UPDATE ON STUDY OF WELDING POROSITY IN NB EBW

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Abstract

We have been developing high-resolution inspection systems and the connected instruments for SRF cavity developments. They include the cavity camera – so-called Kyoto-Camera, eddy current scanner, high-density T-map and X-map system and the local grinding system. They revealed an existence of voids beneath the surface of EBW seam. Study on the welding porosity in the Nb EBW seams is reported.

INTRODUCTION

Nondestructive Inspections have been playing important roles on improving yield in production of high performance SC Cavities. Starting from the high-resolution camera for inspection of the cavity inner surface, high resolution T-map, X-map and eddy current scanner have been developed [1-7]. The position identification based on the inspection results enabled us to fix a defected cavity by the local repair technique. Throughout these processes, voids have been found in the Nb EBW seams. Since the buried defects cannot be observed by the optical inspections, other techniques have to be applied to study their characteristics such as distributions. X-ray or neutron radiography has been tried for the purpose.

EXISTENCE OF VOID

Figure 1 shows the combined cavity camera and the local grinding system. The camera cylinder and the grinder cylinder can be switched quickly for the series of inspection and repair process. Defects found on the surface by the optical inspections have been effectively eliminated for many cases as shown in Figure 2. In spite of this success, it has been found that new defects sometimes appear after the EP on a cavity repaired by the local grinding technique as shown in Figure 3. They grew with the local grindings: the further the ground depth went, the bigger the pit size grew. This alludes that they are voids buried beneath the surfaces. These voids appeared again after the local grinding followed by EP process.

VOID INSPECTION EFFORT

Thus study on the welding porosity in the Nb EBW has been found to be important to us in order to discard such cavities at early stage in the production sequence. Since these voids cannot be observed by the optical inspection system, other technique had to be developed. The eddy-current scanner is not easy to apply on the EBW seam since it was developed for the inspections on the flat Nb sheets before the press. Another techniques are radiographies where X-rays or neutrons are used. Since Nb has larger atomic number Z=41 than iron (Z=26), X-

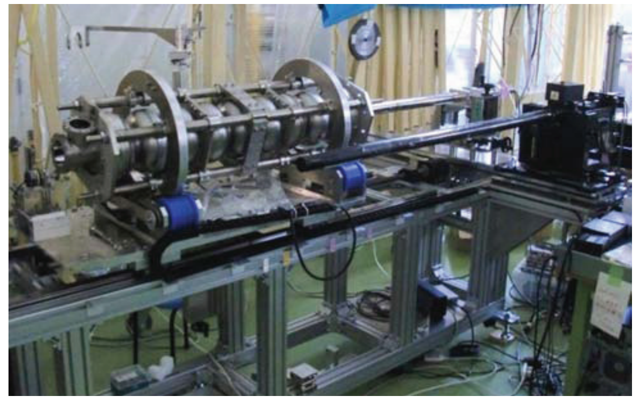

Figure 1: Combined cavity camera and local grinder system. The cylinders can be switched for a cavity in inspect and repair cycles.

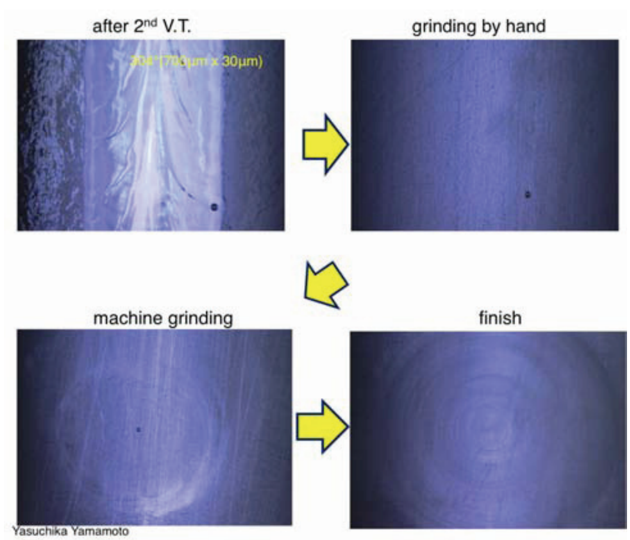

Figure 2: Succeeded example on the local grinding.

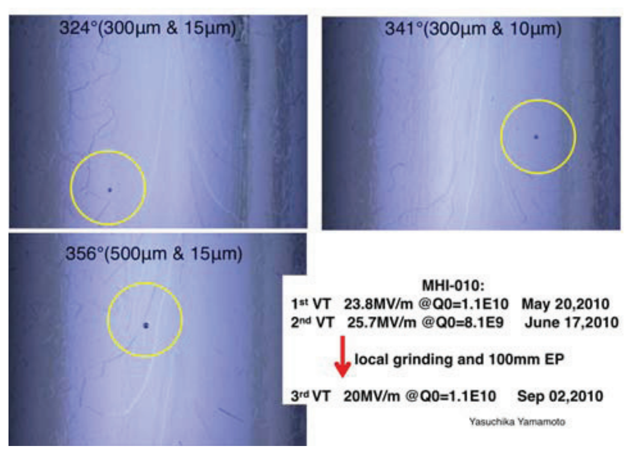

Figure 3: Voids appear after EP on the locally grounded cavity for repair.

