Karlsruhe Institute of Technology

Analysis of C5G7-TD benchmark with the AZTRAN code

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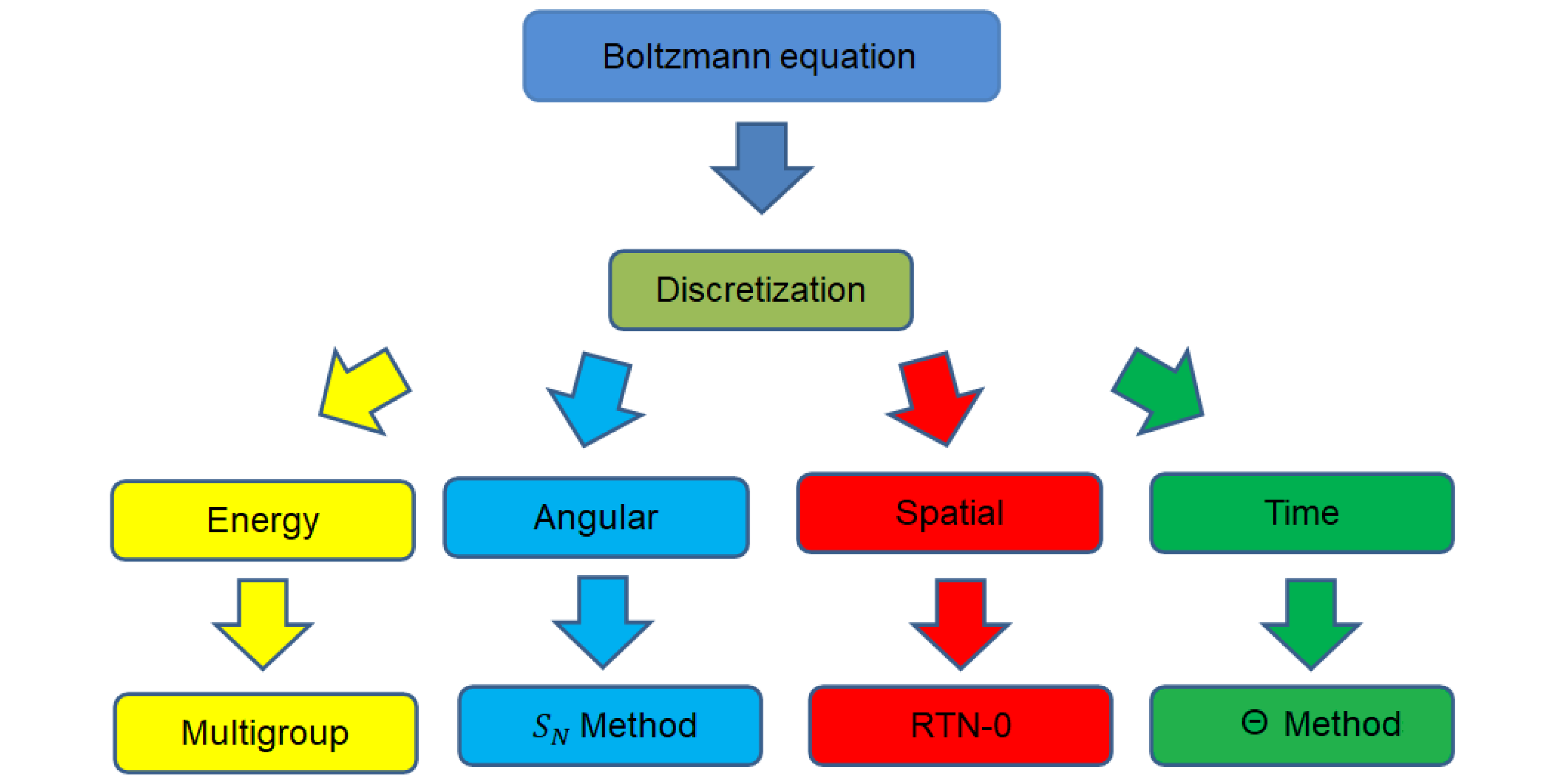
Introduction

At Karlsruhe Institute of Technology, there is a significant interest in analyzing SMR cores; For this, It will be used the AZTRAN code (S_N) [1] and the in-house PARAFISH code (P_N) [2].

