Issues of the Irradiation Testing of ARAA and TP 304H Steels in HANARO

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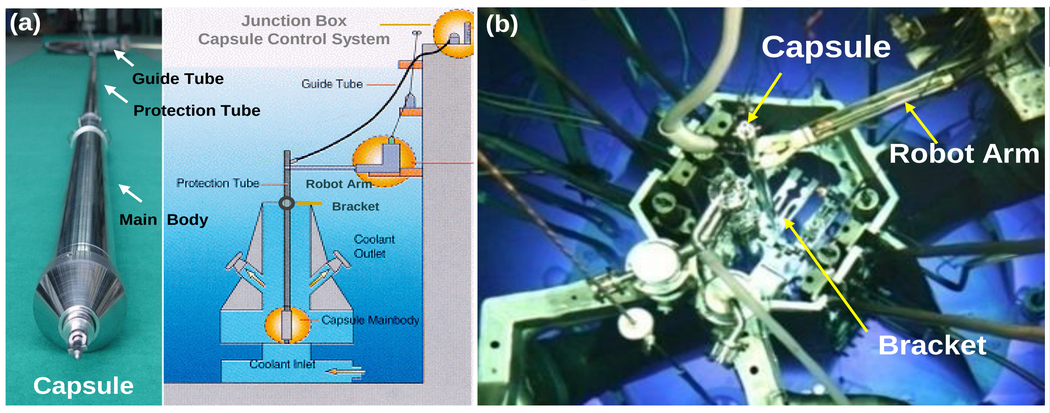
◆ Introduction

- ✓ Increasing necessity for national R&D projects relevant to future nuclear systems such as Fusion reactor and SMR programs, in addition to reactor safety R&D projects of commercial PWR in Korea
- ✓ A series of irradiation testing of ARAA materials for fusion reactor was required at ~330℃ up to 3 dpa.
- ✓ Optimized irradiation capsule design for thermal embrittlement-resistant S.Steels at ~340℃ up to 5 dpa.
- ✓ A series of testing for evaluating irradiation embrittlement characteristics of RV/CV materials for innovative small modular reactor(i-SMR) and for Spent Fuel Storage Cask materials, are planned in HANARO.

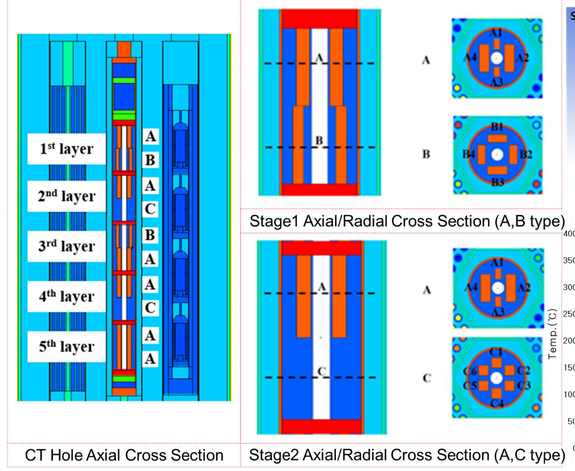
◆ HANARO Irradiation Capsule Systems



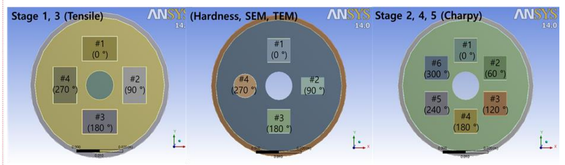
1) Capsule Design Process

1) Basic Design : Material & Specimen configuration > Capsule type
2) Nuclear Characteristics of capsule parts were evaluated using Monte Carlo transport analysis (N. flux, γ heating, reactivity effect)
3) Thermal Analysis : Specimen temp. was adjusted by specimen configuration, part gaps, He pressure, micro-heaters in the capsule
4) Instrumentation & Safety Analysis : 14 thermocouples, 5 micro-heaters, Fluence monitors are installed in the capsule

