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Current R&D Activities on Process Simulation for the Fusion Fuel Cycle in Korea

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Recently, as many countries are developing their demonstration fusion plant, Korea has also begun developing the Korean-style demonstration fusion plant. For the fuel cycle design, the handling of a large amount of tritium is an essential problem to be solved. Several activities related to process modeling and simulation are in progress for process design optimization and tritium inventory analysis of sub-systems in the fusion fuel cycle.

First, pure component physical properties of liquid and gaseous hydrogen isotopes are investigated to be applied to the process simulation. They include vapor pressure, density, heat capacity, the heat of formation, and virial coefficients. Collected data are used to obtain an appropriate equation of state and property calculation methods. Peng-Robinson equation with twu-alpha function shows accurate results for fugacity, density, and enthalpy of hydrogen and deuterium compared with the NIST REFPROP database. The properties of other isotopes are estimated with the same EOS and calculation methods. Second, experiments for a permeator for hydrogen separation have been conducted to assess the developed palladium membrane model. Single and double-stage palladium membranes are tested under several feed conditions. The one-dimensional palladium membrane is modeled using Aspen Custom Modeler. The simulations and experiment results show similar recovery rates at 3.5E-5 kmol/(m·hr·bar0.5) hydrogen permeability. Third, an optimization framework for distillation configuration is developed by establishing superstructures for the distillation system using Python. The goal is to minimize tritium inventory by adjusting the positions of the feed stream, positions of catalytic reactors, and the number of column stages. Bayesian optimization is applied to solve the problem. As a result, an optimized design that reduces tritium hold-up compared with the existing distillation configuration is obtained.

In this presentation, the progress and detailed information for the above activities will be summarized. Through above studies, it is expected to contribute to improving and developing the Korean demonstration fusion fuel cycle.

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