THE QUALITY ASSURANCE AND ACCEPTANCE SYSTEM OF NIOBIUM MATERIAL FOR RAON CAVITIES

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Abstract

The QAAS (Quality Assurance and Acceptance System) of superconducting material for RAON's cavities has been set up. The subject was selected by how the part is affected by RF (Radio Frequency) in the cavity operation at cryo-temperature. The QAAS consist of property analysis and checking the surface condition. Each step has criteria its own to pass the assurance and acceptance system. The method to analyze the properties and to inspect the niobium surface was described. The certificates were classified by RRR values of Nb pieces due to distribution of RRR value. The Nb properties slightly different by RRR values, so we will set a bunch of niobium pieces for one specific cavity with Nb pieces having similar RRR value.

INTRODUCTION

The high quality material is needed to make a high performance resonator. The niobium is widely used as superconducting material for SRF (Superconducting Radio Frequency) cavity and the niobium surface condition is one of the important factors to determine the cavity performance because the surface resistance is related to the energy of the cavity and the surface resistance depending on material quality and surface condition. There are two aspects about quality control of material. One is to control the material's chemical, mechanical, electrical and optical properties. The other is that to control the niobium surface. Many other institutes carry out the checking the properties and surface inspection using various methods before doing machining [1-5]. The material properties are determined at the production stage by project demands, so it is necessary to verify the properties by sampling. In case of surface checking, it is necessary step for mass production. However, it is practically impossible to inspect all of the niobium because of the time limitation and man power. For this reason, the subject for inspection was selected by considering RF (Radio Frequency) effect. The parts where the highest electric and magnetic field is exerted was selected and it is called as RDP (Radio frequency Dominant Part). It will be explained about the kind of inspection, inspection process, subject selection, the criteria of acceptance and the inspection and measurement method. Also the certificates of Nb provided by the ATI metallurgy were classified.

QAAS OF NIOBIUM FOR RAON

QAAS (Quality Assurance and Acceptance System) will be introduced in this section.

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The Type of Niobium and the Subject Selection

There are three types of niobium for RAON's cavity.

- Big sheet (635*1200 mm, 3t)
  (600*800 mm, 3t)
  (450*600 mm, 5t)
- Cut set (specific size corresponding to the part, 3t)
- Rod or Tube (Φ 60, 3t)

Big sheet is used for cavity prototype and extra sheet. Cut set is a bunch of Nb pieces which were cut by a required size of each cavity part with extra margin. The rod or tube of Nb is for beam port. And big sheet has two types of grade, which are RRR (Residual Resistivity Ratio) 300 and RRR 50 (Reactor grade). And it has different thickness which are 3mm and 5mm. The RRR 50 grade sheet is only used for supporting structure such as ribs for upper part or doubler of beam port cup. All of Nb cut set and Nb rod have 3mm thickness.

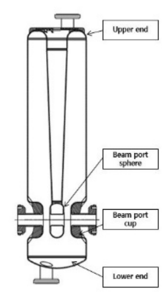

Figure 1: QWR cross section.

Figure 1 shows the RDPs (Radio frequency Dominant Part) which are strongly affected by RF field in the cross section of QWR (Quarter Wave Resonator). In case of QWR, upper, lower and beam tube parts are RF dominant part. The RISP (Rare Isotope Science Project) will make four kinds of the cavities which are QWR, HWR (Half Wave Resonator and two kinds of SSRs (Single Spoke Resonators).

Whole Process

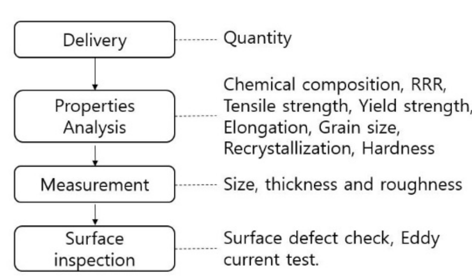

Figure 2: Whole process of QAAS.

