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R&D of prediction system for tritium transport in pebble bed breeder blanket

微小球充填方式増殖ブランケット内のトリチウム輸送における予測システムの工学的研究

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Development of test blanket module (TBM) in water cooled solid breeder is being performed as the primary candidate of ITER-TBM of Japan. Prior to the installation of each TBM, it is necessary to develop the capability of the prediction analyses of all essential functions of the blanket to validate the analyses tools by the TBM. Especially the prediction tool of tritium concentration in the blanket system is one of the most important issues to control tritium recovery. From this view point, this paper discusses the flow phenomena and the tritium transport of the helium purge gas in the pebble bed.

1. Introduction

Research and development of a blanket module of water cooled solid breeder is being performed as the primary candidate of ITER- test blanket module (TBM) of Japan as seen in Figure 1 (a). Prior to the installation of each TBM, it is necessary to develop the capability of the analyses of all essential functions of the blanket, because the validation of the analyses tools by the TBM performance data under the real fusion environment of ITER enables extrapolation of the design and performance analyses to DEMO blanket. Especially the prediction tool of tritium concentration in the blanket system is one of the most important issues to control tritium recovery. From this view point, this paper discusses the flow phenomena and the tritium transport of the helium purge gas in the pebble bed.

Tritium behavior in the blanket is a complex phenomenon which consists of tritium generation, tritium diffusivity in crystal grain of Li_2TiO_3, tritium release from a breeder material of a pebble [1], purge gas thermo-hydraulics through the pebble bed [2] and tritium permeation to a blanket structural material as seen in Figure 1 (b). Objective of this study is shown in Figure 2, which is to construct an integrated simulation approach of heat and mass transfer in whole domain of the blanket corresponding to real size. It aims to estimate a generated tritium and its transport and to contribute to the design of blanket. Verifications and validations of the experimental data and empirical equations of earlier studies are achieved by using the prediction results of the integrated simulation. Moreover, the prediction of the total tritium behavior simulation taking into account all essential tritium transfer process contributes to an engineering design of a blanket.

