Metallurgical Characteristics and Ultrasonic Testing of W/H Reactor RCS Piping

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1. Introduction

In-service inspection of nuclear power plants requires that piping welds in primary pressure boundary of reactors be subjected to nondestructive examination based on rules contained the American Society of Mechanical Engineers(ASME) code section XI.

Cast austenitic stainless steel(CASS) is used in the primary cooling piping system of Westinghouse type nuclear power plant for it's relative low cost, corrosion resistance and easy of welding. However, the coarse-grain structure of cast austenitic stainless steel can strongly affect the inspectability of ultrasonic testing. The major problems encountered during inspection are beam skewing, high attenuation and high background noise of CASS component[1]

To develop more accurate and reliable technique for the UT inspection of primary pressure boundary LWR welds in CASS pipe, massive study were under taken since 1980's. Currently, most of researchers are studying to overcome these challenge issue[2] In this study, we want to identify and analysis the metallurgical characteristics of RCS piping in Westinghouse reactor by sectioning the calibration blocks which was manufactured when the plant was initially built. This calibration blocks may stand for same ultrasonic characteristics as RCS piping in plant. Therefore, this study gives us meaningful information to develop inspection technique.

2. Methods and Results

2.1 Calibration Blocks

Ultrasonic calibration block is essentially required to inspect a component by ultrasonically in the field. According to ASME code requirements, the ultrasonic calibration should have same material specification. From the field survey results, the specification of RCS piping is SA351 CF8M and CF8A. Fig. 1 shows the calibration block of Kori nuclear power plant.

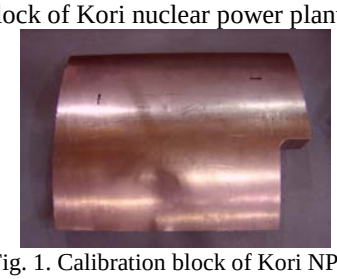

Fig. 1. Calibration block of Kori NPP.

We acquired a ultrasonic calibration block from Korean NPP. It's stand for similar metallographic characteristic as built piping material in NPP. We made axil and circumferential slice sample from the block to analyze the metallographic characteristic of CASS material in Korean NPPs. And three coupons are made from each slice. Fig 2 shows locations of each coupon from the ultrasonic calibration block.

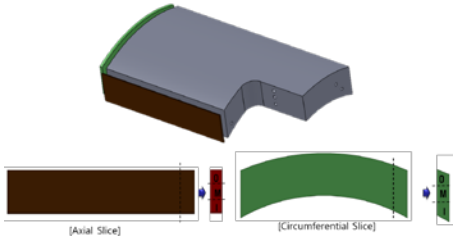

Fig. 2. Preparation of sample for metallurgical analysis

2.2 Chemical Composition of Calibration Blocks

The chemical composition of SA351 CF8M is shows table 1.

Table I: Chemical Composition of ASTM SA351 CF8M

Spec	C	Mn	Si	S	P	Cr	Ni	Mo
CF8M	0.08	1.5	1.5	0.04	0.04	18~21	9~12	2~3

The chemical compositions of all Westinghouse NPP are analyzed to confirm whether meets the ASTM code requirement. Fig. 3 shows the results of chemical composition analysis of Kori NPP.

The chemical components in calibration blocks meet the ASTM code specification.

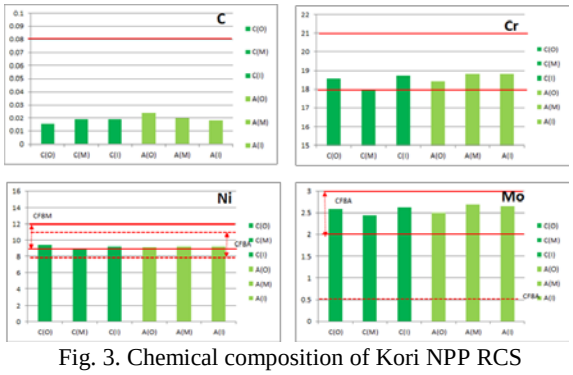

Fig. 3. Chemical composition of Kori NPP RCS

2.3 Metallographic analysis

To understand the typical characteristics of CASS microstructures, microscopic views are analyzed for every calibration blocks. The results show the ferrite phases, of which size is smaller enough than the wavelength of ultrasound in the material if higher than 1 MHz frequency probes are applied, precipitate in the majority of austenite base. This implies that the reflection or refraction at the boundaries between ferrite phase and austenite phase can be neglected from the UT point of view.[3]

