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17M-01K Instrumented Capsule for HANARO Irradiation Test to Evaluate the Neutron Irradiation Embrittlement Behavior of SA533 B1 Reactor Pressure Vessel Steel

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1. Introduction

SA533 B1 Mn-Mo-Ni low alloy steels were used for the RPV(reactor pressure vessel) from Kori-2 to Hanbit-2, Westinghouse-type nuclear power plants, which are plate type materials. Therefore, there exist axial welds as well as circumferential welds in the reactor pressure vessel in plate type materials. Compared to SA508 forged steel, SA533 B1 low alloy steel shows distinct anisotropy with different mechanical properties depending on the direction of specimen.

In the case of domestic Westinghouse-type nuclear power plants, neutron fluence level of the beltline of RPV are much higher than those of the Korea standard nuclear power plants(KSNP). Therefore, it is necessary to study the behavior of high dose irradiation embrittlement in order to evaluate the integrity of long-term operating RPV.

In this study, we designed and fabricated an instrumented capsule 17M-01K for Hanaro irradiation test to evaluate the high fluence irradiation embrittlement behavior using the Kori 2 and Hanbit 2 RPV steels.

2. Determination of Irradiation Condition

Fig. 1 shows the change in irradiation fluence of RPV steels according to the operating years of Kori 2 and Hanbit 2. The cumulative fluence of the RPV wall is larger than that of the KSNP in the WH-type nuclear power plants operating in Korea. For more than 80 years of operation, the maximum fluence of Kori 2 will reach 1x10^{20} n/cm^2. Therefore, the target maximum irradiation fluence was set to 1x10^{20} n/cm^2 and the irradiation temperature was set to 290°C, which is the operating temperature of the RPV.

Fig. 2 shows the distribution of flux according to axial position of CT irradiation hole and OR4 irradiation hole in Hanaro. In the case of the CT irradiation hole, there is no flux difference according to the orientation at the same axial position, but the OR irradiation hole has a large deviation of the irradiation fluence depending on the orientation, and in the OR irradiation hole, more than two cycles are necessary to obtain the target irradiation fluence. Therefore, in order to obtain the uniform fluence distribution in the orientation and to reduce the irradiation period, the instrumented capsule will be irradiated for 8 days at the CT irradiation hole.

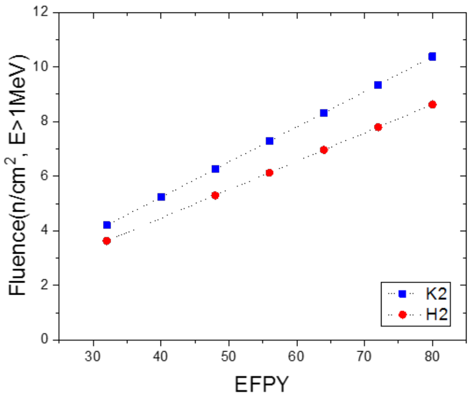

Fig 1. Estimated fluence level of Kori 2 and Hanbit 2 reactor vessels

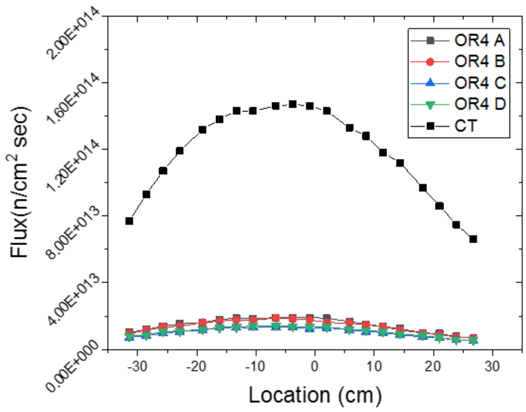

Fig 2. Flux distribution of OR4 irradiation hole and CT irradiation hole in Hanaro depending on axial position

Table 1: Chemical compositions of RPV steels

Materials		C	Mn	P	S	Si	Ni	Cr	Mo	Cu	V
K2	Base	0.193	1.35	0.005	0.005	0.211	0.62	0.072	0.5	0.001	0.036
	Weld	0.121	1.51	0.01	0.01	0.415	0.153	0.181	0.51	0.003	0.026
H2	Base	0.222	1.43	0.009	0.004	0.22	0.54	0.182	0.46	0.002	0.058

3. Materials and Specimens

In this study, we used the nozzle cut-out material used in RPVs of Kori 2 and Hanbit 2. Table 1 shows the chemical composition of the two materials.

