Development Status of TRACE model for PGSFR Safety Evaluation

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1. Introduction

Prototype Generation IV Sodium cooled Fast Reactor (PGSFR) of 150MWe is under developing targeting licensing application by 2017 [1].

KINS is preparing review of its licensing application, especially the audit calculation tool for transient and accident analysis is being prepared for review. Since 2012, TRACE code [2] applicability study has been doing for the Sodium-cooled Fast Reactor.

At first, Sodium properties and the related heat transfer model in the code were reviewed.[3] Demonstration Sodium cooled Fast Reactor (DSFR-600) were model and representing DBAs were assessed until the PGSFR design is fixed.[4][5][6]

EBR-II Shutdown Heat Removal Test (SHRT) experiment is also being analyzed in terms of IAEA Cooperated Research Program.

In this paper, PGSFR TRACE code modeling status and considerations for SFR DBA assessment is introduced.

2. Sodium Related Model Review in TRACE code

2.1 Sodium Properties

Sodium Properties in the code is based on the sodium property handbook published by Argonne National Lap. (ANL)[7]. Enthalpy, Conductivity, Viscosity and Density of the code were compared with ANL's and MARS-LMR code as Fig 1.

Most of sodium properties showed good agreement with conventional one except enthalpy. In this study modified TRACE code that enthalpy model is corrected.

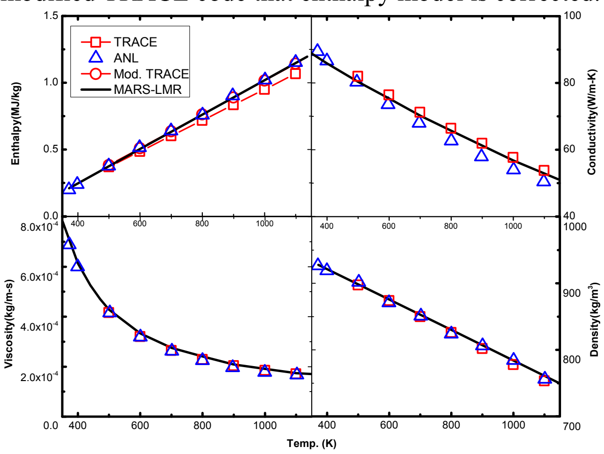

Fig. 1. TRACE code sodium properties comparison [4]

2.2 Sodium-wall Heat Transfer Model

TRACE code uses Lyon-Martinelli heat transfer correlation for sodium coolant as below.

$$Nu = 4.8 + 0.025 \cdot Pe^{0.8}$$

Where: Nu = Nusselt Number
Pe = Peclet Number

Other heat transfer models and available data were reviewed in Fig 2. Since the pitch to diameter for PGSFR fuel is 1.14, data were selected within range of 1.1 to 1.25.

Data and correlation shows scatter for the heat transfer for PGSFR fuel. In accident assessment it is need to be validated the model with experiment data or its uncertainty is considered in assessment.

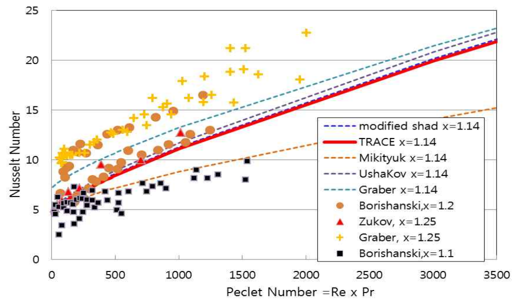

Fig. 2. Sodium Heat transfer model comparison between TRACE code and other conventional models

2.3 Fuel Bundle Pressure Drop

Wire is wound for SFR fuel pins to provide flow path between fuel pins. So the pressure drop characteristic is different from that of LWR's fuel bundle.

In prediction of pressure drop in wire-wrapped fuel bundle, Cheng and Todreas correlation is widely used as well in designer's code. There is no wire-wrapped correlation incorporated in the TRACE. Instead, Flow dependent form loss model in which pressure drop or K-factor is expressed as a function of Reynolds Number as below.

$$K \text{ or } f = A + B \cdot Re^{C}$$

Application of the flow dependent K to PGSFR fuel geometry and normal condition shows in Fig. 3. Maximum error to the Cheng and Todreas correlation is 5.3% along 300 to normal operation condition in terms of Re.

