Subchannel Analysis of VVER-440 Using SUBCHANFLOW

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Introduction

This work focused on modelling of specific transients of the VVER technology using subchannel analysis . There were presented the results from the steady-state analysis and transients in comparison with the safety criteria. The simulation was performed in **SUBCHANFLOW (SCF)** for the fuel **Gd-2M⁺**.

Subchannel Analysis

Subchannel analysis is a special case of the porous media approach. This analysis is not describing a fully three-dimensional flow because the simplification is in the lateral exchanges between the neighbouring subchannels. When the flow is leaving the region of a subchannel, it is assumed that this flow loses its sense of direction. This approach simplifies the lateral convection terms of the linear momentum balance equations. Subchannel analysis's definition of **control volume** is described in **Fig. 1**.

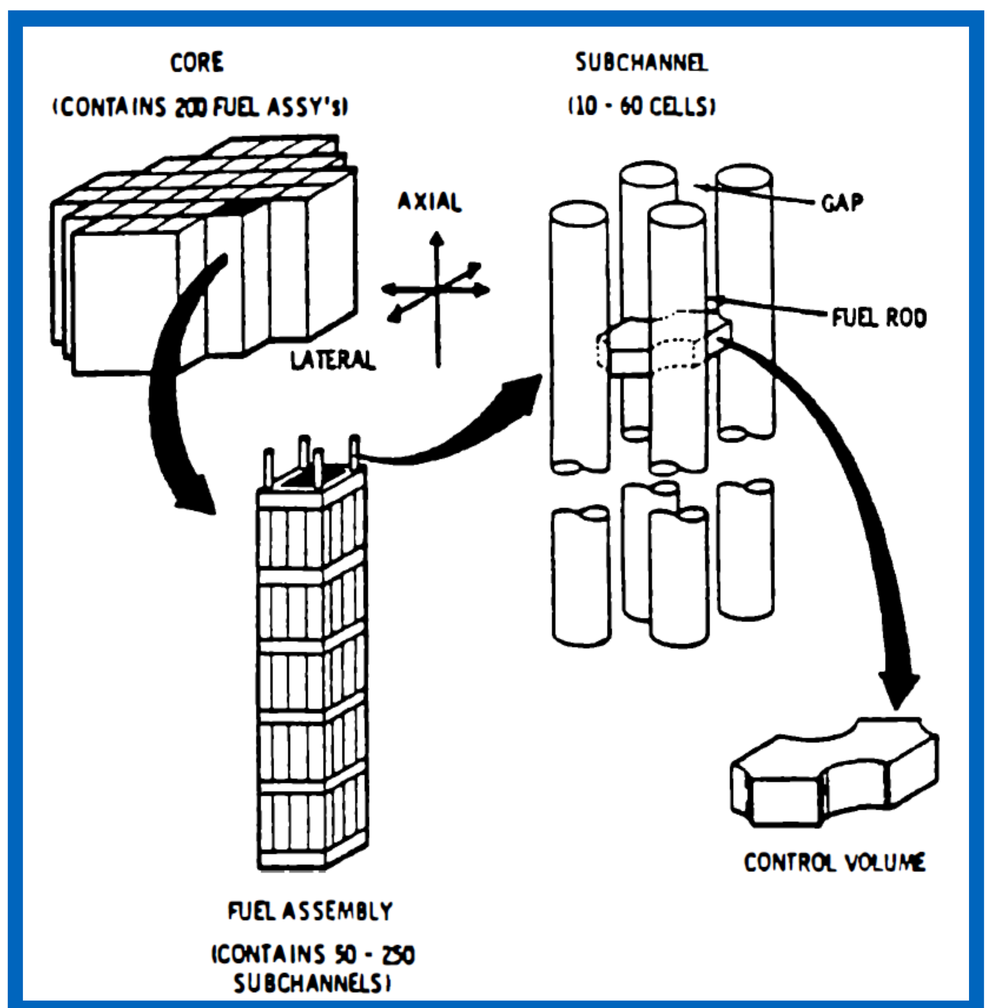

Figure 1: Relation of subchannel control volume to the reactor core [1].

Loss of Flow Accident

The calculation was provided for **four LOFAs** scenarios: 1/6 reactor coolant pump (RCP) trip, 2/6, 3/6 and total LOFA (6/6 RCPs). The results presented in this poster describe the worst case (3/6 RCPs trip) due to the fast SCRAM in the case of total LOFA.

Besides, for the LOFAs are considered following **criteria**: MDNBR > 1.0 (OKB correlation), maximum fuel temperature: 2480 °C and maximum cladding temp.: 1200 °C [2].

