NON-DESTRUCTIVE INSPECTIONS FOR SC CAVITIES

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Abstract

Starting from the high-resolution camera for inspection of the cavity inner surface – so-called Kyoto Camera, high resolution T-map, X-map and eddy current scanner have been developed. R&D for radiography techniques is also going on to detect small voids inside the Nb EBW seam, where the target resolution is 0.1 mm. Some radiography tests with X-rays induced from an ultra short pulse intense laser were carried out. The local treatment technique on the found defects is also realized by the Micro-Grinder.

INTRODUCTION

Non-destructive Inspections play important roles in improving yield on production of high performance SC Cavities. Starting from the high-resolution camera for inspection of the cavity inner surface [1], high-resolution T-map, X-map and eddy current scanner [2,3,4,5,6] have been developed. We are also investigating radiography to detect small voids inside the Nb EBW seam, where the target resolution is 0.1 mm. We are carrying out radiography tests with X-rays induced by irradiations of an ultra short pulse intense laser on a target metal sheet. Defects found by the inspection technique can be locally treated by the Micro-Grinder.

CAVITY CAMERA UPDATE

In order to inspect the SPL cavity at CERN, whose frequency is about a half of ILC cavity and the diameter is about twice larger, the illumination system has been enhanced to illuminate the wider surface area (see Fig. 1). Although the iris diameter is about twice larger than that of ILC's, the bore diameter at the flange position is limited (just below ø80mm). This limits the camera cylinder diameter is ø70mm. Fig. 2 shows the modification on the illumination system to illuminate the wider area with enough strength. While the former system used two LED's for each strip, the new system uses 14 LED chips on a line and two lines consist one strip. Thus 28 LED chips are used for a strip. Furthermore, the LED chip has three LED's in a package. This illumination system should provide enough light for the wider cavity surface area. Because of the larger cavity size, the working distance is longer than former model and a bigger lens system is adopted. Fig. 3 shows the overview of this system. The illumination plate on the cylinder is shown in Fig. 4. The camera cylinder can be rotated to see the annular area in a cavity without movement of the cavity, while the cavity table can rotate the cavity if it does not wear its He jacket around. The table has a function to move the cavity in its axial direction.

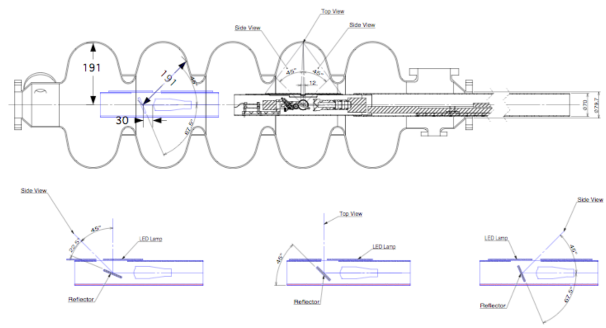

Figure 1: CavCam3 in SPL cavity.

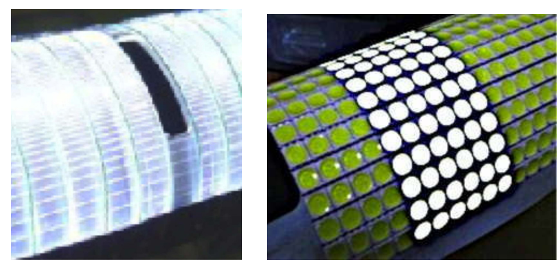

Figure 2: Enhanced illumination for wider surface area (Armadillo Illumination). 28 LED chips (right) instead of 2 LED's per strip (left) are installed.

Figure 3: Latest CavCam-3 for SPL cavity at CERN.

