PREPARATION OF THE STAND-ALONE TRACE MODEL FOR NEACRP-L335 BENCHMARK

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Abstract: This study is a part of developing thermal-hydraulic model of Control Rod Ejection Benchmark – NEACRP-L335, which is necessary for performing coupled calculation together with reactor core simulator PARCS. Simplified model based on basic TRACE components is done and results of steady state convergence are given within this study. Brief description of thermal-hydraulic code TRACE is provided along with the model definition and TRACE components.

Keywords: TRACE, thermal-hydraulic, NEACRP-L335

1. INTRODUCTION

There have been number of previous benchmarks in the reactor core simulation. NEACRP L336, MOX/UO2 Core Transient Benchmark and NEACRP L335 to which is dedicated this paper. There are many others benchmarks, but it is not necessary to mentioned all of them.

Benchmark NEACRP-L335 is focused on neutron physics as a part of nuclear reactor evaluation. For this purpose there is under development PARCS model of this benchmark. Definition of the PARCS model can be divided into several parts – geometry model, cross-section libraries and simplified thermal-hydraulic (TH) feedback model.

Simplified TH feedback could reduce accuracy of the whole model. Therefore, separate TH model could be done to improve accuracy of the calculation. There are many different TH codes all around the world. However, the reactor core simulator PARCS is maintained by US Nuclear Regulatory Commission (US NRC) and as such its TH code TRACE was chosen.

Development of the model is created through definition of the input file. This could be done either by written command in ASCII or through graphical interface SNAP. Second option was evaluated as better options for this purpose.

The steady-state calculation is done to proof that the model can reach steady-state conditions based on input parameters. Reached steady-state conditions are initials for further transient calculations.

2. THERMAL-HYDRAULIC CODE - TRACE

There were several independent TH codes across the United States. Each of them was specially developed to investigate specific type of reactor. In the mid-of 1990s the decision of reducing number of TH codes was made. TH codes for Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), Very High Temperature Reactor (VHTR) or Canadian Deuterium Uranium (CANDU) were merged together and the TRACE code development began. The current version is V5.880. [2]

TRACE capability is to calculate one-phase and two-phase flow. One-phase flow is used for core flow calculation, performing calculation during steady-state condition, respectively. Two-phase flow is used to perform steady-state calculation of BWR, transient calculation of BWR or PWR and to evaluate parameters in the secondary circuit of PWR. Wide number of components allows to model different types of nuclear power plant and other facilities. [2]

3. MODEL OF THE REACTOR CORE

As the benchmark is focused on neutronics, there is provided only specification of the reactor core region. The specification does not give information about type of reactor which is investigated. Whole reactor vessel cannot be modeled due to this limitation. Therefore only reactor core is modeled by reactor vessel component. Inlet and outlet parameters are defined as boundary conditions of this model. TRACE model is shown in the Picture 1. Whole model consists of 9 components and 157 heat structures. Each heat structure represents one fuel assembly.