Analysis

The input model contains information from the Final Safety Analysis Report (**FSAR**) of **Dukovany NPP**, which were implemented in the code **TRACE** and in newly developed software in **Python** programming language (as can be seen in **Fig. 2**).

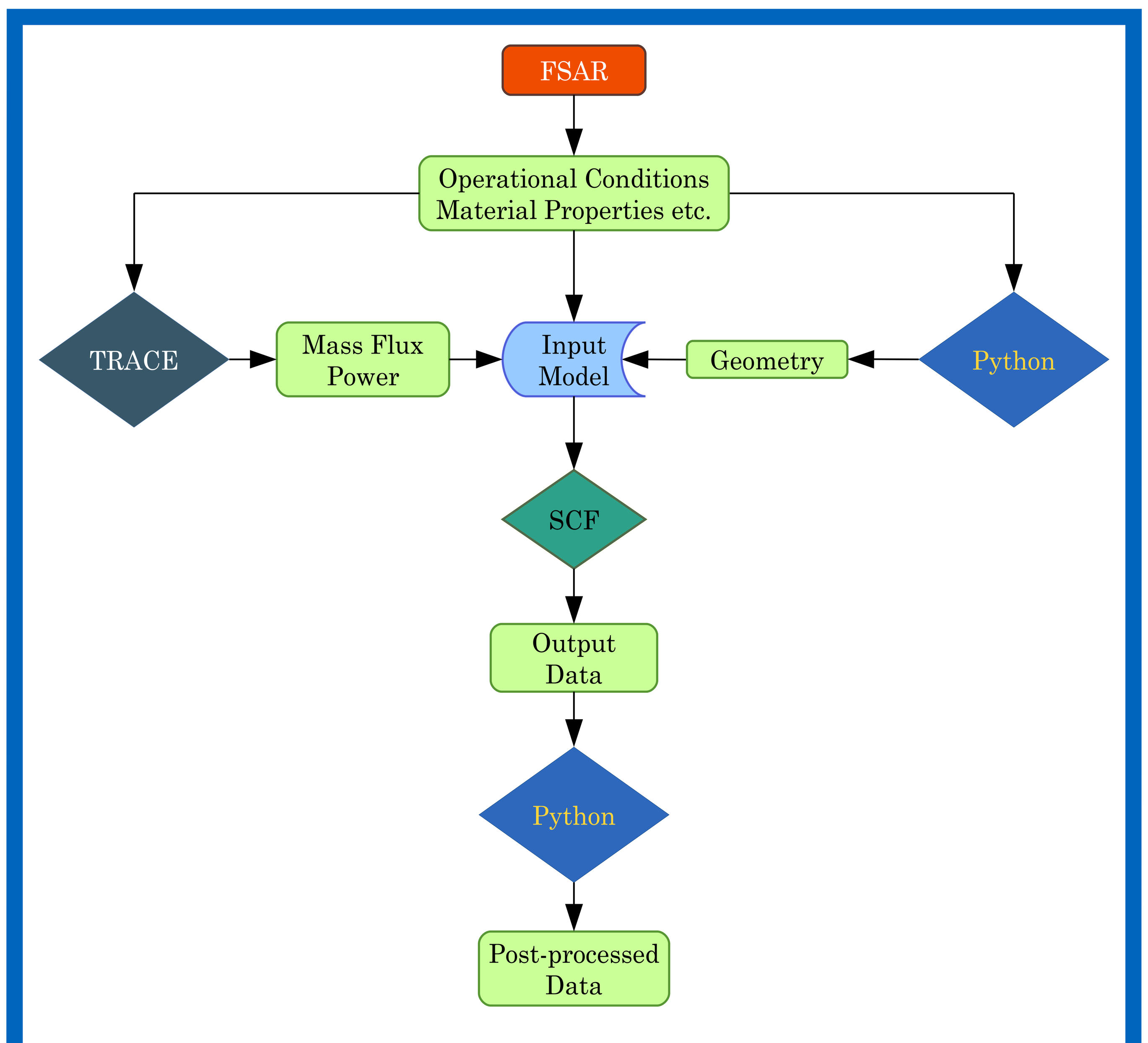

Figure 2: Scheme of the calculation procedure

Results

Table 1 summarizes the results from the subchannel safety analysis which were calculated in the SUBCHANFLOW. The first criterion was exceeded in the case of 2/6 and 3/6 RCPs trip, on the other hand, the second row is related to the MDNBR calculated by Savitzky-Golay smoothing data filter, which describes obtained data appropriately.