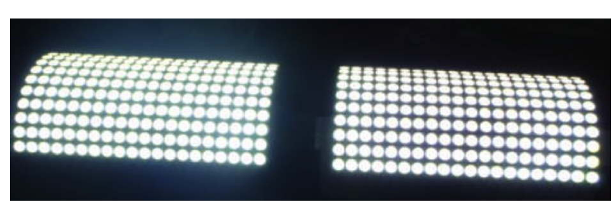

Figure 4: All the LED's are lighten. A diffusing panel will be install on the LED's to form the light strip. 14 chips/line x 2 lines/strip x 10 strips/side x 2 sides = 560 chips are used.

HIGH DENSITY T-MAP & X-MAP

The high density Temperature mapping system (T-map) and X-ray mapping system are under development. These systems utilize multiplexing technique to reduce the number of lines from the sensors to the measurement circuits. The temperature sensors are put on a Nb cavity surface during the vertical test to detect the temperature rise from the quench phenomena due to a defect on the inner surface, if any. Since one temperature sensor / cm^2 is assumed for the surface density, 1024 sensors will be installed on a cell and about nine thousands of sensors will be need to be connected to the measurement circuit. The number of lines needed for these connections is reduced by multiplexing the analog signals in the cryogenic area. The reduced lines include the three power supply lines (0V, ±5V), one clock line, one reset line, and two signal lines for each type of system (t-map and X-map) as shown in Fig. 5. T-sensors are installed on the inner side and X-sensors are located on the other side. T-sensors contact on the cavity surface (see Fig. 6). As shown in Fig. 7 the leaves can be instantly attached on a cell, which helps to reduce the installation time for a vertical test.

A dedicated X-map system for installation under the stiffener ring is also developed (see Fig. 8). Only X-sensors are installed on the PCB, which can slide into the space under the stiffener ring as shown in Fig. 9.

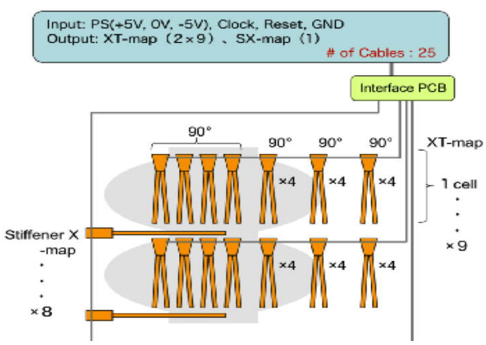

Figure 5: The inter-connection for the XT-map system.

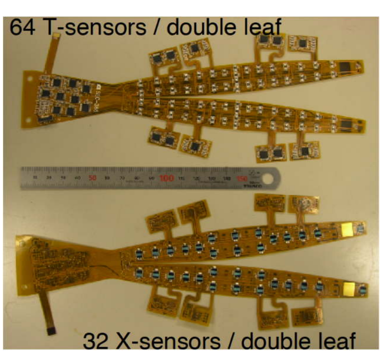

Figure 6: Leaf shaped flexible PCB.

HIGH RESOLUTION EDDY CURRENT SCAN

A Nb sheet before the press to form the cup will be inspected by a Eddy current scan [7]. Using a

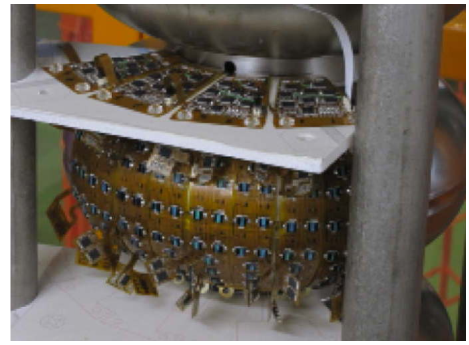

Figure 7: Installed XT-map leaves on a cell.

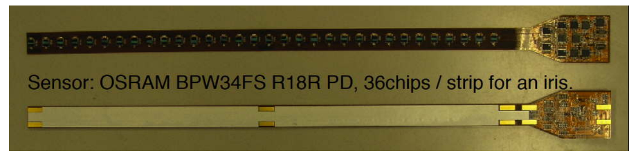

Figure 8: Stiffener X-map.

