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Comparison of mechanical analysis results by ARAA properties on the different development stage

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1. Introduction

Korea has formulated a long-term program for the development of its own RAFM steel, called ARAA (advanced reduced activation alloy), for ITER TBM/DEMO fusion reactor applications since 2012 [1]. The 9Cr-based new alloy has been designed and fabricated based on the out-of-pile performance results from the test of a series of batches. They were named ARAA-1, 2, and 3 according to the time of mass production. In the CD (conceptual design) phase of HCCR TBM-set, Eurofer steel properties which is different RAFM steel were used in thermal-hydraulic and structural analysis [2]. In the PD (preliminary design) phase of HCCR TBM-set, mechanical analysis was performed with ARAA-1 properties. ARAA's representative material properties was presented and compared with the analysis results by performed with ARAA-1 material properties.

2. Material properties

Tables I and II show the material properties of ARAA-1 and ARAA-2/3. The value indicated by ARAA-2/3 is the representative material properties of ARAA. In terms of density and coefficient of thermal expansion, the physical properties of ARAA-1 and ARAA-2/3 are similar. The mechanical strength of ARAA-2/3 is higher than that of ARAA-1. ARAA-2/3 also has higher thermal properties like the specific heat and the thermal conductivity than ARAA-1.

Table I: Material properties of ARAA-1

Temp. [℃]	Density(ρ) [kg/m^3]	Specific heat (C_p) [J/kgK]	Thermal cond (λ) [W/mK]	($R^t_{p0.2}$) [MPa]	($R^t_{p0.2}$) [MPa]
20	7730	357	25.7	533	501
100	7708	456	27.1	484	476
200	7679	492	27.5	459	444
300	7650	527	27.4	445	444
400	7620	570	27.3	411	398
500	7589	631	27.2	390	381
600	7558	714	26.8	323	315
700	7526	867	26.1	-	-

Table II: Material properties of ARAA-2/3

Temp. [℃]	Density(ρ) [kg/m^3]	Specific heat (C_p) [J/kgK]	Thermal cond (λ) [W/mK]	($R^t_{p0.2}$) [MPa]	($R^t_{p0.2}$) [MPa]
20	7828	465	29.7	552	491
100	7807	493	29.1	520	459
200	7778	524	28.8	497	435
300	7748	558	28.8	481	419
400	7717	609	29.0	457	396
500	7686	688	29.1	411	349
600	7654	807	28.9	327	265
700	7621	979	28.1	189	127

3. Structural analysis

3.1 Model

The PD-3 model of HCCR-TBM was used as shown in Fig. 1. The HCCR-TBM consists of four sub-modules, and the main components are first wall (FW) and breeding zone (BZ) in each sub-module and common BM. In HCCR-TBM, ARAA is used as structural material, and the lithium ceramics, beryllium and graphite are used as functional materials such as breeder, multiplier and reflector, respectively. The BZ comprises total seven layers, i.e. three breeder layers, three multiplier layers and one reflector layer.

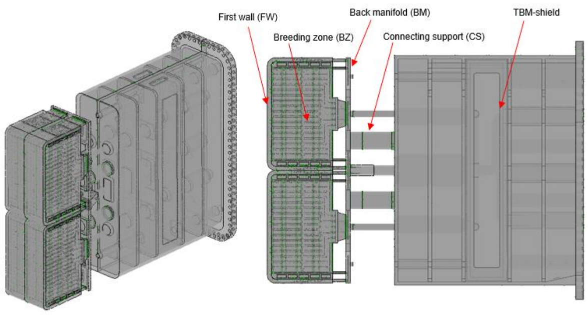

Fig. 1. HCCR TBM PD-3 model

3.2 Boundary condition

TBM-set is bolted to the flange of the vacuum vessel equatorial port extension. The front side of the TBMshield is mounted on the rear side of the TBM frame with a bolted connection. The frame is simplified to simulate the bolted connection. The frame is considered that x-, y-, and z-axis were fixed at the end of the flange. The pre-tension is applied in the assembly of the bolts and nuts. The geometry model for the analysis is shown in Figure 2. The applied loads are dead weight load (DW), operation pressure load (PresO), operation thermal load (THO), electron magnetic load, outgassing load, and load combinations. Specific load contents and boundary conditions are described in the following report [4]

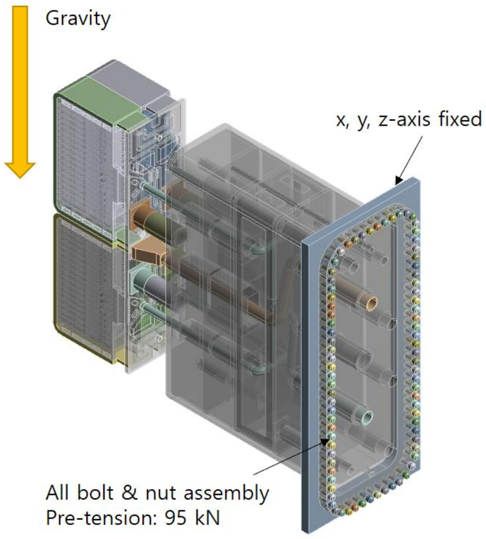

Fig. 2. Boundary condition for mechanical analysis

3.3 Results

Table III and IV show the maximum stress and the location of the single load and load combinations. The maximum stress of the structural analysis using the ARAA-2/3 properties was higher than that of the structural analysis using the ARAA-1 properties, but the difference was only about 2.5% maximum. This difference only occurs when the thermal load (THO) is included. For other loads, the difference in structural analysis results is insignificant.

Table III: Maximum stress of single load analysis

Load	Max. Von Mises Stress [MPa]	
	ARAA-1	ARAA-2/3
DW	633	633
PresO	631	631
THO	1134	1146
PresOTG	630	630
THOTG	2722	2722
EM, MXWstd	630	630

Table IV: Maximum stress of load combination analysis

Event Cat.	Load conditions	Max. Von Mises Stress [MPa]	
		ARAA-1	ARAA-2/3
I	DW, PresO, THO(INT-TBM), MXWstd	1116	1127
II	DW, PresO, THO(INT-TBM), MXWstd	1116	1192
I	DW, PresOTG, THOTG, MXWstd	2715	2715

4. Conclusions

Structural analysis was performed on the PD-3 TBM-set model using ARAA-2/3 material properties and compared with the analysis results using the existing ARAA-1 material properties. Structural analysis results were almost similar to the previous results. In the assessment of structural integrity using the new allowable stress of ARAA-2/3, the same results as those obtained in the structural analysis using the ARAA-1 material properties were confirmed

REFERENCES

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