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Safety-related behaviour of water-cooled solid breeder blanket
固体増殖水冷却ブランケットにおける安全上の特徴

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Blankets are located on the vacuum vessel wall in fusion reactors, and have functions of thermal energy transfer, tritium production and neutron shielding. Shielding blankets in ITER do not have function of tritium production and coolant temperature is low because electric power generation is not planned. In the fusion reactors, the coolant temperature will be higher for the electric power generation and tritium breeding materials will be packed in the blankets. Therefore, safety-related characteristics of the blankets are different between ITER and the fusion reactors. In this study, thermal-hydraulic behaviour in a blanket with water-cooled ceramic breeder concept is analyzed to understand safety-related characteristics.

1. Introduction

In current designs of ceramic breeder blankets for fusion DEMO reactors, neutron multiplier materials are packed into the blankets to obtain tritium breeding capability [1]. Beryllium and titanium beryllide are typical candidates for the multiplier. For the blanket with water cooling concept, concern related to a chemical reaction between water/vapor and the multiplier is addressed. Design development and safety assessment are necessary to ensure plant safety for the DEMO reactors.

JAEA is developing a Test Blanket System (TBS) for in situ experiments in ITER. The TBS consists of a Test Blanket Module (TBM) with a water-cooled ceramic breeder, water cooling and tritium extraction systems. The TBM has a similar configuration with the currently expected DEMO blanket as shown in Fig.1 [2], and functional demonstrations including thermal energy transfer, tritium production and neutron shielding are planned. Assessment of safety-related characteristics in the TBS is important to show its applicability for DEMO reactors. Additionally, safety analysis is required in view point of the ITER licensing.

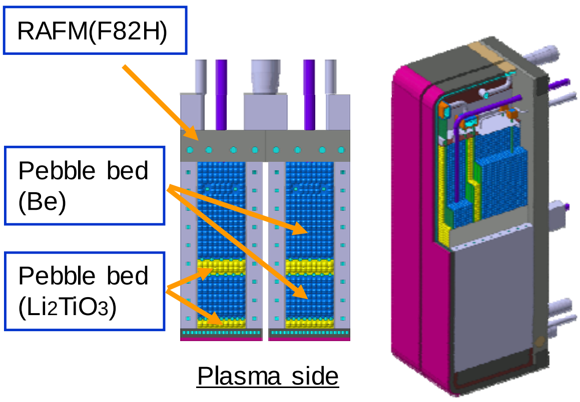

Fig.1. Schematic drawing of test blanket module

In the present study, thermal-hydraulic behaviour is numerically analyzed for the TBS, and safety-related characteristics of DEMO blanket is assessed taking account of the difference in loading conditions between ITER and DEMO.

2. Thermal-hydraulic calculation for safety analysis

2.1 *Definition of Postulated Initiating Events*

Safety analyses require clarifying the overall possible accident initiators and selecting the most representative events as postulated initiating events (PIEs). In previous study PIEs were determined from more than 250 event sequences through failure mode and effect analysis [3]. The event of coolant water ingress into the box structure of the blanket is assessed in the present study, because it leads to a chemical reaction between water/vapor and beryllium.

2.2 *Modification of TRAC-PF1 code*

Modified TRAC-PF1 is used for calculations. The TRAC-PF1 is a thermal-hydraulic calculation code based on two-fluid model, and originally developed for safety analysis of pressurized-water fission reactors [4]. The code was modified to implement necessary functions for safety analysis of ITER, for example, chemical reactions between water/vapor and metals including beryllium [5]. Additionally the code has been modified for the present study to treat heat transfer and chemical reaction inside the packed pebble bed.

2.3 *Calculation model*

Figure 2 shows the arranged model including the TBM, main components in the coolant loop and neighboring components/compartments in ITER. Pressure of the coolant water is 15.5 MPa, and inlet/outlet temperatures are regulated as 280/325°C. The TBM is modeled by pipe and heat slab components as shown in Fig.3. The packed pebble beds of breeder and multiplier are treated as continuum model by the heat slab component. A container with equivalent volume to void in the pebble bed is modeled and the ingress behaviour of the coolant water to the container is calculated taking account of flow resistance, heat transfer and chemical reaction in the pebble bed.

2.4 *Results and discussion*

Figure 4 shows thermal response in the TBM for the event that coolant water ingress into the box structure and loss of electric power. Result for loss of electric power without water ingress is also presented. The results show temperature decrease in the blanket is promoted by the ingress of water into the box. When the coolant water blows into the pebble bed, two processes simultaneously arise, heat production due to the chemical reaction and increase in heat-transfer area between the vapor and pebbles. In the present conditions, effect of increase in the heat-transfer area is dominant compared to that of the chemical reaction. In DEMO blankets, effects of chemical reaction might increase due to higher temperature of the pebble bed and decay heat than those in ITER.