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rays usually used for parts made of steel can hardly penetrate the 3mm Nb sheet. Neutron radiography was tried for that reason [5]. Although the results of neutron CT were promising, their availability is somewhat limited and thus is not handy. X-rays, which has a better accessibility, have been also tried at a few facilities with high energy for better penetration depth (see Figure 4). The high energy X-rays, however, was found to be not adequate, since the high penetration power makes the contrast poor and the poor visibility was resulted. Thus we are trying to use conventional X-rays with W target, where the energy of K-X-ray is about 70keV. Figure 5 shows an imaging example currently obtained. Using the magnifying imaging with factor 8.8, 200 µm dents seem to be observed.

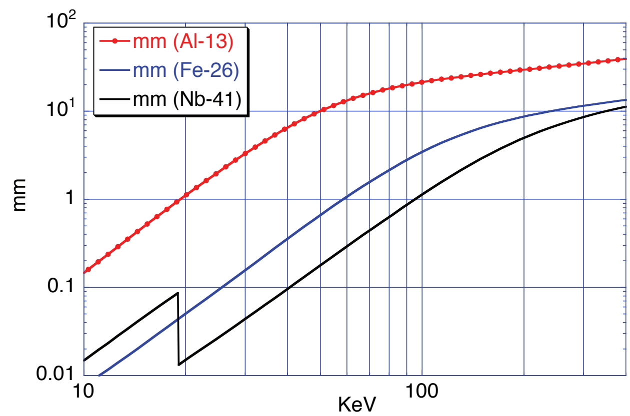

Figure 4: Penetration depth as functions of X-ray energy against Al, Fe and Nb.

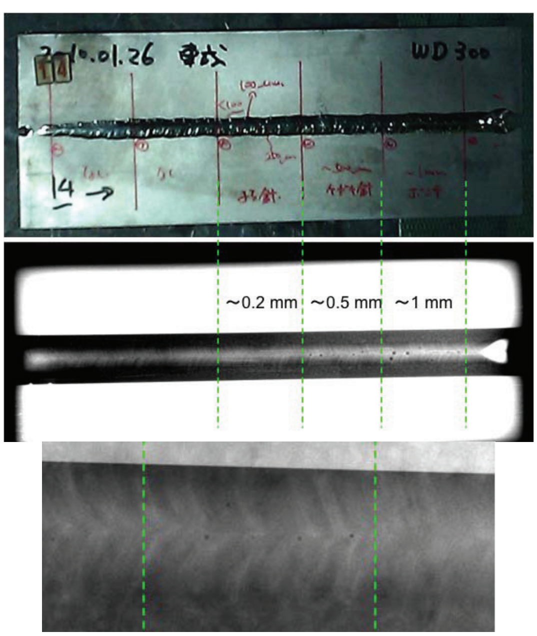

Figure 5: Observed EBW seam with artificial dents with 200 m and 500 m diameters (top). The 500 µm dents are visible in the right area (middle), while 200 µm dents located in the left area are detected in a magnifying imaging with factor 8.8 (bottom).

CARBON CONTAMINANTS

Contaminants found on the Nb surface after BCP as shown in Figure 6. They are firm solids and difficult to come off. According to EDX (Energy Dispersive X-ray spectroscopy) analysis, they seem carbon oxides. This carbon could be a source of the voids. A speculation of defect formation at EBW seam is shown in Figure 7. After BCP on the trimmed edge, this kind of carbon contaminants may be resulted on the edges. When the contaminants were buried in the joints between the dumbbells, they might form the voids during the EBW process.

Nb test pieces with steps at the joint were prepared for investigation of the hypothesis as shown in Figure 8. BCP'ed samples were carefully stored in a container box keeping from any contaminations. Some of them are

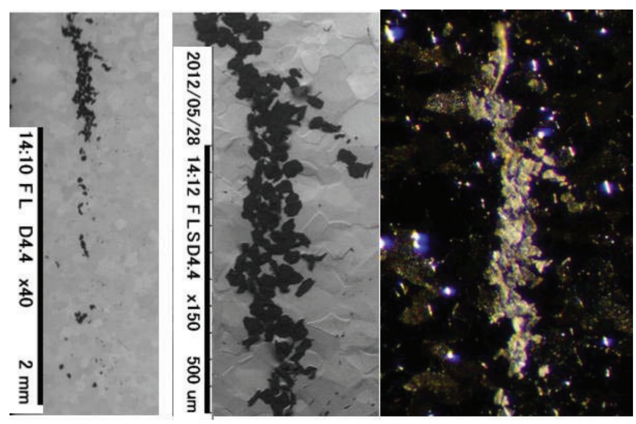

Figure 6: Contaminants found on the Nb surface after BCP. Left to right: camera image, SEM and optical microscope. (by Dr. M. Sawabe)

