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Management strategy of radioactive waste in the fusion DEMO reactor
核融合原型炉における放射性廃棄物のマネージメント戦略について

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We are considering the reduction of radioactive waste which is generated in every replacement of an in-vessel component such as a blanket segment and divertor for DEMO reactor. The assessment for an 8.2 m DEMO indicates the radioactive waste generated in every two years is estimated to amount of about 7,600 tons. A waste management scenario has been considered because the scenario has a large impact on planning DEMO design. A management scenario of the radioactive waste in every replacement has been proposed for volume reduction.

1. Introduction

There is no high-level radioactive waste in the fusion reactor, but low-level radioactive (LLR) waste is generated in large amounts for high energy neutron. The LLR waste is positioned an issue related to social receptivity because its waste is needed to be managed over several hundred years. Especially, a large amount of the LLR waste is generated in every replacement of an in-vessel component such as a blanket segment and divertor cassette. Therefore, the management of the LLR waste must be addressed in a relatively early stage of the operation of fusion DEMO reactor. This problem is a new research topic that is not addressed in waste previous studies.

2. Specifications of a fusion DEMO

A fusion DEMO reactor is assumed that the major parameters of DEMO reactor are a plasma major radius of 8.2 m and aspect ratio of 3.0 as shown in Fig. 1. In the case of DEMO reactor with the fusion output of 1.35 GW, the average Neutron Wall Load is 0.9 MW/m^2. The main reactor components are blanket modules, divertor cassettes and back plate, which the weight of waste are about 1,575 ton, 924 ton and 3,777 ton, respectively. Here, the blanket has reduced-activation ferritic/martensitic steel (RAFM), Li_2TiO_3 tritium breeder and $Be_{12}Ti$ neutron multiplier. The blanket is filled with the mixture of Li_2TiO_3 and $Be_{12}Ti$ pebbles [1]. A tungsten coating is required on first wall surface to suppress erosion by physical sputtering. For the purpose, the surface of the blanket is covered with 0.2 mm thick tungsten (W). The divertor is made of W mono-block and RAFM cooling tubes and substrates [2]. Back-plate (as shield) contains RAFM and water for neutron shielding, and ratio of RAFM and water is assumed to be 60% and 40 %, respectively. Table 1 lists the summary of the amount of materials used in replaceable components. The amount of the waste as in-vessel component assumed to be about 6,650 ton.

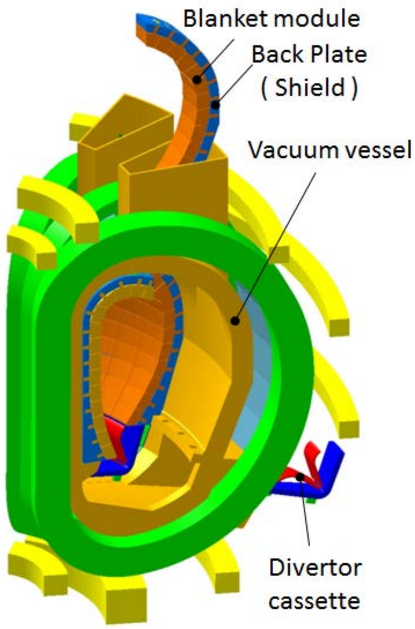

Fig. 1. Schematic view of a DEMO reactor

Table 1 Weight of radioactive waste for replaceable components

Componet	material	Method	Weight (ton)		Disposal amount (ton)	Max DPA (dpa/year)	Allowance (dpa)
Blanket module	W coating	Disposal	4.6	1574.6	693.7	8.8 @ FW	<20
	F82H	Disposal	689.1				
	Mixed breeder (Li_2TiO_3 & $Be_{12}Ti$)	Recycle	881.0				
Conducting shell	CuCrZr	Reuse	372.4	372.4	-	0.2	< 2
Back-plate	F82H + SUS316L	Reuse	2947.1+829.5	3776.6	-	0.18	< 3
Divertor	W mono-block	Disposal	153.1	924.2	296.4	1 – 1.5 @ Cu tube	< 1
	F82H substrate	Disposal	143.3				
	F82H cassette body	Reuse	627.8			0.6 @ cassette	< 20
Total			6647.8		990		

3. Waste management scenario for DEMO

A management scenario is proposed to reduce the radioactive waste. The back-plates and cassette bodies of divertor was reused. As a result of three dimensional neutron transportation code MCNP-5 [3] with the nuclear data library FENDL2.1 [4], the displacement per atom (DPA) of the back-plates of SUS316L was 0.8 DPA/4years and that of the cassette bodies of F82H was 1.0 DPA/year. Therefore, reusing the back-plates and cassette bodies would be possible, if re-welding points are arranged under neutron shielding. It was found that radioactive waste in 2 years could be reduced to 17%, when tritium breeding materials are recycled.

In a hot cell, the blanket module is removed from the back-plate by a remote handing. A tritium, radioactive dust and decay heat are inherent in the in-vessel component. The hot cell environment for the maintenance is cooled by natural air convection to prevent diffusion of the tritium and radioactive dust. Since the hot cell made a concrete, on the other hand, the temperature of the hot cell must be maintained below 65 °C for preventing water evaporation. As a result of thermal analysis, the maintenance of blanket segment is started after 6 years of storage until the temperature required for the concrete in the hot cell. 6 years after shutdown, a dominant contact dose rate of the component was 100 Sv/hour. In an interim storage, moreover, the blanket module and divertor cassette is kept at least 9 years to segregate waste for recycling.

4. Discussion and Summary

The management strategy of radioactive waste generated in the periodic replacement is important in the point of view of fusion reactor design. We make a provisional assessment of amount of radioactive waste. An exchange frequency of the blanket and divertor are assumed to be two and one years, respectively. The assessment for the DEMO indicates the radioactive waste generated in every two years is estimated to amount of about 7,600 tons. This result suggests the necessity of reducing the waste by recycling and reducing materials. In the scenario, whether or not the back-plate is reused is key in terms of volume reduction and RAMI (Reliability, Availability, Maintainability and Inspectability). Since the back-plate is expected to be 57 % of the sector assembly in weight, it should be reused to reduce the amount of radioactive waste. However, this strategy imposed assembly and inspection of the sector assembly using RH equipment in high radiation environment, which will be a serious concern regarding RAMI.

The volume reduction of radioactive waste is more important for fusion commercial plant. When it comes down to DEMO, the backplate is not reused. However, it is assumed that the backplate made of RAFM steel is reused on a trial basis.

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