3. Summary

Thermal-hydraulic responses both in the blanket and its coolant loop were calculated using modified TRAC-PF1 code for the event that coolant water ingress into the box structure and loss of electric power. Under the conditions for ITER, temperature decrease in the blanket is promoted by the ingress of water into the pebble bed. Effect of difference in loading conditions expected in DEMO blankets will be discussed.

References

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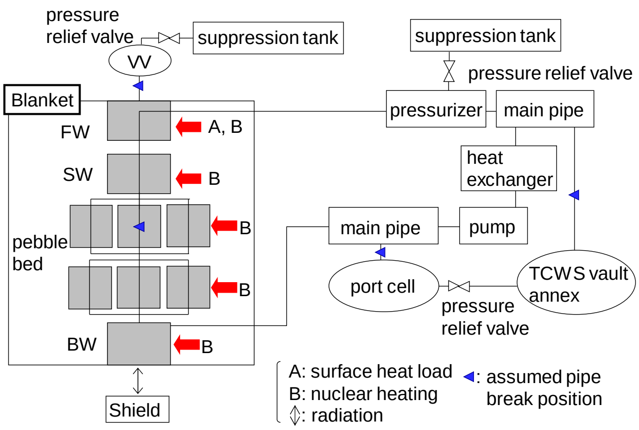

Fig.2. Calculation model for blanket and coolant loop

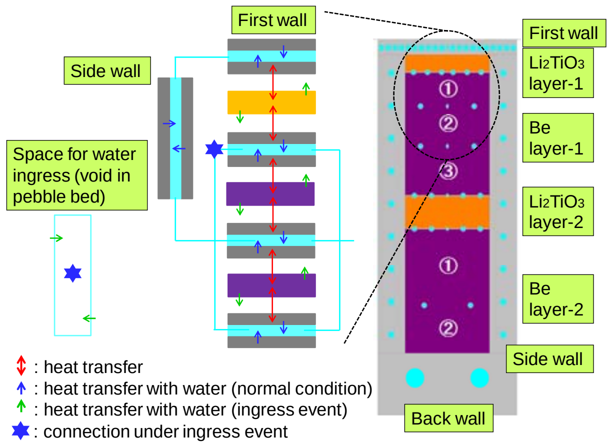

Fig.3. Calculation model for blanket with pebble bed

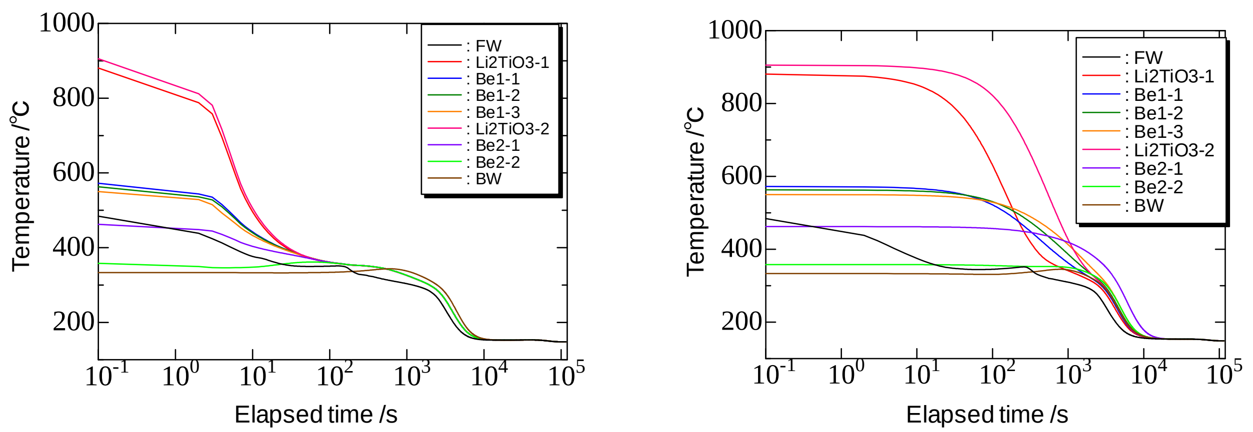

Fig.4. Thermal response in blanket under loss of electric power (left: with water ingress, right: without water ingress).