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IMPROVEMENT OF MAGNETIC CONDITION FOR KEK-STF VERTICAL TEST FACILITY TOWRD HIGH-Q STUDY

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Abstract

Improvement of unloaded Q-values of SRF cavities are important to reduce surface loss of cavity and heat loads of He refrigerators. R&D activities have been developed worldwide. We also started work toward high-Q, but soon realized that magnetic condition of KEK-STF vertical test facility was not good enough to carry out high-Q measurements. First, magnetized components were searched. Shafts to move variable coupler were found to be most magnetized one and exceed more than 1 Gauss. Magnetized components were exchanged to non-magnetized one. In order to further reduce remnant magnetic field, a solenoid coil was prepared and used to cancel it. To suppress flux trapping, a heater was located around an upper beampipe of cavity and made thermal gradient. Owing to these efforts, Q-value of more than 1×10^{11} can be measured with a condition of residual resistance of ~3 nΩ. Clear flux expulsion signal can be also observed. In this presentation, we report about efforts to reduce ambient magnetic field and to realize high-Q measurements. Results of vertical tests, including flux expulsion measurements, are also presented.

INTRODUCTION

Realization of high-Q for SRF cavity is desirable to reduce cryogenic loss of accelerator system. Recently high-Q studies, such as N-doping, N-infusion, flux expulsion and optimized cooling procedure, are often carried out at world-wide [1]. However, to perform such measurements, control of magnetic field is essential. It is known that remnant magnetic field around cavity surface can be trapped during cool-down process and trapped magnetic flux become source of residual resistance [2].

Magneti field of KEK-STF vertical test facility was not well controlled and measurement of high-Q was difficult. We tried to de-magnetize vertical test components and cancel remnant magnetic field using a solenoid coil.

HISTORY OF VERTICAL TEST RESULTS

Several single cell cavities were fabricated at KEK-CFF (cavity fabrication facility) and carried out vertical test at KEK-STF vertical test area [3,4].

Left of Fig. 1 shows history of residual resistance for single-cell vertical test measurements at KEK-STF from 2014 to 2015. Data for large grain, fine grain and seamless cavities are plotted. It shows that measured residual resistance tend to gradually increase with time. Right of Figure 1 shows Q-E curve for large grain single-cell cavity at low temperature, less than or around 1.5 K. It was measured at 2014/February, 2014/April and 2015/May. At first measurement, very high-Q value around 1×10^{11} was observed. After that, we tried to reproduce this high-Q results, but Q-values rather degraded measurement by measurement. It was difficult to get high-Q results at KEK-STF vertical test system.

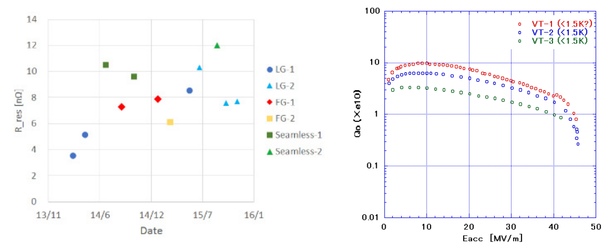

Figure 1: (Left) Residual resistance for vertical test of single-cell cavities. (right) History of Q-E curve for large grain single-cell cavity for three times vertical tests.

KEK-STF vertical test dewar has single magnetic shield inside. After cool-down by liquid He, its shielding characteristics degraded. As a result, around 10mG of remnant magnetic field remain inside vertical test dewar [5]. Cancelling of this remnant field is one important issue.

Components, such as flanges, which are directly touching to Nb are made by SUS316, but some of others are made by SUS304, for which magnetization was suspected. De-magnetization of vertical test components is also essential.

MAGNETIZED MEASUREMENT FOR VT COMPONENTS

Magnetization of each of vertical test components were surveyed by using a three axes flux gate sensor, Bartington Mag-03MS100, inside the magnetic shield whose size is 300 mm diameter and 1 m long, as shown in Fig. 2.

It was found that relatively large number of components were magnetized. Table 1 and Fig. 3 show a list and pictures of highly magnetized components. The numbers shown in Table 1 is absolute of measured magnetic field. One of metal valve and SUS304 long-nuts showed large magnetization of 430 and 300 mG, respectively. Some SUS304 bolts and washers were also magnetized around 100 mG. These are components magnetized more than 100 mG. Table 2 also shows a list of magnetized components. But this time magnetized less than 100 mG. D-sub connectors, bolts, nuts, washers etc. are magnetized. Even value is not large, but sometimes we use many of them. Then we need to care about these components too.

