Component Modeling Description for COMMIX Analysis of 600MWe Sodium-cooled Fast Reactor

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1. Introduction

Under the Mid- and Long-term Nuclear R&D Program, various conceptual design options for sodium-cooled fast reactor have been proposed to fulfill the safety criteria and secure a reliable decay heat removal performance. In the recently proposed reactor pool design for 600MWe demonstration reactor DHX was positioned in hot pool and the baffle plate was removed as shown in Fig 1[1].

For the investigation on thermal-hydraulic behavior in the pool type reactor, various computational approaches have been utilized. Recently commercial computational fluid dynamic analysis tools are widely utilized to estimate the thermal–fluid phenomena under steady state condition. However its computational costs become enormously increased for the transient analysis.

In this research a complex geometrical arrangement in the reactor pool was modeled in COMMIX-1AR/P using porous-medium approach. The related modeling approaches are described mainly on the major components such as the reactor core, IHX, and DHX. The thermal-hydraulic distribution in the reactor pool also has been evaluated at steady state condition.

2. Component Modeling Description

The COMMIX-1AR/P code is a multi-dimensional numerical code designed for analyzing steady and transient states of a fluid flow and a heat transfer. In order to analyze thermal-hydraulic behavior correctly the related information for each component should be provided. In this modeling the quarter of reactor was considered.

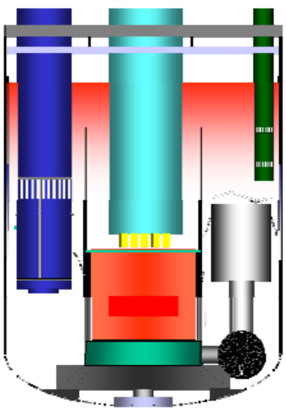

Fig. 1 Schematics of 600MWe Sodium-cooled Fast Reactor

2.1 Core

The active reactor core is 85.0cm of height and 219cm of equivalent radius with 1548.2MWt of thermal power. The core region can be classified into two fuel regions(inner and middle core regions) and other(reflector, B_4C shield, IVS(In Vessel Storage) and etc.) as shown in Fig. 2. In our calculation hexagonal core is modeled by an equivalent radius circular porous medium, and the related friction loss and regional power are modeled based on the design values. The inner core region and middle core region is divided into four and two grid respectively in radial direction. The other region is divided into two grids.

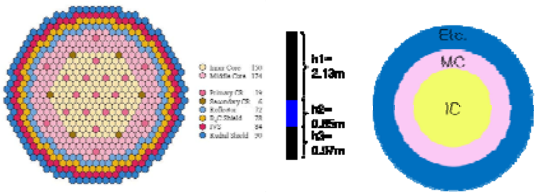

Fig. 2 Schematics of core and its model

Table 1 Volumetric heat generation rate

IC(Inner Core)	983.17E+6 [W/m3]
OC(Outer Core)	814.33E+6 [W/m3]
Reflector, IVS, etc.	0.0

The pressure drop correlations for fuel assembly with wire wrap spacers is based on the Novendstern Model[2]. In that model the influence of the wire wrap is accounted for by means of an effective friction factor. The Blasius relation for the friction factor, fs, is adopted for this modeling.

$$f_1 = M \times fs$$

$$M = \left\{ \frac{1.034}{(P/D)^{0.124}} + \frac{29.7(P/D)^{6.94} Re_1^{0.086}}{(H/D)^{2.239}} \right\}^{0.885}$$

where $Re_1 = \rho V_1 D_{e1} / \mu$.

$$\Delta p = M \times fs \times \frac{L}{D_{e1}} \frac{\rho V_1^2}{2}$$

The residual pressure losses is accounted at the orifice to make the total pressure drop to be the same as the design value[3].

2.2 IHX

The IHX is 4.25m of tube length and 2.3m of diameter with 1549.9 MWt. The heat loss via IHX tube bundle is modeled by adopting the constant heat sink at tube side porous medium region. A downcomer which is positioned at center of IHX and tube bundles are modeled using porous medium approaches.