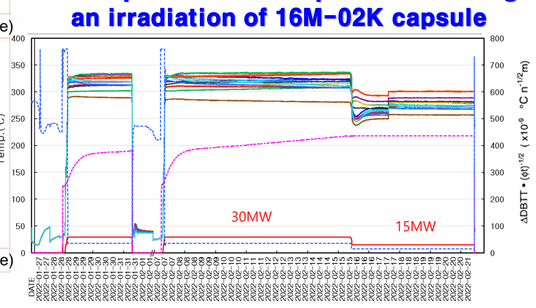
Model for MCNP6.1 Code (24M-05K)



Thermal Analsys of 16M-02K Capsule



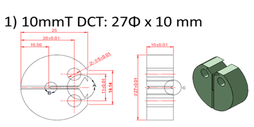
◆ Temp. variation of specimens during an irradiation of 16M-02K capsule



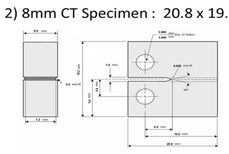
◆ Irradiation Specimens & Composition (Fe balance)

Capsule	Material	Composition								
16M-02K 23M-01/02F (Fusion)	ARAA	C	Mn	Si	W	V	Ta	N	Cr	Ti/Zr
		0.1	0.45	0.1	1.2	0.2	0.07	0.01	9.0	0.01
24M-05K (APWR)		C	Mn	Si	P	S	Cu	Ni	Cr	Mo
	304H- Base	0.051	1.09	0.42	0.017	0.002	0.02	8.03	18.15	0.01
	E308L-SMAW weld	0.029	0.84	0.83	0.027	0.004	0.10	9.42	19.54	0.12
	ER308L-GTAW weld	0.022	1.92	0.43	0.013	0.010	0.06	10.79	19.85	0.13
25M-02K (i-SMR)	SA508 Gr3 Cl2	C	Mn	Si	P	S	Cu	Ni	Cr	Mo
		<0.25	1.2-1.5	<0.4	<0.025	<0.025	<0.2	0.4-1	<0.25	0.45-0.6

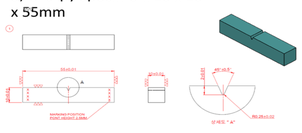
1) 10mmT DCT: 27Φ x 10 mm



2) 8mm CT Specimen : 20.8 x 19.2 x 8mm

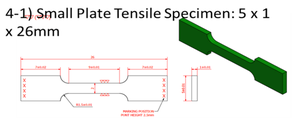


3) Charpy Specimen: 10 x 10 x 55mm



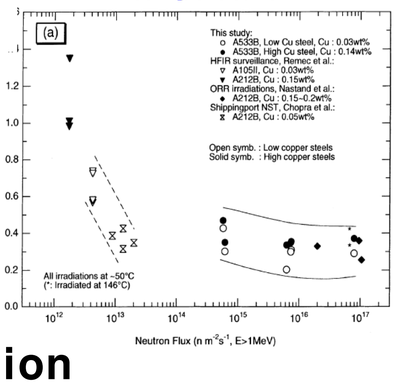
4) Case: 12 x 10 x 55mm
- Same materials to specimens

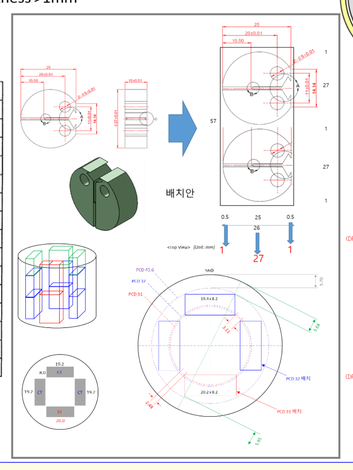
4-1) Small Plate Tensile Specimen: 5 x 1 x 26mm