Savitzky-Golay filter (also called a digital smoothing polynomial filter or a least-squares smoothing filter) performs unweighted linear least-squares fit using a polynomial of a given degree.

Next two criteria were not exceeded in any case and the **results of the 3/6 RCPs trip** are visible in the **Fig. 3-6.**

Table 1: Results for four transients

	1/6	2/6	3/6	6/6
MDNBR [-]	**1.39**	**0.96**	**0.82**	**1.37**
MDNBR S-G [-]	**1.64**	**1.37**	**1.07**	**1.63**
T_{fmax} [°C]	1728	1728	1728	1728
T_{cmax} [°C]	383	382	382	380

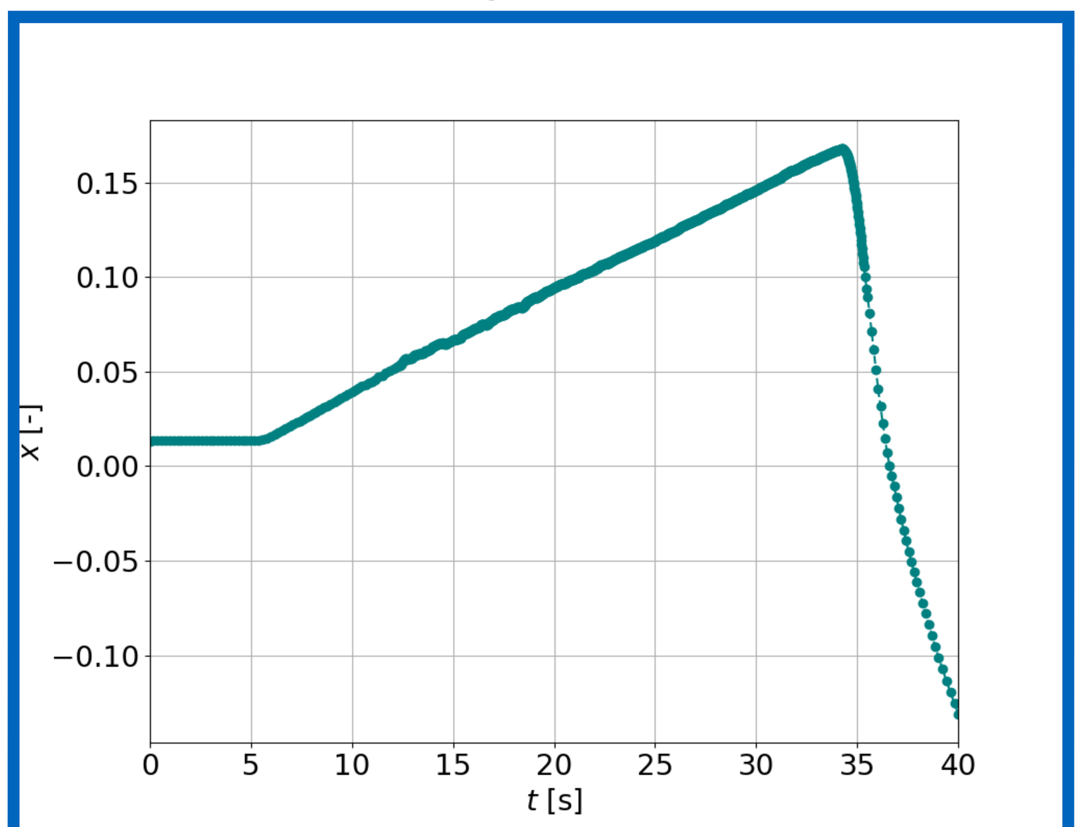

Figure 3: The highest value of equilibrium quality x in the hot channel 176.