The pressure drop for IHX inlet window is calculated based on the window opening ratio. In the case of shell side tube bundle the pressure drop is estimated based on the pitch to diameter ratio of 1.5.

The pressure drop for outlet nozzle is also accounted however pressure drop due to lower chamber is not taken into accounted.

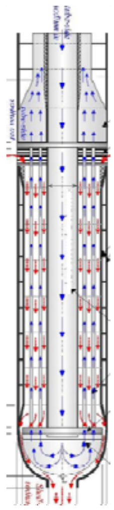

Fig. 3 Schematics of IHX

- Inlet

$$\Delta p = \frac{\rho V_1^2}{2} \frac{(1.707 - f)^2}{f^2}$$

- Tube Bundle
  - Laminar

$$\Delta p = \alpha \times k_{bun} \frac{64}{Re} \times \frac{L}{D_{e1}} \frac{\rho V_1^2}{2}$$

  - Turbulent

$$\Delta p = \alpha \times k_{bun} \frac{0.1364}{Re^{0.25}} \times \frac{L}{D_{e1}} \frac{\rho V_1^2}{2}$$

- Outlet

$$\Delta p = \epsilon \frac{\rho V_1^2}{2}$$

2.3 DHX

The DHX is 1.73m of tube length and 0.71m of diameter with 1.2 MWt at normal power operation mode. The heat loss and the pressure drop at the inlet and outlet of DHX is the same as that of IHX and that of IHX inlet respectively.

The pressure drop for DHX tube bundle could be calculated in the same way as IHX, however the related hydraulic diameter should be reevaluated.

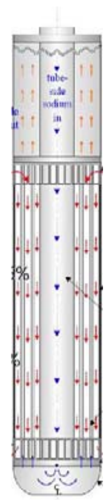

Fig. 4 Schematics of DHX

2.4 Thermal-Hydraulic Distribution

Based on the described thermal hydraulic parameters, the numerical analysis for 600MWe Sodium-cooled Fast Reactor has been performed and calculated results are shown in Fig. 5.

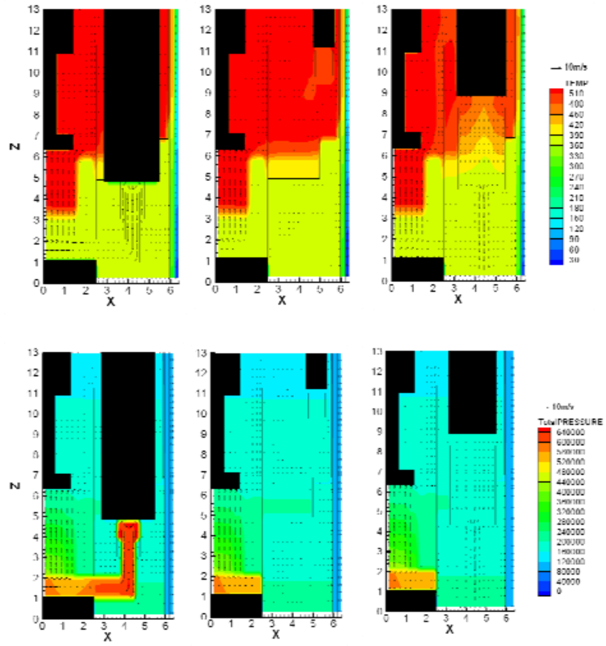

Fig. 5 Temperature and Pressure distribution

The overall and local temperature and pressure distribution presents the design value well. This model and related calculation results will be employed to analyze the flow behavior in the reactor pool in the following research.

3. Conclusion

In this study COMMIX modeling approaches are described mainly on the major components such as the reactor core, IHX, and DHX. The thermal-hydraulic distribution in the reactor pool also has been evaluated at steady state condition. It was found that component modeling employed in this research represents the components' design value well.

REFERENCES

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[3] Choi, S. R., Input Data for Safety Analsys of Demonstration Reactor, SFR-CD120-IR-07-2010Rev.00, KAERI, 2010.