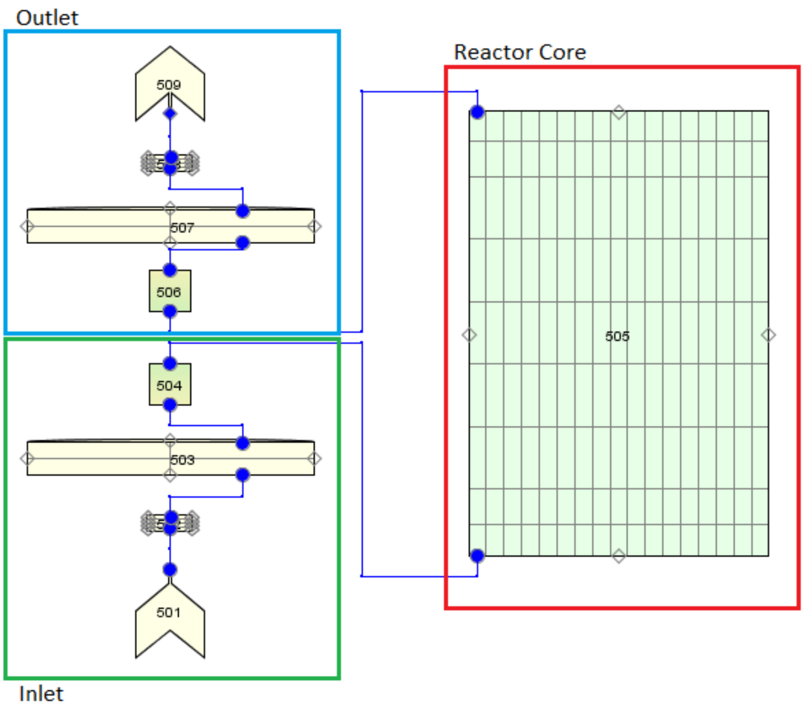


Figure 1: Modeling of the reactor core in the TRACE input deck

3.1. REACTOR CORE VESSEL

Reactor core is divided into 9 axial layers and this nodalization is chosen according to further usage of this model. First and ninth layer represents lower and upper plenum. Second to eighth layer represents fuel region. In this region the fission energy is released. Reactor core consists of 157 fuel assemblies therefore the reactor core vessel is divided into 221 radial channels. The difference of 64 channels is result of needs to accommodate additional 64 assemblies which represent reflector in reactor core simulator PARCS. In these 64 assemblies there is zero power release and zero mass flow. Thermal-hydraulics parameters of each vessel cell are given in Table 1. Table 1 shows that all cells in the reactor core vessel are identical and also that the fraction and hydraulic diameters are not dependent on height of the cell. [3]

3.2. BOUNDARIES OF THE REACTOR CORE

Reactor core inlet and outlet parameters are modeled by 8 different components. These components are shown in the Figure 1 (blue and green rectangle). Inlet of the whole system is modeled by fill component. This component defines initial mass flow, temperature and pressure of the system. Following components - cylindrical vessel with vessel junction distributes liquid flow into reactor core channels. Similar principle and components are used to model outlet of the reactor core. [1,3]

Axial Layer	*Height [m]*	*Volume Fraction*	*Edge X Fraction*	*Edge Y Fraction*	*Edge Z Fraction*	*Hydraulic Diameter X*	*Hydraulic Diameter Y*	*Hydraulic Diameter Z*
9	0.3	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
8	0.336	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
7	0.6	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
6	0.6	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
5	0.6	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
4	0.6	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
3	0.6	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
2	0.337	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073
1	0.3	0.518	0.236	0.236	0.518	0.00600	0.00600	0.01073

Table 1: Calculated thermal-hydraulic parameters of the Reactor core vessel cells

3.3. POWER COMPONENT

This model going to be coupled with reactor core simulator PARCS, so only basic power information is needed in the power input. Each fuel assembly is represented by one heat structure in the thermal-hydraulic model. All of the heat structures are powered by one power component. Power component can be defined by various ways. For this purpose constant reactor power card is defined. Point kinetics model is not necessary buildup. Axial power shape is defined by PARCS calculation.

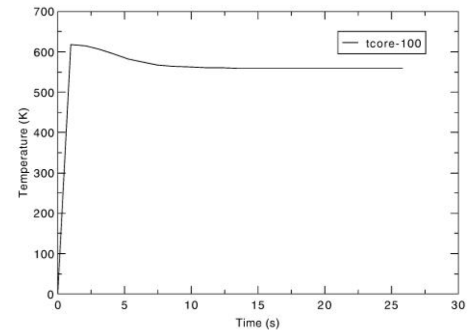
4. RESULTS OF THE STEADY-STATE CONVERGENCE

Steady states results are summarized in the Table 2. Main TH parameters stated below in this benchmark are reactor core inlet temperature, reactor power, reactor core inlet mass flow and reactor core pressure. The comparison of obtained results with reference results [4] is also given in the Table 2.

