The ECT System for RAON'S Cavities

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Received: October 17, 2014 / Accepted: November 24, 2014 / Published: January 25, 2015.

Abstract: The ECT (eddy current test) system is in use for Nb surface quality control in many laboratories. This system can inspect Nb surface quickly using high resolution probe. The ECT system for RAON's cavity was made with these features: it has a 3-axis acting probe movement system, it can inspect a big size of Nb sheet, which is 1,200 mm $\times$ 365 mm and it contains the analysis program that can show the result as a 2D and 3D images as well as the relative figure of the surface level. The standard sample was made with various sizes of defects using the same Nb sheet that was used to make RISP (Rare Isotope Science Project) cavity. The ECT system conditioning was carried out to optimize the ECT operation on the frequency of which the range is from 300 KHZ to 2 MHz. The result of 900 KHZ showed the strongest signal. The conditioning experiment on other parameter will be carried out in the near future.

Key words: SRF (superconducting radio frequency) cavity, eddy current, non-destructive, niobium, ECT system.

1. Introduction

It is very important to make high performance cavity in the SRF cavity field in terms of reducing the cost as well as getting a high quality beam. There are three aspects in terms of quality control: purity, workability, and surface quality [1]. Because of this reason, many non-destructive tests were used for SRF cavity fabrication. The ECT system is one of the non-destructive inspection methods and it has been used to control the surface quality of Nb in many accelerator laboratories such as FNAL (Fermi National Accelerator Laboratory), DESY (Deutsches Elektronen-Synchrotron) and KEK (Ko Energy Kasokuki Kenky Kiko) [2-9]. The ECT system is for finding out defects under the surface. It can also detect foreign material like Ta, W and so on. Compared with other non-destructive inspection systems, the ECT system has some advantages. It is faster, has higher resolution and easier to operate.

1.1 RISP (Rare Isotope Science Project) Cavity

The goal of RISP is to make the accelerator which can generate the 200 MeV/m beam energy based on uranium beam [10]. A total of over 550 cavities are needed to make the linac part of the RISP accelerator which was named RAON. We will use four kinds of cavities to meet the beam quality of RAON and each cavity needs 3-4 Nb sheets that have the size of 1,200 mm $\times$ 635 mm. The Nb sheet for RAON's cavities has similar properties with other SRF cavity material. The RRR (residual resistance ratio) value is larger than 300 and the average grain size of Nb is finer than 64 μ m [11].

The paper is organized as follows: Section 2 introduces the RISP ECT system; Section 3 introduces the standard sample for RISP ECT system; Section 4 presents result of frequency conditioning; Section 5 presents further work; Section 6 gives conclusions; and Section 7 presents acknowledgment.

2. RISP ECT System

Fig. 2 shows the ECT system for RAON's cavities. It has the features as follows:

- The probe moves by a 3-axis machinery system:

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Fig. 1 Four types of SRF cavity used for RAON superconducting linac [12].

Fig. 2 The ECT system for RAON's cavities.

Fig. 3 RISP ECT analysis program.

it is more accurate than using a turntable to find out the position of defect on the sheet;

- The RISP ECT system can inspect a large sheet which is 1,200 mm × 635 mm;
- The probe was a customized product by ZETEC, Inc.;
- The ECT main body was also made by ZETEC, Inc.;
- The analysis program made by 4UTEC, which is one of the domestic companies in South Korea, can show the 2D and 3D results including the relative surface level of the sample.

Fig. 3 shows the main screen of the analysis

program:

- (1) The original signal of X-axis and Y-axis from the ECT machine;
- (2) Lissajous' pattern which was made by XY-axis original signal;
- (3) The 2D image of sample. The color indicates the relative surface level;
- (4) This part is for controlling of the ECT probe movement system.