The type and shape of the specimen to be loaded into the instrumented capsule are shown in Fig. 3. For the evaluation of tensile properties, two kinds of plate-type test specimens were used as shown in Fig. 3 a). For the fracture toughness evaluation in the transition region, PCVN (pre-cracked Charpy V-notched) specimens were prepared according to ASTM E1921. In order to evaluate the change in fracture toughness in the transition region according to the neutron fluence level using the limited space of the instrumented capsule, a 1/2 PCVN specimen smaller than ST-PCVN was used. 10-mm-thick DCT(disk-type compact tension) specimens were also used to evaluate crack propagation resistance,

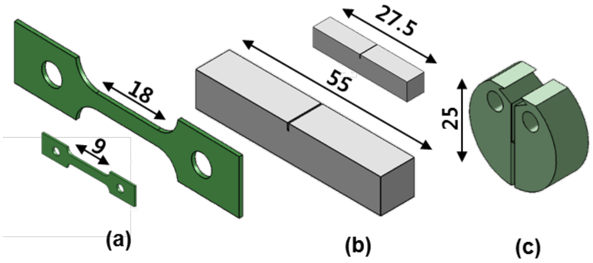

Fig 3. Specimen types and shapes for irradiation

4. Fabrication of Instrumented Capsule

As shown in Table 2, specimens were placed in the capsule. Since there is a difference in the distribution of the neutron flux depending on the axial position, the specimens are arranged so as to have the similar neutron fluence level in the same type of specimen. Three sets of 1/2 PCVN specimens were also placed in consideration of the fluence distribution in the instrumented capsule. These three sets of 1/2 PCVN test specimens were used to evaluate the variation of transition characteristics according to the fluence difference. Fig. 4 is a photograph of the 17M-01K instrumented capsule. Currently, the capsule is ready for the neutron irradiation at the Hanaro.

5. Summary

Instrumented capsule 17M-01K for HANARO irradiation was prepared to evaluate the neutron irradiation embrittlement behavior of plate-type RPV steels used in domestic Westinghouse-type NPP. Base metal and weld of Kori 2 and base metal of Hanbit 2 were used for the preparation of the instrumented capsule. The neutron irradiation will be conducted for 8 days at the CT irradiation hole in Hanaro. The target maximum fluence is $1x10^{20}$ n/cm^2 and the target irradiation temperature is 290 ^{o}C.

Table 2: Sample type and location in the 17M-01K instrumented capsule

Pos.		Specimen type	ID			
			0°	90°	180°	270°
1	U	0.4T-DCT	K301-04			
	L	1/2 PCVN	K301, 03-09	K310-13,15,16, 18		
		S-Tensile		K301-05		
		SP				5 set
2	U	ST-PCVN		Y301	Y302	Y303
		TEM	T1-T2			
	L	ST-PCVN		Y304	Y305	Y306
		P-Tensile	Y301-10			
3	U	ST-PCVN	K801	K802	K803	K804
	L	ST-PCVN	K805	K806	K807	K808
4	U	ST-PCVN		K809	K810	K811
		P-Tensile	K801-10			
	L	ST-PCVN		K812	Y307	Y308
		SP	4 set			
5	U	ST-PCVN	Y309	Y310	Y311	Y312
	L	1/2 PCVN	Y301-08	Y309-15	K801-08	K809,10, 12-16
		S-Tensile		Y301-05		K801-05

Fig 4. 17M-01K instrumented capsule for Hanaro irradiation test

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