SIMULATION OF HEAT EXCHANGER TUBE RUPTURE ACCIDENT FOR CN HCCB TBS

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1. INTRODUCTION

Deuterium -tritium fusion reaction is considered the suitable solution for the next generation of fusion reactors, necessitating substantial quantities of tritium as fuel. This demands tritium self-sufficiency within the fusion reactor. The main purpose of International Thermonuclear Experimental Reactor (ITER) programme is to explore the feasibility of magnetic confined fusion technology, with one of the most significant objectives being the testing of the tritium breeding blanket. This is to verify the possibility of the tritium breeding technology and its maturity. Nowadays, there are several conceptual designs of tritium breeding blankets, namely: helium-cooled ceramic breeder blanket, helium-cooled liquid lithium-lead blanket, water-cooled ceramic breeder blanket, self-cooled liquid lithium-lead blanket, self-cooled molten salt blanket and so forth. China has selected the first two options to develop its own testing blanket technology based on years of domestic research and our strategic goal of fusion energy development [1], and the China Helium Cooled Ceramic Breeder Testing Blanket Module (CN HCCB TBM) utilized on ITER is of considerable importance.

In accordance with French legislation, it is required to submit a safety analysis report of the testing blanket system (TBS), elucidating the safety design and potential radiological consequences before its installation into the ITER facility. The methodology employed and the conclusions obtained will furnish a substantial foundation for the establishment of laws and standards for fusion reactors in various nations either [2]. All participants in ITER have conducted accident analysis, including Design Basis Accidents (DBAs) and some Beyond Design Basis Accidents (BDBAs) [3][4][5] [6][7][8].

The CN HCCB TBM, as an important component within the ITER facility, also requires accident analysis before installed. In this paper, a typical DBA, the Heat Exchanger Tube Rupture Accident (HX Tube Rupture Accident), is selected for analysis with the objectives of:

(a) To verify the safety of the CN HCCB TBS design, ensuring that it meets the acceptance criteria specified by ITER under accident scenarios;
(b) To propose some improvements for the design and provide data for the subsequent work.

2. MODELS

The model utilized consists the TBM and the Helium Cooling System (HCS). The TBM is modelled with some reasonable simplifications to ensure the realistic phenomenon inside the model. The HCS has been designed in an "8" -shaped arrangement, with the recuperator connecting the cold leg and hot leg. The main equipment of the HCS includes the recuperator, heat exchangers, electric heaters, the main helium pump, the pressure control system, the safety isolation valves and some related pressure, temperature and flow sensors, etc. The present paper also proposes a complete secondary water cooling loop model of the ITER Component Cooling Water System (CCWS).

3. RESULTS

The results indicate that:
1. With conservative assumptions, the temperature of the First Wall (FW) material exceeds the design temperature of 550°C with a short duration as shown in Fig. 1, which is deemed acceptable based on the conclusions obtained from previous experiments;
2. The pressure fluctuation in the pipeline of the secondary side of the heat exchanger is violent in the early stage of the large break accident, besides the pressure is higher in the later stage of the heat exchanger under the small break accident. This is attributed to that the isolation valves are not activated in the small break accident;
3. The distinct variations of helium spray rates cause the different helium leakage as shown in Fig. 2. In the large break accident, the helium leakage tends to stabilize in approximately 10 seconds, with a helium leakage amount

of 10.014kg within 30 seconds. In the small break accident, the helium leakage amount reached a peak value of 1.972kg in approximately 20 seconds. It should be noted that in a small break accident, the cooling water in the secondary loop will flow back into the helium 1st loop, causing serious consequences.

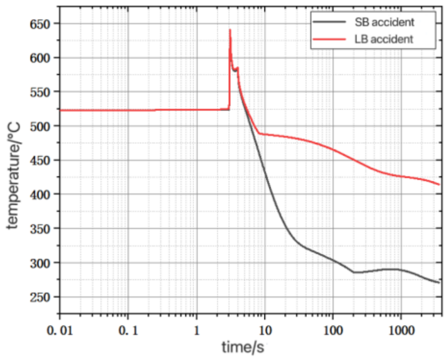

Fig. 1Temperature of FW material

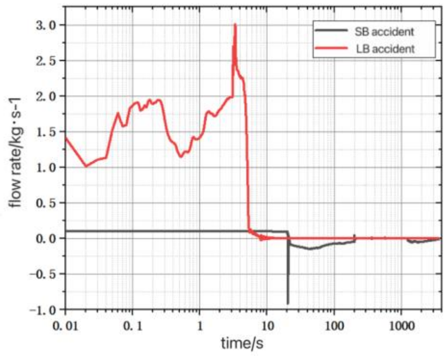

Fig. 2 Helium spray rate via break

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