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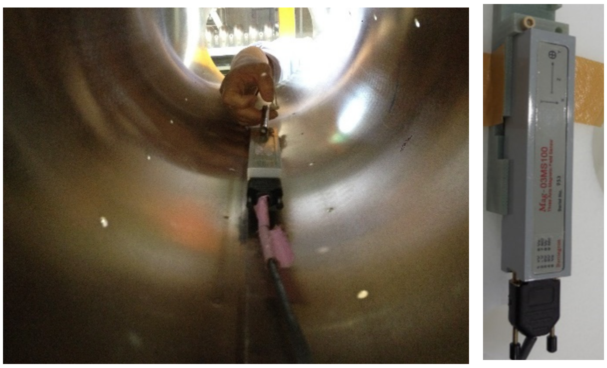

Figure 2: (left) Magnetization measurement inside magnetic shield. (right) Three axes flux gate sensor used for magnetic flux measurements.

Table 1: List of Highly Magnetized Components

No	Components	Magnetization [mG]
14	ϕ034 metal valve(No.1)	430
25	Bolts and washers for input coupler shafts	140
28	Nuts and washers for hanging cavity	110
29	Long nuts for hanging tools	300

Figure 3: Picture of highly magnetized components. number in the pictures are reference for Table. 1.

Table 2: List of Magnetized Components

No	Components	Magnetization [mG]
2	Heater	40
3	D-sub connector	30
4	D-sub connector stopper	40
8	Inside of D-sub connector	26
15	ϕ034 metal valve(No.2)	80
17	ϕ70 metal valve	24
19	ϕ034 metal valve(No.3)	59
21	Volts and washers for flanges	44
23	Volt sets	36
26	Stat-volt for hanging cavity	40

After the investigation of small components, we also checked large components. SUS 304 shafts for variable input coupler, which is shown in Fig. 4, was surprisingly high magnetization. Not only some part, but almost all of this shaft was magnetized and maximum part showed more than 1 G. The effect from this shaft to cavity surface was checked by simulate vertical test setup. The shaft created more than 100 mG of magnetic field on the cavity surface. Furthermore, horizontal field was also strong and it made asymmetric and non-smooth magnetic field distribution around the cavity.

Figure 4: Highly magnetized SUS304 shaft, which is for variable input coupler.

Vertical Test Performance

After above measurements, magnetized components were exchanged as much as possible. The SUS 304 variable input coupler shaft were exchanged to new one made by Titanium. Magnetization of two kind of metal valves were investigated and better one has been used for vertical tests. Magnetized bolts, nuts and washers were exchanged to less-magnetized one and so on. Supporting tools for vertical tests were originally made by SUS304. These tools were simplified and made from Aluminium.

In order to cancel remnant magnetic field inside vertical test dewar, a solenoid coil was fabricated.

VERTICAL TEST SETUP

After above improvement, first vertical test was carried out for a 1.3 GHz fine grain single-cell cavity. Before the measurement, 900 degrees, 3hours heat treatment and 20 µm EP was applied to the cavity.

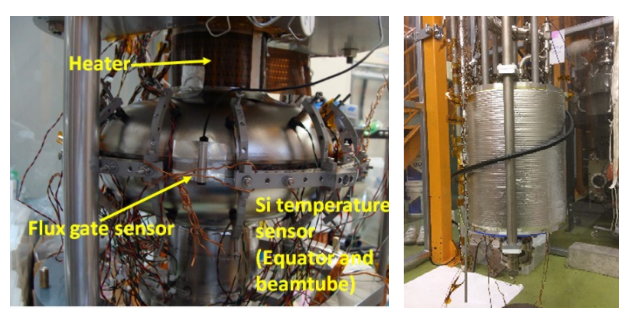

Figure 5: (left) Sensor setup for single-cell vertical test. (right) mounted solenoid coil for magnetic field cancelling.

Left of Fig. 5 shows sensor setup for vertical test. Two flux sensors were located around equator with opposite direction to measure magnetic flux on cavity surface. Four

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calibrated Si temperature sensors measures thermal distribution. Two of them are at equators at opposite angles. One is at bottom iris and another is at upper beampipe. Heater at upper beampipe is used to make thermal gradient.

Right of Fig. 5 shows a solenoid coil to cancel or control magnetic field inside the vertical test dewar. To cancel 10mG of remnant field, around 5 mA of current is fed.

VERTICAL TEST RESULTS AFTER IMPROVEMENTS

Results of the vertical test were shown below. Remnant magnetic field inside the vertical test dewar were cancelled to less or around 1 mG using the solenoid coil, while thermal gradient was made by the heater to expelle magnetic flux well.

Improvement of Q-values

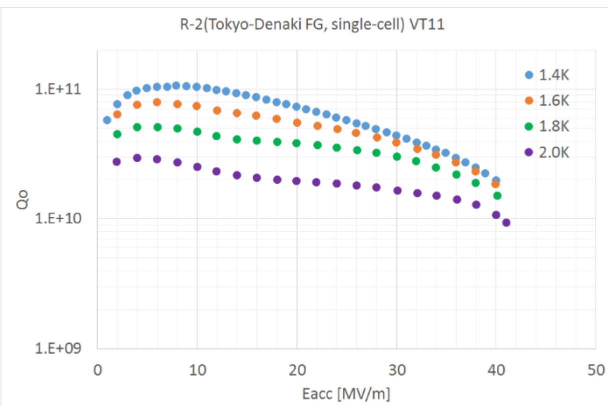

Figure 6: Q-E curve for vertical test of the fine grain single-cell cavity.