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Figure 2 shows the whole process of QAAS. First of all, quantity checking is needed when Nb is delivered to IBS from the vendor. Secondly, the analysis of Nb property is carried out in various aspects to verify the certificates of the niobium. Thirdly, only RDPs undergo size, thickness and surface roughness measurements. Fourthly, only RDPs are inspected the surface to detect the defects, such as pit, scratch, dent and so on. Lastly, only RDPs are tested with the ECT (Eddy current test) to find the defect under the surface which is effected by RF in cavity operation at 2K.

Criteria of Acceptance

Table 1: Criteria of each steps

	Criteria	Unit	Chemical composition	Max. Weight (ppm)
Tensile strength	> 100	Mpa	C	20
Yield strength	50<Rp<80	Mpa	N	20
Elongation	> 40 (Longitudinal)	%	O	40
	> 35 (Transverse)	%	H	5
Hardness	< 50	HV10	Ta	1000
Grain size	64	μm	Fe	50
Recrystallization	> 95	%	Si	50
RRR	> 300		W	70
Size	± 3.175	mm	Mo	50
Thickness	± 0.254	mm	Ti	40
Surface defect	< depth 25	μm	ECT : No defect under the surface	

Table 1 shows the criteria of all steps. The criteria of chemical, mechanical, electrical and optical properties were determined from the specification of niobium for RAON's cavities. Each property is widely used in linear accelerator field [6-8]. The defect on the niobium surface is allowed only when the size is less than 25μm in depth. According to the inspection result, the defects which exist on the niobium surface have the size of around 10μm in depth. And other defects are not allowed under the surface of niobium.

Inspection & Measurement Method

Figure 3 shows the samples for property analysis and the chemical, mechanical, electrical and optical properties were analysed by table 2.

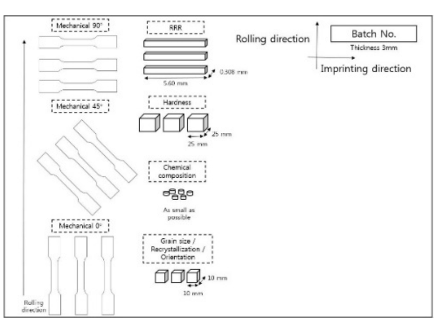

Figure 3: The samples for properties analysis.

The property analysis was carried out with niobium pieces which have 3 different types of RRR values, which are RRR 363, RRR 434 and RRR 500. Each analysis is carried out 3 times to verify the results. Different RRR values of niobium will be discussed in the section of certificates analysis. All of the niobium pieces have the identification number. This number is imprinted in a vertical direction to the rolling direction of sheet. We call this identification number as batch number.

The measurements of size, thickness and surface roughness were carried out with a special ruler, thickness measurement and surface finish measurement. The size checking is not tested fastidiously because pieces have extra margin. When Nb pieces fit in or is bigger than the special ruler corresponding to specific size, that piece is passed. In case of thickness measurement, 5 positions on the surface were measured, four corners and a center of each Nb piece. The surface roughness is tested with same position regardless of the piece size because this result will be used to compare with the surface roughness result after doing machining.

Table 2: The method of each analysis

Properties		Standard	Method	Spec.Min	Spec.Max	
Longitudinal	Tensile Strength	ASTM E8	Tensile test	100 Mpa		
	Yield Strength	ASTM E8		50 Mpa	100 Mpa	Offset 0.2%
	Elongation	ASTM E8		40 %		Gage 1"
Transverse	Tensile Strength	ASTM E8		100 Mpa		
	Yield Strength	ASTM E8		50 Mpa	100 Mpa	Offset 0.2%
	Elongation	ASTM E8		35 %		Gage 1"
RRR			PPMS	300	-	
Chemical composition			ICP(metal impurities) / EA(C,H,O,N)	-	Ta <1000ppm	
Hardness		ASTM E-384	Vicker's hardness	-	60 HV10	Long./ Trans.
Recrystallization			EBSD	95%	-	
Grain size		ASTM E112	EBSD	-	< 64μm	Long./ Trans.
Orientation			EBSD	-		

ICP : Inductively Coupled Plasma
EA : Elemental analyzer
EBSD : Electron Back Scatter Diffraction

The surface defect checking is carried out by visual inspection. If there is suspicious part on the niobium surface, the size of depth will be measured with surface finish measurement and the size of depth is represented by Rz (Average maximum height of the profile) and Ry (Maximum height of the profile). The ECT (Eddy Current Test) is tested with optimal frequency of niobium. The optimal frequency depends on the material, probe design and the target depth. The optimal frequency of niobium for RAON's cavity has been submitted to the journal name of Nondestructive Testing and Evaluation.