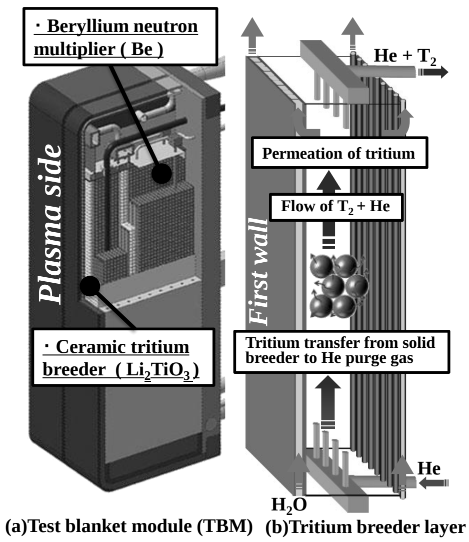

Fig.1. Configuration of test blanket module

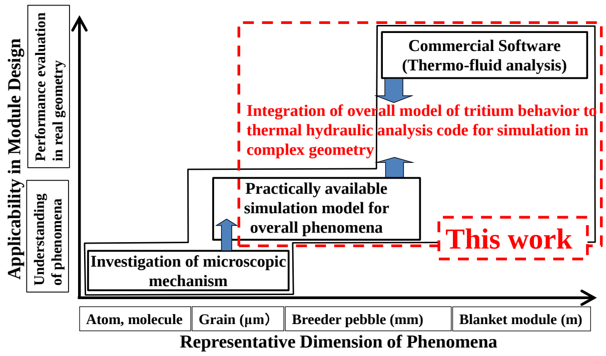

Fig.2. Diagram of scale of phenomena for this scope

2. Computational condition

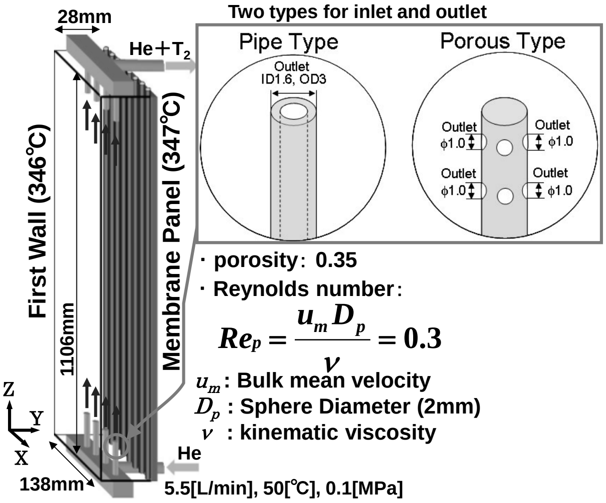

Fig.3. Computational configuration in breeder layer

Computational configuration in breeder layer of TBM is shown in Figure 3. The value of porosity is 0.35 on the basis of earlier experimental studies [2]. A Reynolds number is set to 0.3 so as to be 1 Pa of partial pressure of tritium at outlet, where the Reynolds number is based on the bulk mean velocity, sphere diameter and kinematic viscosity. Inlet and outlet shape of pipe and porous types are applied to observe a dependence of these shapes on the velocity and the concentration. The thermal boundary condition and tritium source apply the values obtained from a neutron-thermal analysis. Porous media model equation of fluid motion is applied with uniform spatial porosity.

3. Results and discussion

In the case of pipe type, the contours of velocity and tritium concentration are shown in Figure 4. The velocity field of the Darcy flow in pebble bed is regarded as a laminar flow. In this case, only a molecular diffusion contributes to concentration diffusion without convection. Moreover, the profile of tritium source stays large value near the wall and exponentially decreases with increase distance from the first wall and membrane panel. Therefore, the concentration of tritium near the walls still remains near two times larger than that in the center pebble bed without homogeneous concentration. The value near the walls increases along streamwise in according with linearity principle of passive scalar. This tendency of tritium concentration near the walls is also similar in the case of the porous type as shown in Figure 5. The difference near the inlet between the pipe and the porous types has a negligible effect on the tritium concentration.

4. Conclusion

By prediction of purge gas flow using a numerical simulation, the result indicates tritium concentration depended on the position of the breeder layer. Namely, the large concentration still remains near the wall with approaching to an outlet.

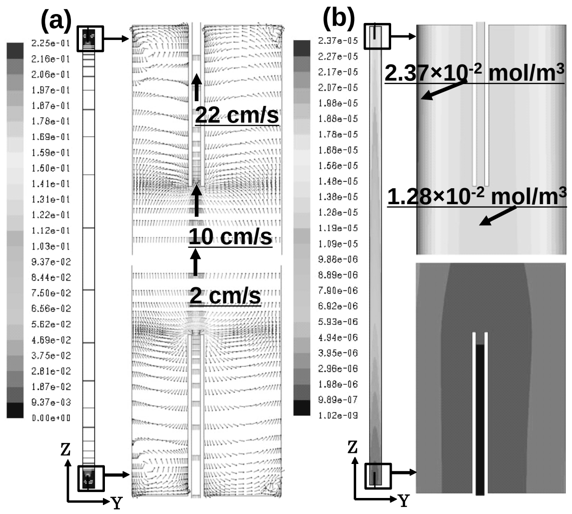

Fig.4. Contours of (a) velocity and (b) tritium concentration for outlet of pipe type

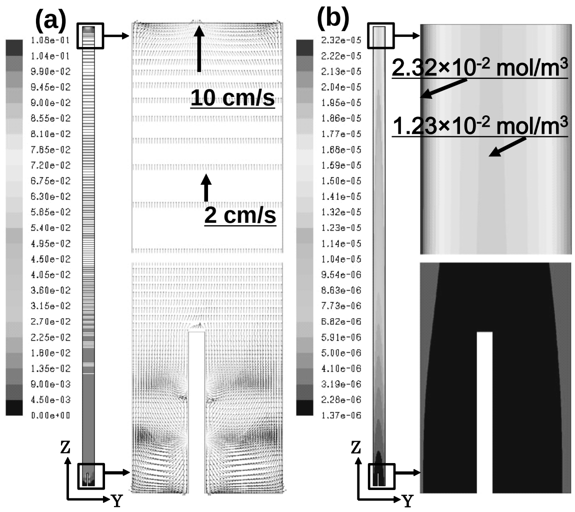

Fig.5. Contours of (a) velocity and (b) tritium concentration for outlet of porous type

Acknowledgments

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References

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[2] Y. Seki, S. Suzuki and M. Enoeda: *Proc. 16th Int. Workshop on CBBI, Portland, USA, 2011.*