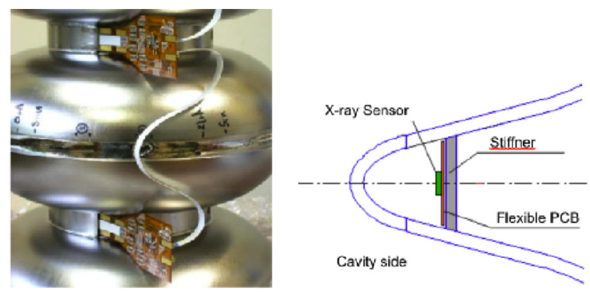

Figure 9: Installed stiffener X-map ribbons. The ribbons go under the stiffer ring.

multi-frequency Eddy current probing system, a small void just under the surface, which may appear after surface treatments such as electropolishing (EP), would be detected. The depth information would be obtained from the three different frequency data simultaneously acquired during the measurement. The detected hole size is currently ø100µm x 50µm depth (see Fig. 10).

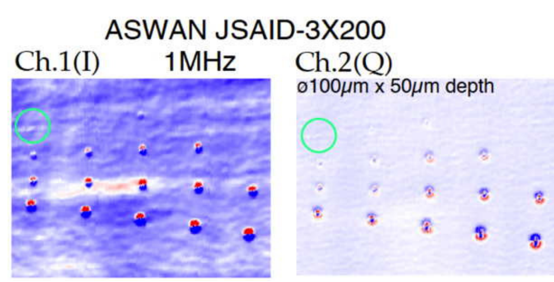

Figure 10: The high resolution eddy current scanner can detect the drilled holes on the Nb sheet down to ø100µm x 50 µm depth.

RADIOGRAPHY EFFORT

In order to inspect the EBW seam especially for possibly buried defects under the surface, various radiography techniques have been investigated such as

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X-ray CT, and neutron CT. Since Nb has larger atomic number, high energy X-rays tend to be preferred for a better transmission. The contrast, however, becomes worse for high energy X-rays. Although the phase contrast techniques should have better contrast even in this case, it is not a handy way. After some trials, laser induced X-ray radiograph is under investigation (see Fig. 11). Fig. 12 shows the obtained radiography images for targets of Zr and Ag, where Zr is supposed to be better because of the X-ray energy just below the K absorption edge of the Nb. Further study is needed for better visibility and practical applications.

LOCAL REPAIR TECHNIQUE

Using the inspection devices, defects on the surfaces can be identified and analyzed. For those defects judged as harmful, the local repair technique should be applied. The micro-grinder can be inserted into the cavity, while the grinding head is retracted (see Fig. 13)[8]. After its positioning, some amount of water is applied to the area and the head with abrasives can start to grind. The grinding time can be limited by a timer up to 99 minutes. Additional EP and following processes are applied to the treated cavity to bring the cavity back to the line. Several cavities have been already repaired and show satisfactory results (see Fig. 14).