CERTIFICATES ANALYSIS

The certificates of niobium were provided by the vender of niobium, ATI, USA and the data on the certificates were obtained at a stage of resource batch. We ordered the niobium which can meet the requirement of specification for RAON's cavities, but it dose not mean all of the niobium pieces have same properties. Because of this reason, the certificates were classified according to different RRR value. There is the distribution of RRR value and figure 4 shows the result.

Figure 4 shows the number of RRR value type in the niobium sets for RAON's QWR, HWR cavities. There are 11 types of RRR values which are between minimum 338 and maximum 500. According to figure 4, we observed two results. One is all of the Nb products satisfied RAON's RRR requirement : average RRR should be large than 300.

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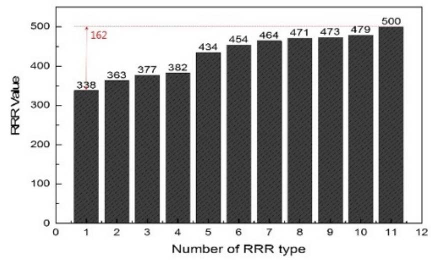

Figure 4: The number of RRR value type.

The other is that RRR distribution is substantial, which means the maximum difference in RRR is about 162. Each piece for one cavity wasn't from the same resource because the pieces were cut in the way that they can make pieces as many as possible in the one big sheet. So we are planning to set the bunch of pieces having similar RRR values. Because the Nb pieces with similar RRR values can give a similar environment to the interface between Nb pieces. And this interface which is called as welding zone usually causes the problem in the cavity operation at cryo-temperature.

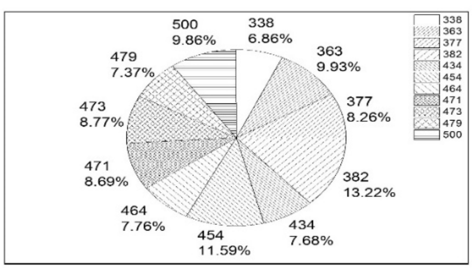

Figure 5: Distribution of RRR value.

Figure 5 and 6 show the distribution of RRR in QWR, HWR niobium cut set. According to figure 5 and 6, the distribution of RRR values over the whole pieces in relatively uniform than RDPs.

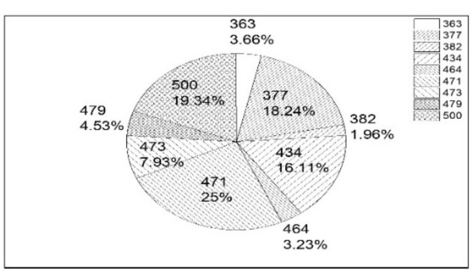

Figure 6: Distribution of RRR value in RDPs.

The RRR values of over 470 account for 56.8% of all of RDPs. We have to focus on the RDPs more than whole pieces because the RDRs will affect to the cavity performance than the rest parts. The RRR value degradation occur by e-beam welding in the range of between 8% and 22% depending on welding condition Especially, this degradation occur around welding zone which is called as HAZ (Heat affected zone) because of the impurity incorporation into the HAZ, such as H_2, N_2 and O_2. RISP set the minimum RRR value as 275, so only less than 8% of degradation is allowable in RISP [9].

CONCLUSION

The QAAS (Quality Assurance and Acceptance System) of superconducting material has been set up for RAON's cavities. The system cover the niobium properties and surface condition. The properties of Nb are analyzed by typical methods, according to ASTM (American Society for Testing and Materials) standard. The niobium surface condition was inspected in the way of visual inspection and eddy current test. The Nb certificates proved by the vendor was classified by RRR values and it will be used to make a bunch of Nb pieces for one cavity. We performed QAAS to guarantee the superconducting material properties and we categorized Nb pieces having similar properties with the certificate.

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