UPDATE ON SC CAVITY INSPECTION

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Abstract

The temperature mapping (T-map), the eddy-current testing and other methods for inspection of the cavity interior surface is under development. T-map system can find heat sources that may be caused by defects on the superconducting accelerator cavity surfaces. The purpose of our studies on T-map is to realize a high spatial resolution and easy installation of the sensors. The production yield of such cavities would be improved by using these inspection systems. The preliminary tests of the T-map system and the eddy-current inspection are reported.

INTRODUCTION

About 15000 superconducting (SC) 9-cell 1.3GHz niobium (Nb) cavities with the average accelerating gradient of 35MV/m are required for the first stage plan of the International Linear collider (ILC). Because of such many SC cavities, several research laboratories have made R&D of the temperature mapping (T-map), X-ray mapping (X-map) and so on as the inspection method. We are developing the inspection of the defects at the interior surface of SC.

By feeding RF power to cavities in the vertical test as shown in Fig.1, the quality of SC cavities are estimated by the results of the average accelerating gradient etc. It is thought that the upper limit of the accelerating gradient greatly depends on the condition of the interior surface of the SC cavity. The high accelerating gradient is obtained by the surface treatment such as the high-pressure water jet cleaning and the electro-polishing. In order to improve the performance and the production of the SC cavities, inspection systems for the interior surface of SC cavity are important.

As a method for survey and observation of defects in the interior surface of SC cavity, the high-resolution camera system was developed as so-called Kyoto Camera in Fig. 2 [1]. Through results of this optical survey system and the temperature measurement on exterior surface of SC cavity during the vertical test, existence of the defects were made clear. A main cause of limiting accelerating gradient is the quench of local heat source due to defects such as scratch, dust particle of a few ten µm and ruggedness of a few hundreds µm on the interior surface. So the inspection of interior surface by order of a few ten µm is necessary during the fabrication and the development of the cavities. So the temperature mapping (T-map) and X-ray mapping (X-map) are good methods for finding defects non-destructively in the vertical testing. T-map is the thermometry measurement with many temperature sensors set on the exterior surface of SC cavity. This method is efficient in comparison to inspect all area of the interior surface with a camera. X-map detects the radiation due to emitted electrons.

As shown in Fig. 3, we are developing another inspection system utilizing eddy-current test. An eddy-current tasting system is under development for the niobium sheet. Possibility of radiography using neutron and X-rays is also investigated. The developments are presented in this report.

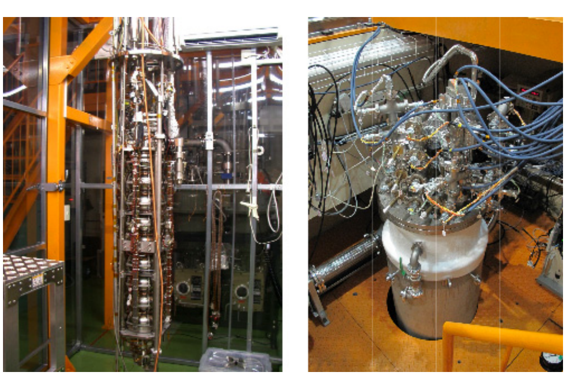

Figure 1: Vertical test in KEK.

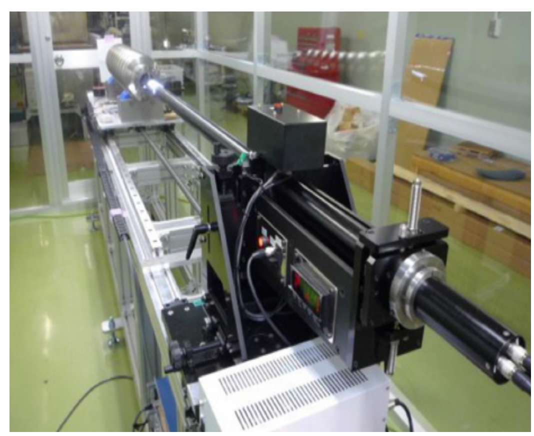

Figure 2: High-resolution camera system.

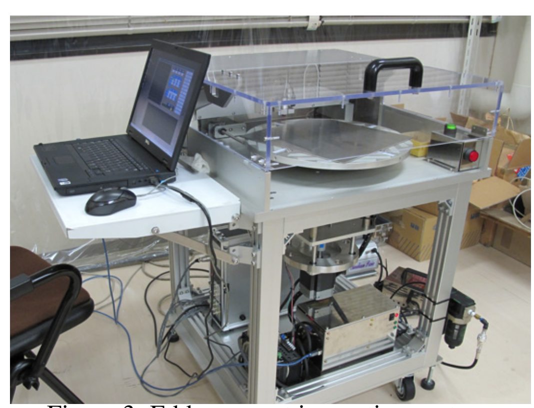

Figure 3: Eddy-current inspection system.