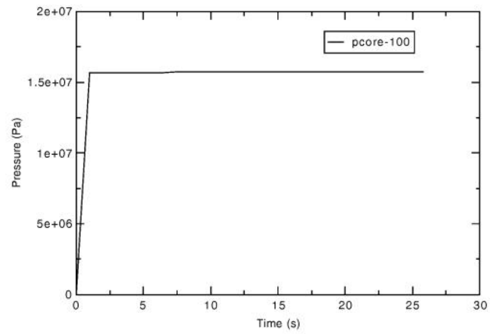
	Obtained Results	**Reference Results**
Inlet Temperature [K]	559.227	559.15
Reactor Power [W]	2722.67	2775
Inlet Mass Flow [$kg \cdot s^{-1}$]	12893	12893
Reactor Core Pressure [MPa]	15.719	15.5

Table 2: Comparison of obtained results with reference steady-state parameters

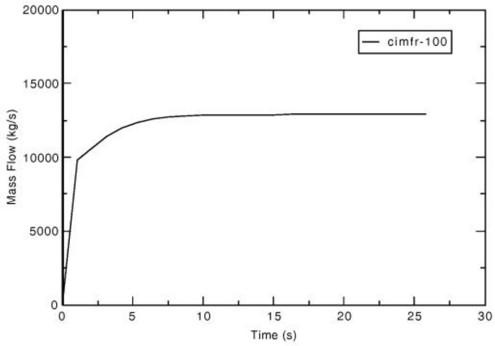
Table 2 gives results at the problem time 26.8 s, which is also time step when all followed parameters reach steady state. Runs of the main TH parameters are shown in following picture.



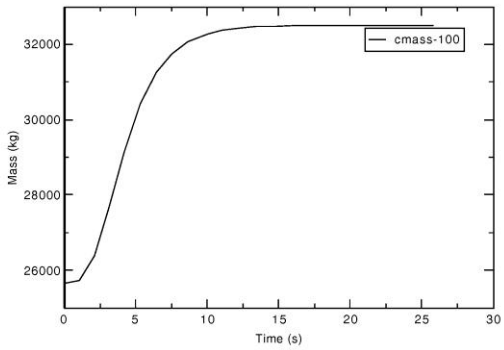
a)



b)



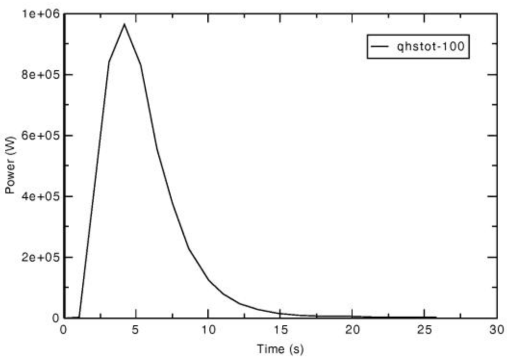
c)



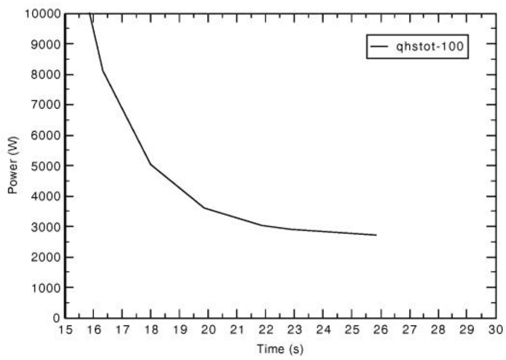
d)

Figure 2: Reactor core inlet temperature (a), reactor core pressure (b), reactor core inlet mass flow (c) and fluid mass in the reactor core (d).

Figure 3 shows rapid change in reactor power during first 10 second of simulation. This is mainly caused by that there isn't large liquid inventory in the reactor core region. This is shown in the Picture 2 case d). When the whole reactor core is filled by liquid power rapidly decrease and power settle down at required power level.



a)



b)

Figure 3: Reactor power during steady state calculation (a) and detailed figure of second half of the simulation (b)

5. CONCLUSION

This paper introduced preliminary results of the thermal-hydraulic steady-state calculation of the NEACRP-L335 Benchmark. All of the main thermal-hydraulic parameters reach expected values. Included figures show that this model gives reasonable results and can be used to further development. Several changes need to be made in the reactor core vessel according to future coupled calculation. This model will be coupled with PARCS model. To perform coupled calculation there will be created mapping file, which assign PARCS to TRACE cells. Finally, coupled set of models can be included into educational set of test problems at the US NRC.

ACKNOWLEDGEMENT

This research work has been carried out in the Centre for Research and Utilization of Renewable Energy (CVVOZE). Authors gratefully acknowledge financial support from the Ministry of Education, Youth and Sports of the Czech Republic under NPU I programme (project No. LO1210).

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