STATUS OF RRR ANALYSIS FOR RAON ACCELERATOR*

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Abstract

Residual Resistance Ratio, which is called RRR, is an important parameter representing the purity of superconducting material. Since a thermal quench, which means the superconductivity no longer exists, is induced by thermal accumulation when a local spot exceeds a critical temperature, the purity control near superconducting surface as about nano meter level is critical. Analyzing RRR characteristics is a key to check out how e-beam welding is carried out. Therefore, optimization and analysis of electron beam welding is very important as the first step to produce superconducting cavity. RISP has been producing low beta cavities including half-wave, quarter-wave, and spoke type cavities to construct heavy-ion accelerator, "RAON". We have conducted series of e-beam welding tests and confirmed that RRR is strongly dependent on the vacuum level, welding power, and welding speed. In this paper, we report RRR results from various welded samples for producing niobium superconducting cavities.

INTRODUCTION

Low-beta cavity requires complicated processes such as cavity part forming by using a pressing machine, part welding by e-beam welding, chemical polishing of a cavity [1], heat treatment, high pressure rinsing for cleaning the inner surface of the cavity [5] [3]. Because the superconductivity is strongly dependent on the surface state of the superconducting cavity, the surface of the cavity should be carefully treated. Welding, which is carried out to assemble two or more parts, is basic process to fabricate the superconducting cavity. However, this welding process must be performed systematically and elaborately as well for successful result. In principle, the welding occurs between liquid metals. Therefore, this moment is very vulnerable for a material to be easily contaminated from environment. According to previous studies [4], vacuum level, welding power and welding speed are known as critical factors to determine the success of the welding, needless to say the clean surface of parts to be joined. We performed various welding of niobium by using electron-beam with the same condition as used for producing prototype niobium cavities. And we analyzed the results of the residual resistance ratio with physical property measurement system (PPMS). In this paper, we will discuss the characteristics of RRR measurement as a function of the vacuum level, welding speed, and welding power.

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EXPERIMENTAL

Sample Preparation and E-beam Welding

RRR 300 grade niobium sheets (Nb,41) were purchased from ATI, Wah Chang Inc. (Albany,USA). Each Nb sheet has the size as $3 \times 635 \times 1200$ mm^3 ($thickness \times width \times length$). Purchased niobium satisfied the mechanical and chemical specifications for producing Nb superconducting cavity [?]. Successfully welded niobium sheet for preparing samples has the size as 200×200 mm^2, which means two identical niobium parts of 100×200 mm^2 were butt-joined by e-beam welding. Welding conditions are summarized in Table 1. Nb samples for RRR measurement have the size as $0.5 \times 0.5 \times 9$ mm^3, and they were cut from the welded Nb sheet perpendicular to the welding line. All dimensions of niobium are summarized in Table 2. Each distance of cut sample was 0, 2, 4, 6, 8, 10, 15, 20, 25, 50 mm from the welding line. This is shown in Figure 1 and Figure 2. Cutting samples was carried out by electrical discharge machining (EDM). Samples were cut from bottom, middle and top part along the welding direction. For instance, twenty samples were cut from the bottom part including both the weld side (front side) and bead side (back side). Ten samples were obtained from one welded sheet. Therefore, sixty Nb samples in total were prepared from the welded Nb sheet.

Table 1: Welding Conditions for Sample Preparation

Items	Values
Voltage (kV)	60 - 120
Current (mA)	30 - 60
Power (kV)	Max. 9
Welded Speed (mm/s)	3-20
Vacuum (Torr)	$2 \times 10^{-5} \sim 5 \times 10^{-6}$

Table 2: Nb Dimensions for RRR Measurement

Items	Dimensions
Nb Sheet	$3 \times 635 \times 1200$mm^3 (T $\times W \times L$)
Welded Sheet	200×200 mm^2
Part for Welding	100×200 mm^2
Nb Sample	$0.5 \times 0.5 \times 9$ mm^3

RRR Experiment

RRR measurement by using physical property measurement system (PPMS) was performed with no magnetic field. Among many definitions of RRR, we defined RRR by measuring the resistance of niobium sample just above 9.2 K, the critical temperature at niobium turns into superconducting

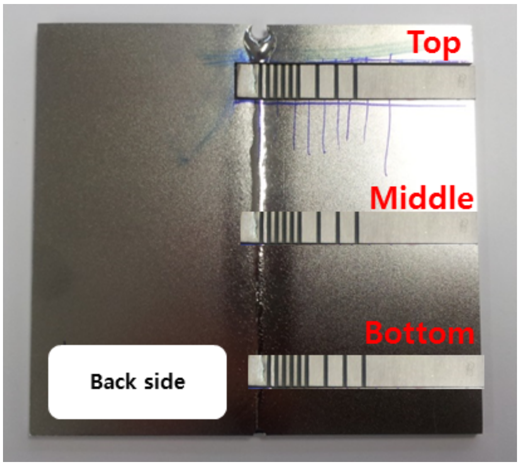

Figure 1: Welded Nb sheet of 200 × 200 mm^2. Welding direction is from bottom to top