EDDY-CURRENT INSPECTION

We plan to apply the eddy-current testing to the defect inspection. The eddy-current inspection will be applied to niobium sheets before pressing to cup shape. The niobium disk is a clipped plate that do not still form to cup. This inspection system in Fig. 3 scan the donuts shape area on the surface of the disk, where the eddy-current sensor moves on the rotating disk from the outside toward the center while the disk is rotated on the turntable. Fig. 4 shows a preliminary result of testing the several holes that were drilled on a niobium sheet. Currently a hole of down to 100μm diameter, 200μm depth can be detected. Typical results scanned by the present system are shown in Fig. 5. Further improvements are going on.

T-MAP SYSTEM

Installation of T-map system is a time-consuming task. We have been developing T-map system that enables quick installation to all cells in the vertical test. The T-map system is desired to operate easily for fabrication of SC cavities.

The schematic diagram of our T-map system is shown in Fig. 6. In order to measure the exterior surface of SC cavity in the vertical test, the temperature sensors also have to be installed into a cryostat. Assuming multipoint measurement with one per cm^2 in order to realize a high spatial resolution, the sensor assemblies of 9-cell T-map system will contain about 10000 sensors.

Cabling of such signals with independent wires for each sensor will make the number of wires enormous. And the heat leak into the cryostat will increase. In order to reduce the number of the signal cables dramatically, digital CMOS circuits such as analogue multiplexers have

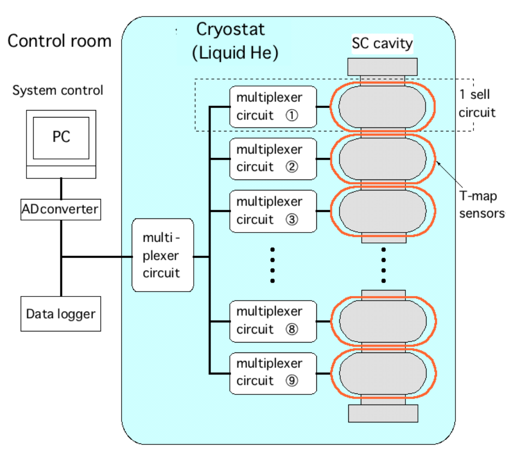

Figure 6: The schematic design for T-map system.

Figure 7: Experimental sensor strips resisters on flexible polyimide film contact with surface of Niobium cavity.

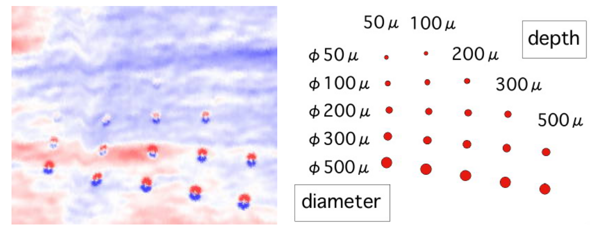

Figure 4: The result of the eddy-current inspection. Several holes as shown in the right figure had been drilled on the niobium plate.

Figure 5: Typical results of the eddy-current inspection. Both side of a niobium disk before the cup forming for SC cavity were measured. Surface at a circle is comparatively rough.

been incorporated in the cryostat as shown in Fig. 6. This multiplexer circuit design decreases the cost of the system components such as cables and vacuum tight feed-through. The multiplexer circuits worked fine in several test operation at cryogenic temperature. The resistance value of analogue multiplexer was found to be negligible compared with that of the according to our measurement.

Low cost surface mount resistor of typical Ruthenium oxide was adopted as the temperature sensor. As shown in Fig. 7, the resistors are mounted on flexible polyimide film [2]. A major advantage of this sensor strip is easy installation of T-map equipment to the SC cavity. So, the inspection time for SC cavities is expected to be short.

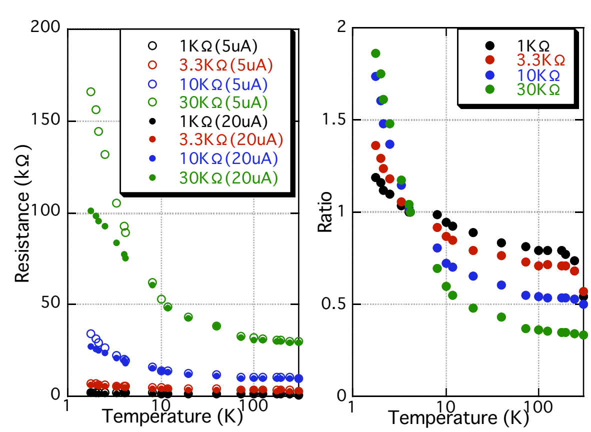

Figure 8: The sensitivity of resistances on the temperature. Values in brackets are the applied current value. Left: The resistances as function by temperature. Right: In case of 5μA, relative values to resistance at the 4.2K.