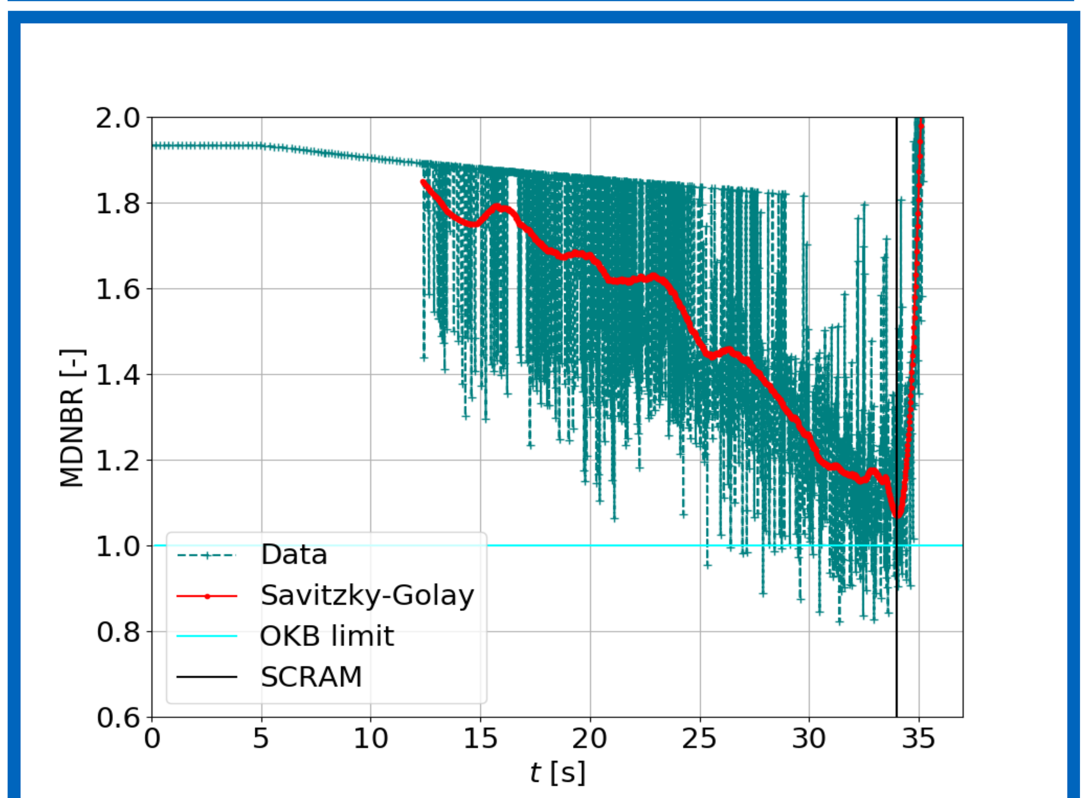

Figure 4: MDNBR on the hot rod 106.

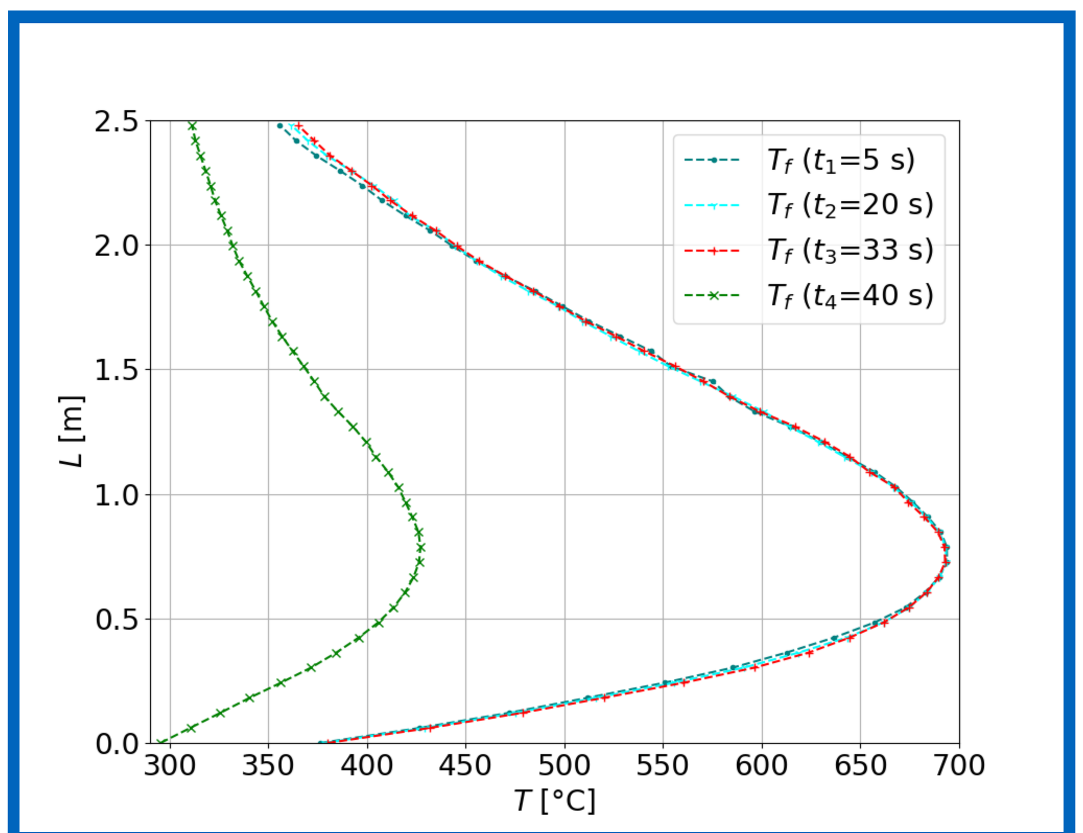

Figure 5: The hot rod 106 fuel center temperature at different times.