REFERENCES

[1] Y. Iwashita, Y. Tajima, H. Hayano, Development of High Resolution Camera for Observations of Superconducting Cavities, Phys. Rev. ST Accel. Beams, 11, [093501-1]-[093501-6], 2008
[2] A. Brinkmann, W.Singer, Nondestructive Testing of Niobium Sheets for Srf Cavities Using Eddy-Current and Squid Flaw Detection, Proc. LINAC08, Victoria, BC, Canada, pp.800-801
[3] L. Cooley, C. Antoine, G. Wu, D. Sergatskov, H. Jiang, R. Schuessler, O. Frianeza, Fermilab QA and QC activities, FNAL slides for TTC meeting Jan 2008
[4] Balle, Ch., Casas-Cubillos, J. et al, Influence of Thermal Cycling on Cryogenics Thermometers in Advances in Cryogenic Engineering 45B, Plenum, New York, 1999, pp. 1817.
[5] H. Tongu, et al., Multipoint T-maps for Vertical Test of the Superconducting Accelerator Tubes, Proc. of the 6th Annual Meeting of Particle Accelerator Society of Japan, (2009) 409-411.
[6] A. Canabal, et al., Development of a Temperature Mapping System for 1.3-Ghz 9-Cell Srf Cavities, Proc. PAC07 2406 - 2408 (2007).
[7] Updates on R&D of Non-destructive Inspection Systems for SRF Cavities, Y. Iwashita, H. Tongu, H. Hayano, T. Saeki, K. Watanabe, to be appeared as Proc. of SRF11, July 2011, Chicago.
[8] K. Watanabe, H. Hayano, E. Kako, S. Noguchi, T. Shishido, Y. Yamamoto, Y. Iwashita, Repair Techniques of Superconducting Cavity for Improvement Cavity Performance at KEK-STF, Proc. IPAC10, Kyoto, 2010

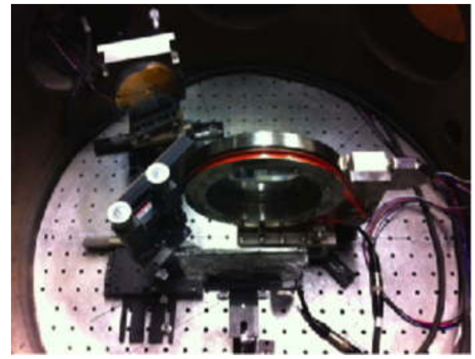

Figure 11: Layout for the laser induced X-ray radiography experiment. Various target materials can be irradiated by the laser to generate X-rays.

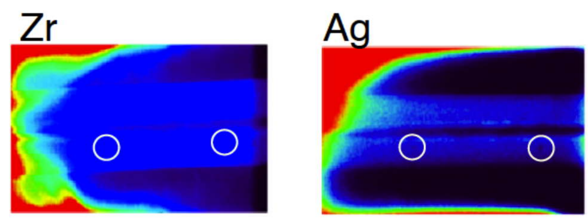

Figure 12: Obtained radiography images for targets of Zr and Ag. Both target materials give better visibility for the defects (sputter balls on the surface).

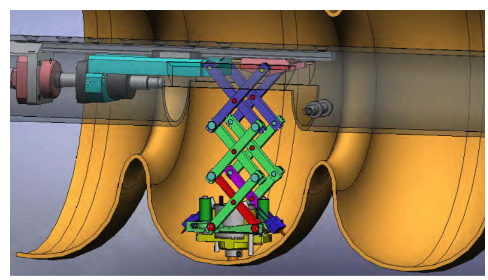

Figure 13: The grinding head assembly that has a tiny monitoring camera protrudes by a motor control towards the area to be treated.

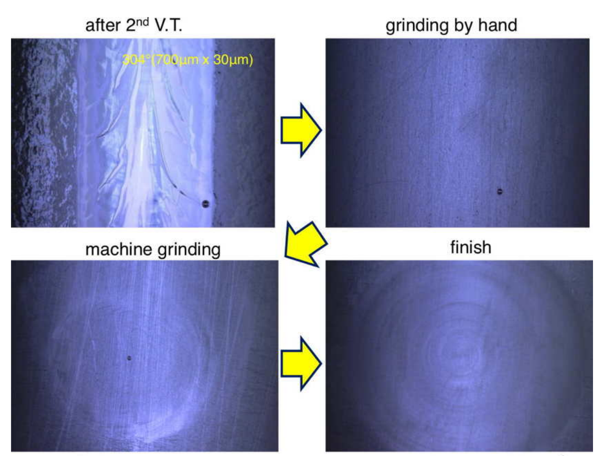

Figure 14: The progresses on the local grinding effect. The defect detected by the optical inspection was removed by the treatment.