7: Strange behaviour of Qo values due to the excitation of the $8\pi/9$ passband mode inside the cavity.

Heating at the HOM Pickup Antenna

Slow quench, which decay time of Eacc was about 10 sec, was occurred at ~14 MV/m. The drop of the Qo value was observed, and the degraded Qo value was still kept even at low fields. It took very long time more than 30 min. to recover the Qo value. This cycle was reproducibly repeated, as shown in Fig. 8. It was thought that transition from a superconducting state to a normal conducting state seemed to be occurring at an isolated location thermally. It was found that this phenomenon was caused by heating at a tip of the HOM pickup antenna made of Nb. This was eliminated by shortening the antenna length in the 2nd test.

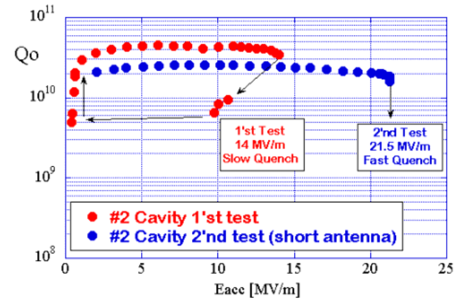

Figure 8: Degradation of Qo values due to heating at the HOM pickup antenna.

ASSEMBLY OF CRYOMODULE

Dressing of the He Jacket

After the cavity performance was qualified in the vertical tests, the four cavities were transported to a company. The four cavities were covered with a titanium jacket for filling liquid He at 2 K, as shown in Fig.9.

Figure 9: Before and after welding of a He jacket. A magnetic shield (centre in left) was inserted in a He jacket.

Installation in the Cryomodule

One cavity for the STF Phase-0.5 was assembled with an input coupler and a gate-valve in a new clean room (class-10), as shown Fig. 10. The cavity equipped with a tuner system was installed in one of the 6m-cryomodules.

String assembly of four cavities for the STF Phase-1.0 is scheduled in Sept. 2007 for the next step.

Figure 10: Installation of an input coupler (Left) and an assembled cavity mounted on 2 K gas return pipe (Right).

REFERENCES

[1] S. Noguchi, et al., "STF Baseline Cavities and RF Components", SRF2005, Cornell Univ., Ithaca, USA, (2005), http://www.lns.cornell.edu/public/SRF2005/. Also, presentation for the ILC seminar at KEK, (May 11th, 2007), http://lcdev.kek.jp/LocalMeetings/.