DESIGN-BASED MULTIDINENSIONAL TRITIUM TRANSPORT ANALYSIS PLATFORM FOR BLANKET SYSTEM

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1. INTRODUCTION

To realize the D-T fusion power plant, the accurate prediction on the tritium behaviour is essential to ensure the safety in the operation environment. To address this point, KFE has developed the Tritium Transport Analysis Platform, THETA-FR (Tritium / Hydrogen Enhanced dynamic Transport Analysis platform for Fusion Reactor), with collaborative work with UCLA. In THETA-FR, two commercial software, COMSOL Multiphysics and Matlab are integrated, and it enables the tritium transport model design and analysis in both component and system level. Furthermore, because the components in THETA-FR are based on the multidimensional design, the heterogeneous tritium behaviour caused by the detailed geometric shape of each component can be captured. In this paper, the features of the THETA-FR are introduced, and the tritium analysis results of HCCP (He Cooled Ceramic Pebble)-TBS is presented as an example.

2. THETA-FR

In THETA-FR, the system-level model builds upon the component-level models developed in COMSOL Multiphysics, which calculate heat transfer, H isotopes transport, and fluid flow. To capture the tritium behaviour occurred in the complex shaped components, THETA-FR employs the detailed 2D/3D representations. These components are dynamically coupled through MATLAB Simulink via S-functions, allowing real-time data transfer and synchronized parameters across all the components.

2.1. Components for HCCP TBS

HCCP (He Cooled Ceramic Pebble) TBS consists of the First Wall (FW), Breeding Unit (BU), He Cooling System (HCS), Coolant Purification System (CPS), Tritium Extraction System (TES). For the efficient design, the FW and BU are integrated as one COMSOL file. In HCS, CPS, TES, the He gas pipe and sub-components are designed.

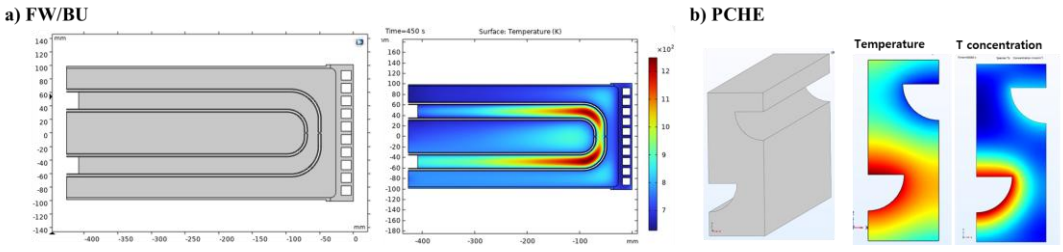

Figure 1. COMSOL files of THETA-FR Components for HCCP TBS a) FW/BU c b) PCHE

2.2. Integrated System for HCCP TBS

Components of the HCCP TBS are analysed in their respective COMSOL files, and the results are transferred via S-function in Matlab simulink. The configuration is shown in the following figure.

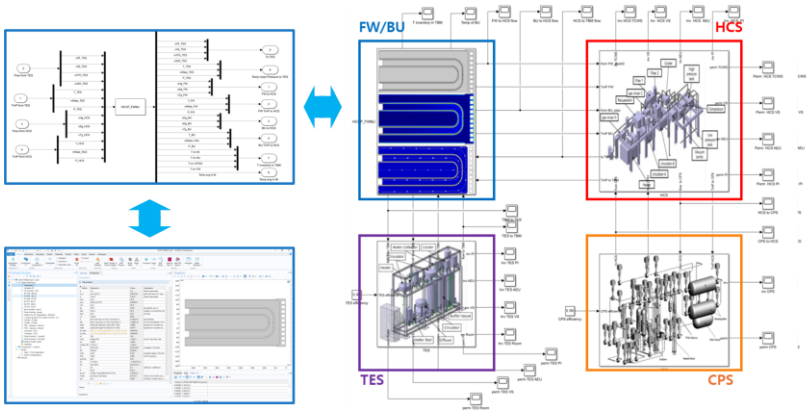

Figure 2. Configuration of THETA-FR Component, S-function and Integrated System of HCCP TBS

3. Analysis Results

The tritium behaviour (i.e. inventory, permeation, release, transport) in the components and the integrated system of HCCP TBS can be obtained in detailed through THETA-FR. The analysis conditions and results are followed;

Table 1. Materials and analysis conditions applied in THETA-FR HCCP TBS

Parts	Breeder	Multiplier	Structural material	Coolant/Purge gas	Pipe
Material	Li_4SiO_4 pebble bed	Be pebble bed	Eurofer97	He gas	316L

Table 2. TOKAMAK Operation Scenario

Input	Fusion power	Repetition time	Burning time	Surface heat flux	Neutron wall load	Tritium generation
Values	500 MW	1800s	450s	0.3 MW/m^2	0.78 MW/m^{2}s	15 mg/d (2 shift)

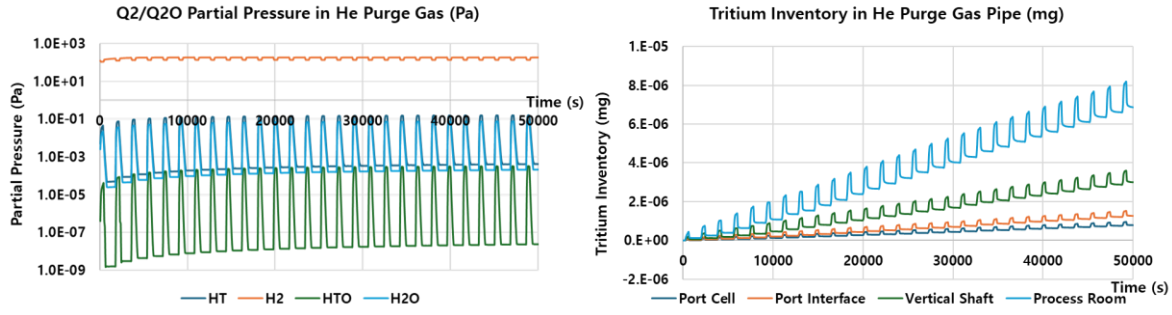

Figure 3.Q2/Q2O partial pressure in He purge gas and Tritium inventory in He purge gas pipe

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