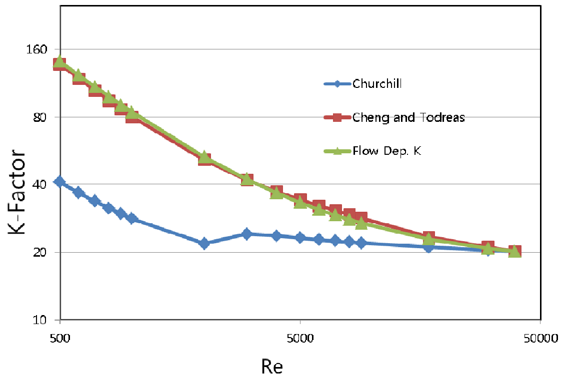

Fig. 3. Flow dependent K model and wire-wrapped K vs Re number

3. PGSFR TRACE code modeling

PGSFR is composed of Primary Heat Transport System (PHTS), Intermediate Heat Transport System (IHTS), Residual Heat Transport System (RHRS) and Power Conversion System (PCS). All of major systems are included in TRACE model except PCS such as Turbine. Overall Plant Configuration and the normal operation condition is showed in Fig. 4

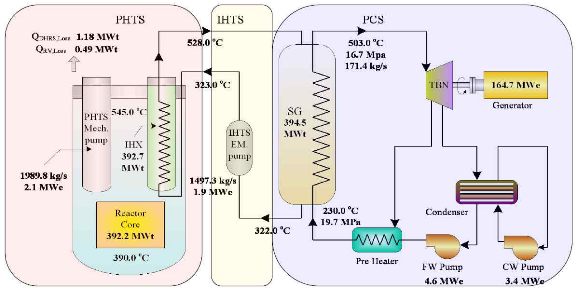

Fig. 4. PGSFR system and normal operation condition [1]

2.1 Flow Path modeling

Main Coolant flow starts with tow PHTS pumps suction from cold pool to the inlet plenum. Cold sodium flows from the inlet plenum to core. Core outlet coolant is collected in the hot pool. Due to Intermediate Heat Exchanger (IHX) is located between hot pool and cold pool, hot sodium is cooled through four IHXs shell side and returns into the cold pool.

Within IHTS, Sodium is heated in tube side of IHXs and transported to the Steam Generators (SG). IHTS flow is formulated by two Electro-Magnetic Pumps (EMP) located between SG and IHXs.

RHRS of PGSFR is composed of four circuits. Two for Active Decay heat Removal Circuits (ADRC) and other for Passive Decay heat Removal Circuits (PDRC). All of them are cooled by air. Decay Heat eXchanger (DHX) is submerged in the upper part of cold pool and outside of the redan structure that provides separation between cold and hot pool.

ADRC have EM pump and blower for Forced Heat eXchanger (FHX). PDRC is composed with DHX and Air Heat eXchanger (AHX) and the air damper.

In modeling, RHRS is modeled with one ADRC and two PDRCs because one of active component is assumed inoperable during accident analysis.

2.2 Core modeling and conditions

PGSFR core is designed with 112 fuel drivers, 78 reflectors, 114 shields and 9 control rod assemblies. In modeling total 313 assemblies are categorized with average, hot and non-fuel divers. Non-fuel drivers are reflectors, shields and control rod assemblies and they do not have wire-wrapped pins within assemblies.

The assembly wise coolant flow and power is considered in decision of flow and power of hot assemblies i.e. the hot assembly flow and power condition is chosen for highest lank in the power/flow fraction.

TRACE code PGSFR modeling is as Fig. 5.

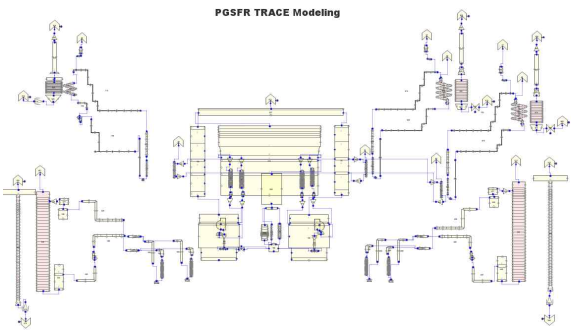

Fig. 5. TRACE nodding diagram for PGSFR

Reactor Vessel is composed of cold and hot pool. Each pool is modeled with two volumes and connected with single junctions to eliminate the dead-end node.

For the simulation of normal operation conditions, Power of PHTS and IHTS pumps and heat loss through reactor vessel was neglected. Therefore calculated heat balance and IHTS hot-leg temperature is slightly different but core inlet temperature and IHTS cold temperature is maintained as the design value.

Simulated steady-state condition for PGSFR is summarized in Table. I

Table I: TRACE code St.-St calculation result

	DESIGN K,MW/kg/s/,m	TRACE Simulation
CORE I/O T. Power/flow	663.15/818.15 392.2/1989.8	662.67/818.34 392.2/1989.8
PHTSpump Q	2.1	-
IHX I/O T. Q/flow	596.15/801.15 392.7/1497.3	595.15/802.67 391.0/1488.3
IHTSpump Q	1.9	-
SG Q/flow	394.5/171.4	391.0/164.1
DHX Q	1.18	1.18
Vessel Q	0.49	-

3. Conclusions

For the preparation of the review of licensing application for PGSFR, TRACE model for the PGSFR is being developed considering the sodium related properties and model in the code.

For the use of licensing purpose, it is identified and need to be improved that model uncertainty in the code and conservative conditions for accident analysis is needs to be defined and validated. And current simulations are applicable only to assembly-averaged assessment. So it is also need to be defined for pin-wise assessment within hot assembly.

On the basis on the developed model, PGSFR design change will be applied and improved for independent audit calculation for incoming licensing review.

ACKNOWLEDGEMENT

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