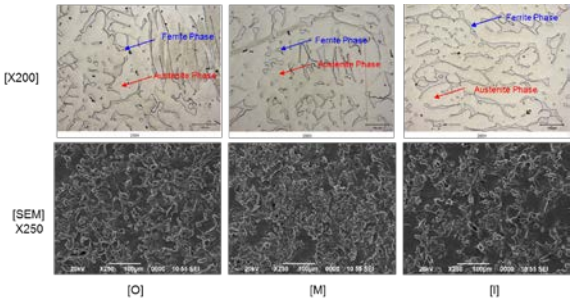

Fig. 4. Metallographic analysis of Hanbit NPP

2.4 Macro Metallographic Analysis

The macro grain structure affects with the propagation of ultrasound energy. Therefore the macro grain structure of CASS material also should have considered to understand the uncertainty of detection and sizing error. The sliced sample of calibration blocks are polished and chemically etched to visualize the macro grain structure of CASS.

Fig. 5 shows the results of macrostructure of type NPPs RCS piping in Korea.

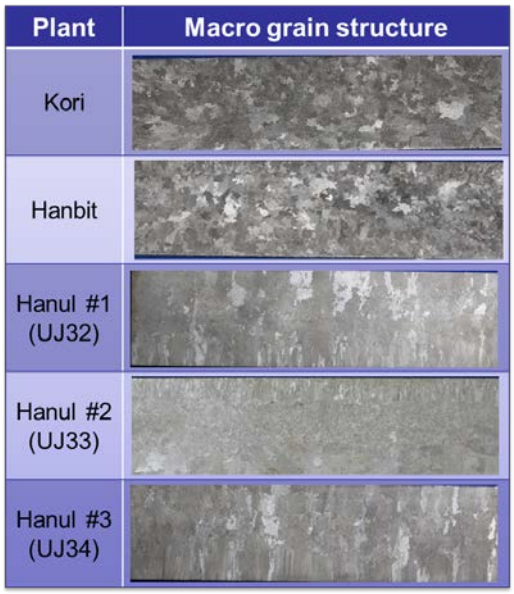

Fig. 5. Macrostructure of Korean NPP's RCS Piping

The macrostructure of Kori and Hanbit plant showed quite similar grain structure. These samples has equiaxed grain structure. However three calibration blocks from Hanul plant has different macrostructure with Kori and Hanbit. One has large grain size and two has banded with dendrite and equiaxed grain structure. From the above macrostructure of CASS material, we can estimate the quantitative difficulties of each plant. The UJ33 block of Hnaul plant considered that show best detectability and sizing result. However the UJ32 and UJ34 are very difficult to inspect by ultrasonic testing. This will also contribute the ultrasonic noise which is generated from the base material.

Fig. 6 shows the modelling results of ultrasonic noise which is caused from the grain structure of CASS material.

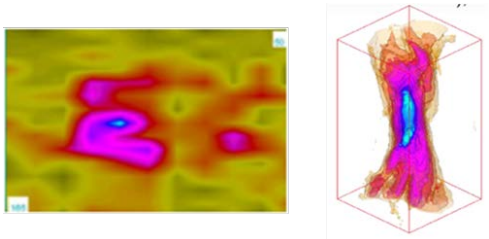

Fig. 6 Ultrasonic modelling result for large grain size

3. Conclusions

The grain structure of CASS material typically found in NPP varies in size, orientation and shape. These grain structure properties are known as challenge issue to inspect by ultrasonic testing. The CASS grain structures, especially columnar-dendrite grain structure, can have anisotropic properties that result in change in ultrasonic velocities and beam skew. From these characteristics of CASS material, it is very difficult to characterize the ultrasonic indications. The metallographic analysis result of Korean NPPs show various kind of grain structure. Therefore we have to consider the metallographic characteristics before inspect the RCS piping. We expected that this experimental result will help development of ultrasonic testing.

REFERENCES

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[3] Kazunobu Sakamoto, Takashi Furukawa, Study on the Ultrasound Propagation in Cast Austenitic Stainless Steel, E-Journal of Advanced Maintenance Vol.4 No.1, p. 5-25, 2012