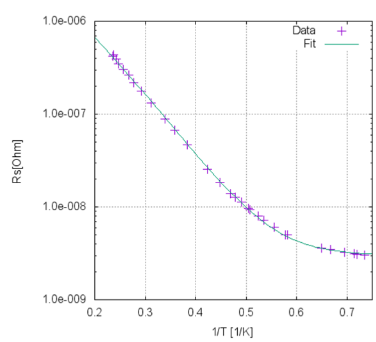

Figure 7: Rs-1/T curve for vertical test of the fine grain single-cell cavity.

Figure 6 shows results of vertical tests. High Q of more than 1x10^{11} were obtained at 1.4 K. Very good cavity performances were obtained. Figure 7 shows Rs-1/T curve. Residual resistance was estimated as to be 3.0 nΩ from the fit.

Both Q-value and residual resistance were best value in KEK-STF measurement compared with before. Clear improvements were obtained.

Flux Expulsion Measurement

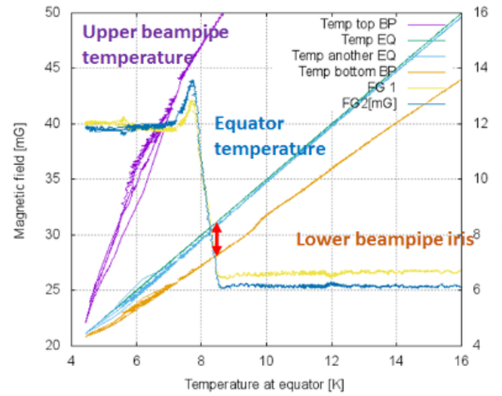

Figure 8: Measured flux expulsion during cool-down. Total of 25 mG, including additional 16 mG, was on the cavity surface before cool-down.

Figure 8 shows magnetic flux expulsion experiment. In addition to around 9 mG of remnant magnetic field, additional 16 mG was applied by the solenoid coil, to see expulsion signal clearer. Total of 25 mG of field existed at the equator positions, while cavity was normal conducting state. When cooled down to superconducting state, clear expulsion signal could be observed.

We use SUS316 flanges for both beampipes. In this situation, flux ratio is around 1.6 for full expulsion condition. Figure 8 shows very good and almost full expulsion. It is noted that the cavity was made by Nb from Tokyo-Denkai and heat treated at 900 degrees.

DISCUSSION

After improvements of magnetic condition, several times vertical tests were carried out for single-cell cavities. Results were fine for any measurements. High-Q can be reproduced. This indicate our approach was adequate.

Now we are ready for high-Q measurements. The studies, such as the Nitrogen-doping and Nitrogen-infusion, are on-going. Some recent results are presented in another proceeding [6].

SUMMARY

In order to realize high-Q measurement at KEK-STF vertical test facility, all of the vertical test components were surveyed for magnetization. The SUS304 shaft for variable input coupler was most magnetized and more than 1G was observed. Magnetized components were removed or exchanged to non-magnetized material as much as possible. The solenoid coil was prepared for magnetic field cancelling.

After improvements of magnetic conditions, vertical test results showed high-Q of more than 1x10^{11} and clear flux expulsion signals. Results were reproducible. High-Q R&D, such as Nitrogen-doping, Nitrogen-infusion and flux expulsion, are now on-going at KEK.

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REFERENCES

[1] A. Grassellino *et al.*, "Unprecedented quality factors at accelerating gradients up to 45 MV/m in Niobium superconducting resonators via low temperature nitrogen infusion", *Supercond. Sci. Technol.* to be published.

[2] S. Posen *et al.*, "Efficient expulsion of magnetic flux in superconducting RF cavities for high Qo applications", *Journal of Applied Physics,* vol. 119, p. 213903, 2016.

[3] H. Shimizu *et al.*, "Fabrication and evaluation of superconducting single-cell cavities manufactured using various materials and methods", *IEEE Trans. Appl. Superconductivity,* to be published.

[4] K. Umemori *et al.*, "Comparison of cavity fabrication and performances between fine grains, large grains and seamless cavities", in *Proc. SRF2015*, Whistler, Canada, Sep. 2015, pp. 1006-1011.

[5] M. Masuzawa *et al.*, "Residual magnetic field inside the superconducting RF cavity shield", *IEEE Trans. Appl. Superconductivity*, vol. 26, no. 4, p. 3500105, 2016.

[6] T. Konomi *et al.*, "Trial of Nitrogen infusion and Nitrogen doping by using J-PARC furnace", present at *SRF2017*, Lanzhou, China, July 2017, paper THPB021, this conference.