3. Standard Sample

Basically, the ECT system needs the standard sample to optimize frequency and to analyze the result by comparing the signal from the sample with the signal from the standard sample. Because of that, the signal changes according to the subject material, defect size and the frequency of probe. Therefore, typical signal and Lissajous pattern of the defect which we already know about, the size are necessary in order to be able to analyze the result from the sample. The information of EDM (electric-discharge machining) was used to make the standard sample. Fig. 4 shows the finished standard sample with the EDM electrode diameter and feasible depth. Since pure Nb is not a commercial material, material property data for SRF cavity are insufficient. No. 1 defect in the standard sample was originally planned at 50 μ m in diameter and 50 μ m in depth. Defects size was planned to be by gradually increasing in size number until No. 23 defect, which has 500 μ m in diameter and 500 μ m in depth.

The standard sample was tested by KTL (Korea Testing Laboratory) by non-contact 3D measurement, with VIEW Benchmark™ 250 made by VIEW,

ECT standard sample		
Aim diameter (mm)	EDM electrode diameter	Feasible depth
0.05	0.035	0.05
0.1	0.08	0.01 ~ 0.2
0.2	0.15	0.01 ~ 0.5
0.3	0.27	0.01 ~ 0.5
0.5	0.45	0.01 ~ 0.5

Fig. 4 Standard sample and EDM electrode data.

Fig. 5 The result of confirming defect size.

Micro-Metrology. Fig. 5 shows the results of the test. It was not made according to the original plan due to the lack of EDM data and skill to handle pure Nb. However, since it has various sizes of defect, it is enough to do the conditioning of the ECT system.

4. ECT System Conditioning

The conditioning needs to be set up on the best operation condition. It should be carried out on the frequency, speeding and spacing during probe movement and lift-off which will be carried out by the Z-axis. The frequency experiment was carried out at the range of 300 KHZ to 2 MHz so far. Each scanned signal was recorded as the relative figure and that can represent the relative surface level of the sample. Fig. 6 shows the raw data of one of the frequency experiment results. The result was painted gradually increased in red color. The higher the number, the

darker the red. The green bar also indicates how high the figure compared with the surrounding. The circle in the middle of the Fig. 6 represents one of the defects of the standard sample.

The frequency experiment results of 300 KHZ, 500 KHZ, 700 KHZ, 900 KHZ, 1 MHz, 1.3 MHz and 2 MHz are shown in Fig. 7. The case of 900 KHZ, as shown in Fig. 7, has the strongest signal and 300 KHZ and 2 MHz are shown to have the faintest signal; especially, the result of 2 MHz has the weakest signal.

Results were also analyzed as a 3D image. Fig. 8 shows the result of the frequency experiment as a 3D image between 300 KHZ and 2 MHz. It is obvious that the result of 900 KHZ shows the strongest signal in the 3D image result. It was carried out between 750 KHZ and 950 KHZ at intervals of 50 KHZ but the results were the same in this range. Thus, we will adopt frequency of 900 KHZ for RISP's ECT system.

Fig. 6 Relative number of surface level.

Fig. 7 Measured by frequency change.

5. Further Work

More conditioning experiment will be carried out on speeding and spacing of probe and lift-off effect. Since the result of ECT shows the relative figure of surface level, it will study that correlation between

Fig. 8 3D images of frequency change.

real defect size and relative figure. Defect size study will be carried out with the further research of non-destructive test of SRF cavity to set up the criteria for acceptable defect size.

6. Conclusions

The ECT system for RAON's cavities was established. It was made by a domestic company in South Korea with ZETEC's ECT products. It has a three axis-acting probe machinery system to get more accurate information of the defect position. It also has an analysis program that can show the 2D and 3D image results and relative figure of the surface level. The ECT experiment was carried out on the frequency between 300 KHZ and 2 MHz. The result of 900 KHZ shows the strongest signal. Thus, we will adapt this frequency to operate RISP ECT system. The experiment on other parameter will be carried out in the near future with defect study.

Acknowledgment

This work was supported by the RISP of Institute for Basic Science funded by the MSIP (Ministry of Science, ICT (Information, Communication and Technology) and Future Planning) and the NRF

(National Research Foundation) of the Republic of Korea under Contract 2013M7A1A1075764.

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