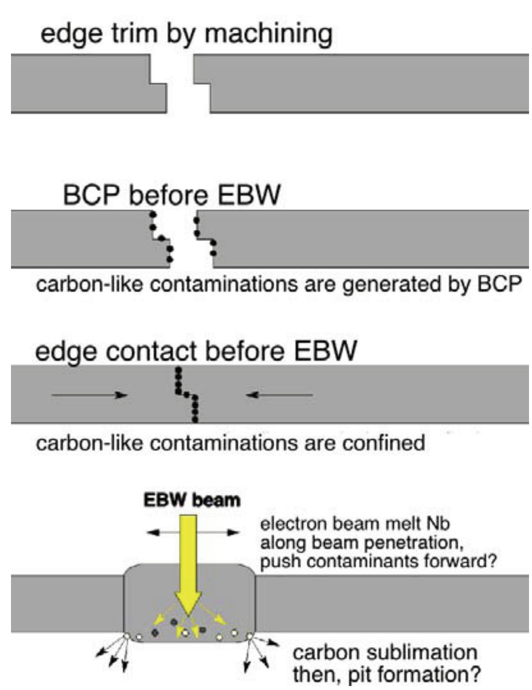

Figure 7: A speculation on defect formation at EBW seam

coated with carbon material before fixed with a jig for EBW (see Figure 9 and 10). Seven pairs including an initial pair for parameter setup were prepared, while four of them have the carbon coats. The EBW rise time was 0.1 s and the speed was at 0.2 m/s, which went down with 0.5 s. The voltage of the electron beam was 60 kV where the currents of 30 mA and 33 mA were supplied for a first half and a last half of EBW. Figures 11 and 12 show the images of the EBW samples. The top figures show the surfaces of the samples without and with thick carbon coating on the edges. Transmission images are shown in the middles. In these measurements, the whole areas were dived into two images because of the limited detector size. The bottom images were taken with the geometrically magnified method (x8.8). We could not observe any void in the seams on this trial. The total length of the EBW seams with the artificial carbon contaminants is less than 40cm. This short length may be a reason why no evidence of a void. Further investigation will be followed on this subject.

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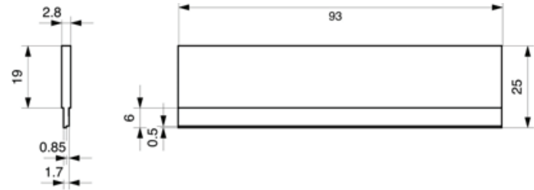

Figure 8: Sample Nb plate for EBW.

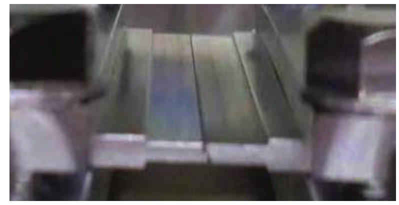

Figure 9: Sample Nb plates fixed on a jig for EBW

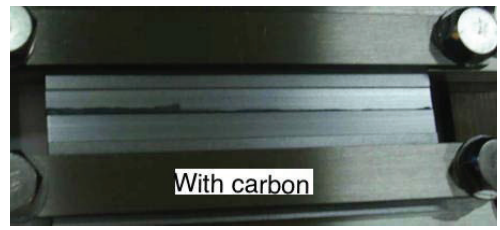

Figure 10: Sample Nb plates fixed on a jig for EBW

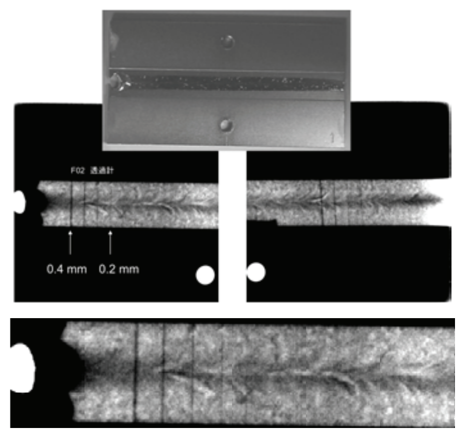

Figure 11: Images of the EBW seam without carbon coat at the edge. Vertical black lines are thin wires from 0.2 to 0.4 mm for resolution check.

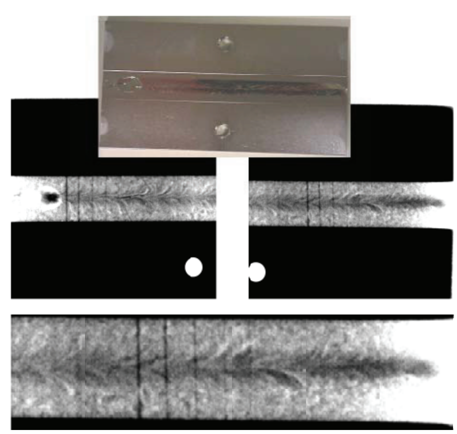

Figure 12: Images of the EBW seam with carbon coat.