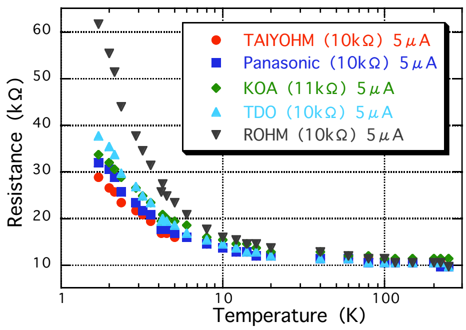

Figure 9: Plots of resistance values as a function of temperature for various manufacturers. The input current is 5 μA.

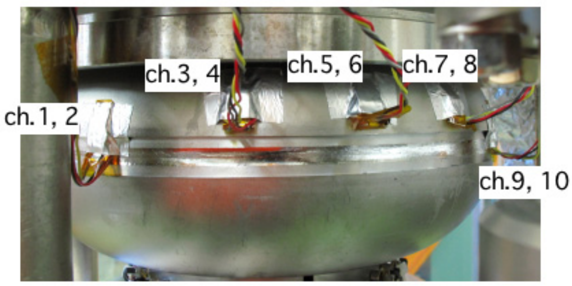

Figure 10: Quench inspection by T-map sensor in the vertical test.

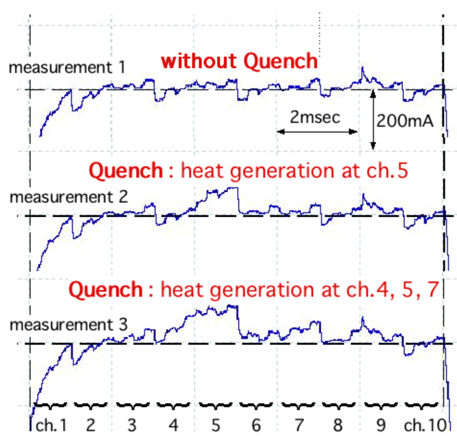

Figure 11: Quench inspection by 10 kΩ resistors. The values are measured at the switching speed (frequency) of 1 kHz.

Thus the installation time can be saved in spite of the large number of sensors.

In order to select resistance value, the resistance were measured as functions of temperature. Fig. 8 shows results of measured sensitivity for variety of resistors from 1kΩ to 30kΩ at low temperatures. The lager resistance sensor gives the more temperature sensitivity. However, the time constant of large resistance sensor becomes large, and the signal's rise-time increases [2]. It is also anticipated that the self-heating should be higher for the larger resistance. Therefore we will adopt 10 kΩ resistor as the temperature sensor considering the balance of the sensitivity. The time constant at cryogenic temperature. The high sensitivity from 2 K to 4 K is should be enough for the cavity inspection in vertical test. Fig. 9 shows the measurement results of the average resistance values of 5 resistors from each manufacturer. The difference of sensitivity among the manufacturers is obvious under cryogenic temperature. The temperature sensitivity in our studies is evaluated by the ratio of resistance increase of the cooling.

The sensor devices were mounted around the exterior surface. The quenches were expected at ch5, 6 in Fig. 10. Typical measurement results of the temperature rise in vertical test are shown in Fig. 11. We were able to observe the temperature rising signal during the quench at ch4, 5, 7 at the channel switching speed (frequency) of 1kHz. In the high speed switching over 2.5 kHz, the output signals attenuate because of the slow time constant. The switching speed of 1 kHz will make the scan time for a cell on second.

SUMMARY

We have been developing the eddy-current scanner and XT-map system for SC cavity after the Kyoto Camera development. These inspection systems are expected to give the good yield of the production of SC cavities. The more spatial resolution is desired for eddy-current scan.

Currently ROHM resistor is the best as the temperature sensor from the sensitivity standpoint under cryogenic temperature. 100 Ω Allen-Bradley carbon resistors has good sensitivity in cryogenic temperature [3]. Compared with this carbon resistor, the sensitivity of 10 kΩ Ruthenium oxide resistor under cryogenic temperature is about 1/3 under 4.2K. Even so, the Ruthenium oxide resistor has enough sensitivity as the temperature sensor for our case.

Now, we are planning to build 1-cell XT-map system consists of the sensor assemblies and its data taking system. The system will be evaluated in vertical test. After the completion, a system to cover the whole 9-cell cavity will be fabricated.

REFERENCES

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