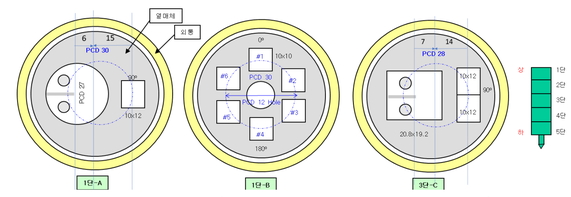
4-2) Microstructure Specimen: thickness >1mm

◆ Normalized increases in DBT temperature

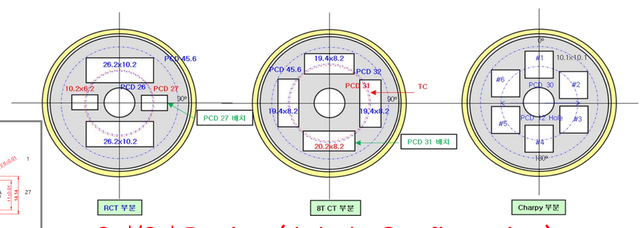




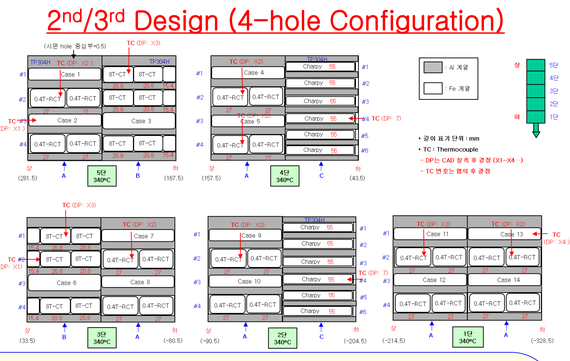
◆ Schematic view of cross section



1st Design (Central Configuration)



2nd/3rd Design (4-hole Configuration)



2) Characteristics of Capsule Design & Irradiation

1) 16M-02K: By a reactor power drop from 30MW to 15MW, the irradiation temperature of the ARAA specimens for Fusion reactor in HANARO (257-301℃) exists in the intermediated temperature irradiation range. It seems to be in a same irradiation-related defect behavior during the irradiation testing without 'accelerating' effects on embrittlement, resulting in a negligible effect of the reactor power drop on the irradiation property of specimens.
2) 24M-05K: For 6-hole design of Charpy and CT specimens of thermal embrittlement-resistant SS (TP 304H and weld) for advanced PWR, an optimized design of the capsule was applied (For CT specimens, a new specimen configuration design (vertical 4-hole design) instead of central configuration). By the design, specimen temp. lowered by 30-40℃ and the specimen temp. difference between center & surface decreased to 39℃ from 67℃.
3) 25M-02K: For application of high strength SA508 Gr.3 Cl.2 steels to reactor vessel (RV) & containment vessel (CV) of i-SMR, a series of testing for evaluating irrad. embrittlement of RV/CV materials are planned. At least 20 sets of alloys will be irradiated at ~290℃ up to $4x10^{19}$ n/cm^2.
4) 25M-01U: Testing of materials (Al+B_4C, Stainless steels) for spent fuel storage cask application at low thermal power (1MW) at 300 ℃ are prepared.

◆ Conclusion

- ✓ A series of irradiation testing of ARAA material that will be used as structural materials in a fusion reactor was required for up to 3 dpa at about 330℃ in HANARO. Abnormal reactor power variation from 30MW up to 15MW during the irradiation testing, seems to have a negligible effect on the defect behavior of the alloy.
- ✓ An optimally designed capsule was made for the irradiation test of thermal embrittlement-resistant stainless steel (TP 304H and weld materials) at ~340℃ for up to 5.0 dpa. It will prove the safety of reactor vessel internal (RVI) components. A new specimen configuration design (vertical 4-hole) was applied to satisfy the required and uniform irradiation temperature of CT specimens for the first time in HANARO.
- ✓ A series of irradiation testing for evaluating neutron irradiation embrittlement characteristics of RV and CV materials for i-SMR (at least 20 sets of specimens) and spent fuel storage cask are planned in HANARO.