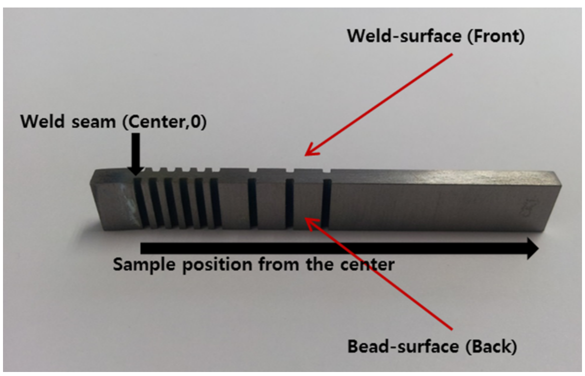

Figure 2: Sample picture: numbers, directions, types (front and back side). Each sample has the dimension of 0.5 × 0.5 × 9 mm^3

state. That temperature range was 9.5 K to 10 K. Input current for RRR measurement was 5 mA, which is acceptable power level for PPMS. In other words, this input current does not affect the resistance of the niobium sample during the RRR measurement. Temperature increments were 0.1 K up to 15 K, 1 K from 16 K to 30 K, and 5 K up to 300 K. The stabilizing time at the certain temperature for one RRR point was between 100 and 200 s.

RRR CHARACTERISTICS

RRR data are shown in Figure 3 and Figure 4. According to the graphs, we confirmed that RRR degradation of the weld side was less than the bead side. RRR values of the bottom part (welding starting region) were higher than those of the top part (welding ending region). We believe that impurity driven effect by continuous welding is one of the factors that decrease RRR of ending region [6]. RRR values degraded maximally around 8 ~ 10 mm from the weld center, and then started to recover at around 15 mm (weld side) and 30 mm (bead side). This length is called a heat affected zone (HAZ) in which the microstructure altered by incorporated heat during the welding. Thus, it is important to optimize welding power and welding speed in order to minimize HAZ

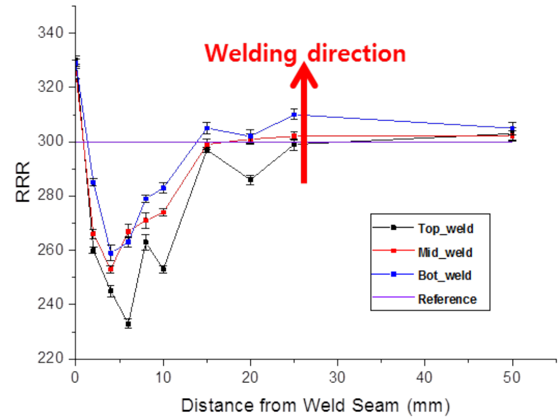

Figure 3: RRR Degradations of weld side (front side) as a function of sample positions and the welding direction

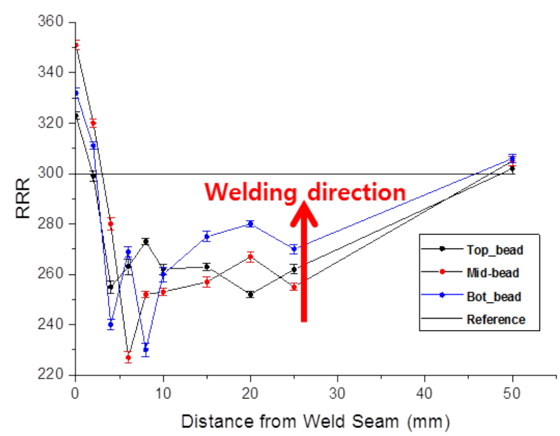

Figure 4: RRR Degradations of bead side (back side) as a function of sample positions and the welding direction

during the cavity production. The average RRR degradation was about less than 10%, the lowest RRR point still lies in about 20%. According to previous studies, RRR degradation is greatly dependent on the vacuum level. Although we set the vacuum level of the e-beam chamber as ~ 10^{-6} Torr, we suspect that the real vacuum in the chamber did not reach target value since the vendor's welding state was not completely set up.

SUMMARY

We have performed various RRR measurements in order to produce niobium superconducting cavities that have good quality. We confirmed that RRR degradation occurred during the e-beam welding, and RRR degradation was serious in the bead side. RRR degradation was affected by the welding direction. RRR of the starting region was higher that that of the ending region. Thus, e-beam welding should be carefully carried out by considering the welding direction. Also, the welding power and the welding speed should be optimized in order to decrease the length of HAZ.

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