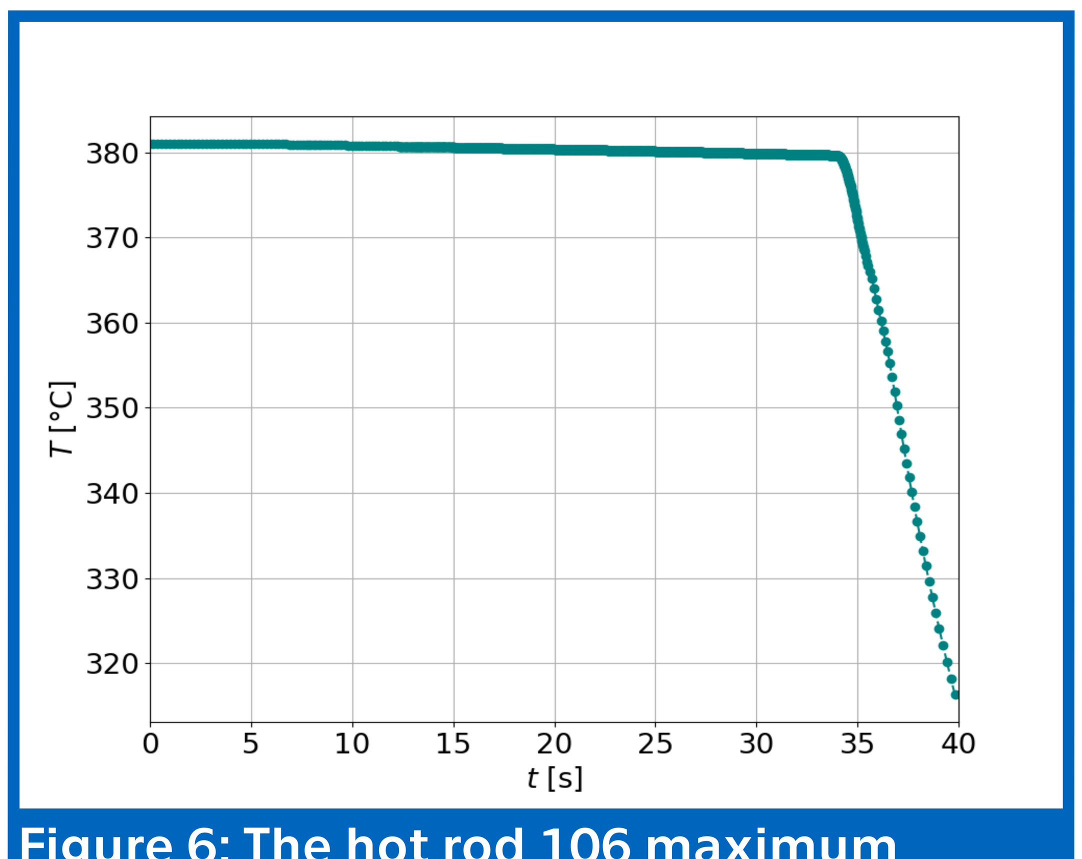

Figure 6: The hot rod 106 maximum cladding temperature.

Conclusion

This thesis presented the application of subchannel analysis for VVER technology. In particular, there was described the nuclear power plant VVER-440 (type V-213), the new fuel Gd-2M⁺ and subchannel analysis terminology. The thesis also performed simulations of steady-state and **LOFA** scenarios for VVER-440 using SCF. The main results have been verified against safety criteria listed in the FSAR.

The experience gained from the safety analysis calculations in this thesis will be helpful in the future for comparison of SCF with other software for subchannel analyses, and it is also possible to perform **code-to-code benchmarks** with other subchannel codes used in the Czech republic.

Important by-products of this thesis are **Python programmes** which were made for simplification of the sensitive analyses and post-processing. Future work will focus on the **coupling of TRACE and SCF**, which may speed up the calculation processes and extend sensitivity analyses possibilities.

References

[1] Neil E. Todreas and Mujid S. Kazimi. Nuclear systems II: Elements of Thermal Hydraulic Design. New York: Hemisphere Pub., c1990. ISBN 9781560320791.

[2] ČEZ, Final Safety Analysis Report Dukovany NPP, revision 2 v17, Prague, 2017.