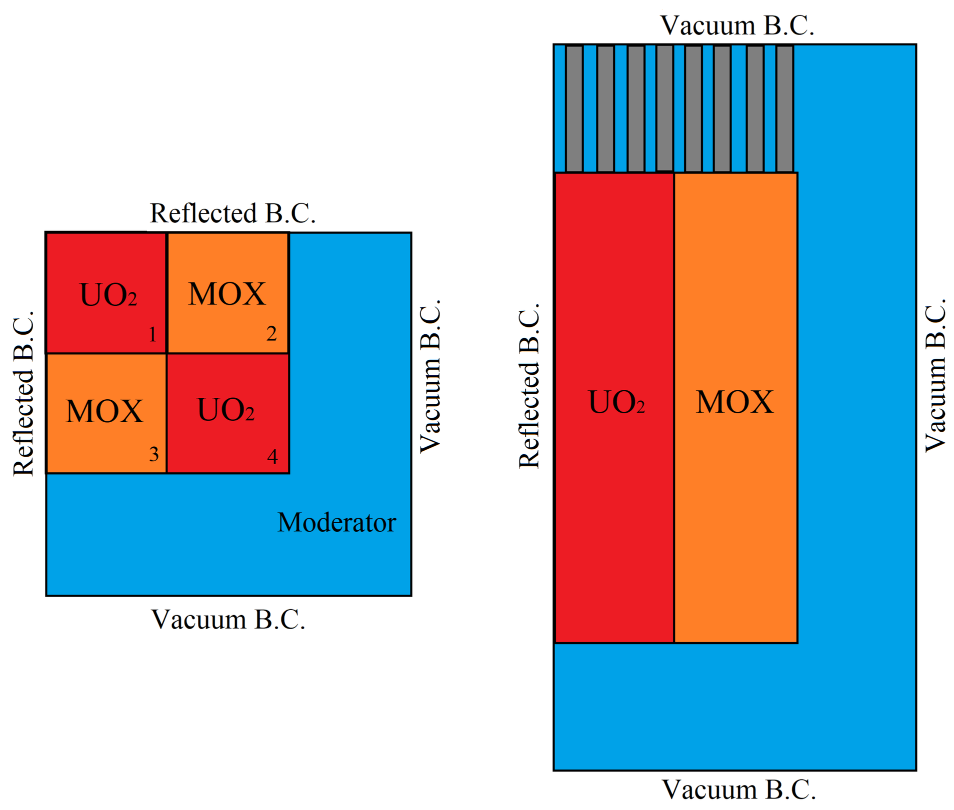
AZTRAN is a deterministic three-dimensional time-dependent parallel neutron transport code based on spatial domain decomposition.

For verification, the well-known C5G7-TD Benchmark [3] was considered for testing the AZTRAN transient capabilities since it provides a complex and heterogeneous core without spatial homogenization.

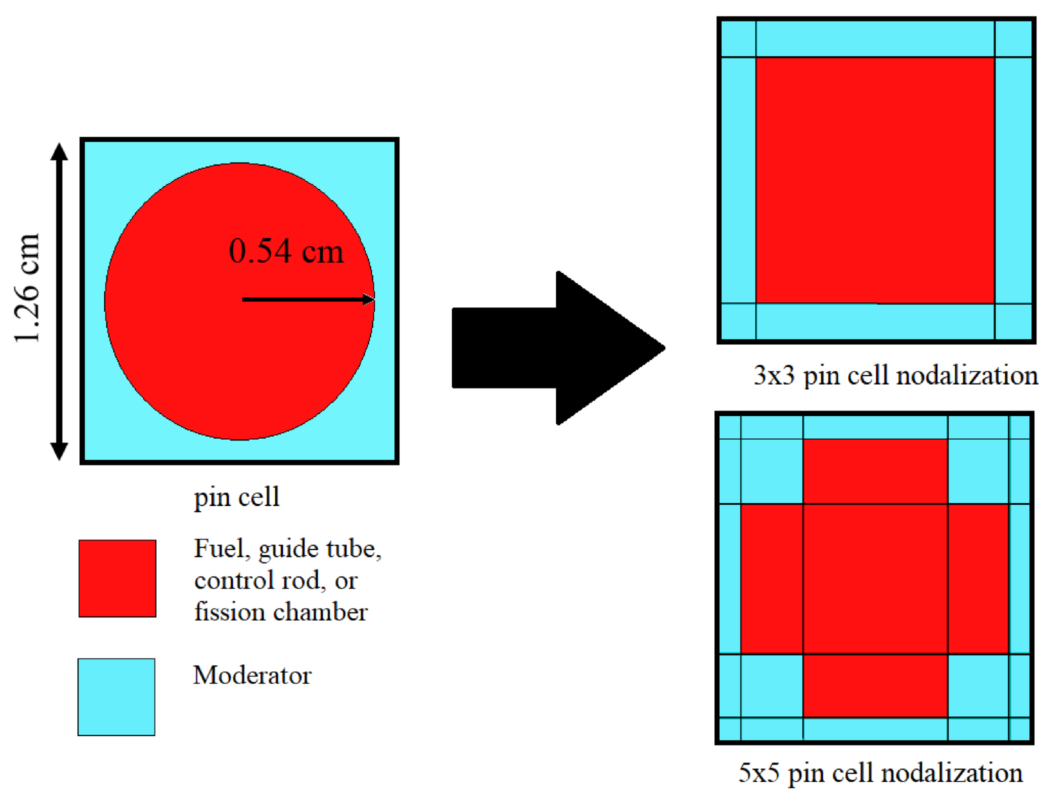
AZTRAN Discretization



Model



C5G7-TD configuration



Proposed pin-cell configurations

TD3 exercise (2D): Varation of moderator density in the fuel assiemblies.

TD4 exercise (3D): Insertion/withdrawal of one or several control rod banks.

Model configuration

Exercise	TD3	TD4*
Spatial configuration	5 × 5	3 × 3
Angular approximation	S_4	S_2
Time-step	0.0025 s	0.025 s

∗ 3D exercise, which involves control rod insertions and withdrawals, the Flux Weighting method [4] is employed to mitigate the cusping effect.

Convergence criteria: Steady-state= 10^{-08} Time-dependent= 10^{-06}

Results

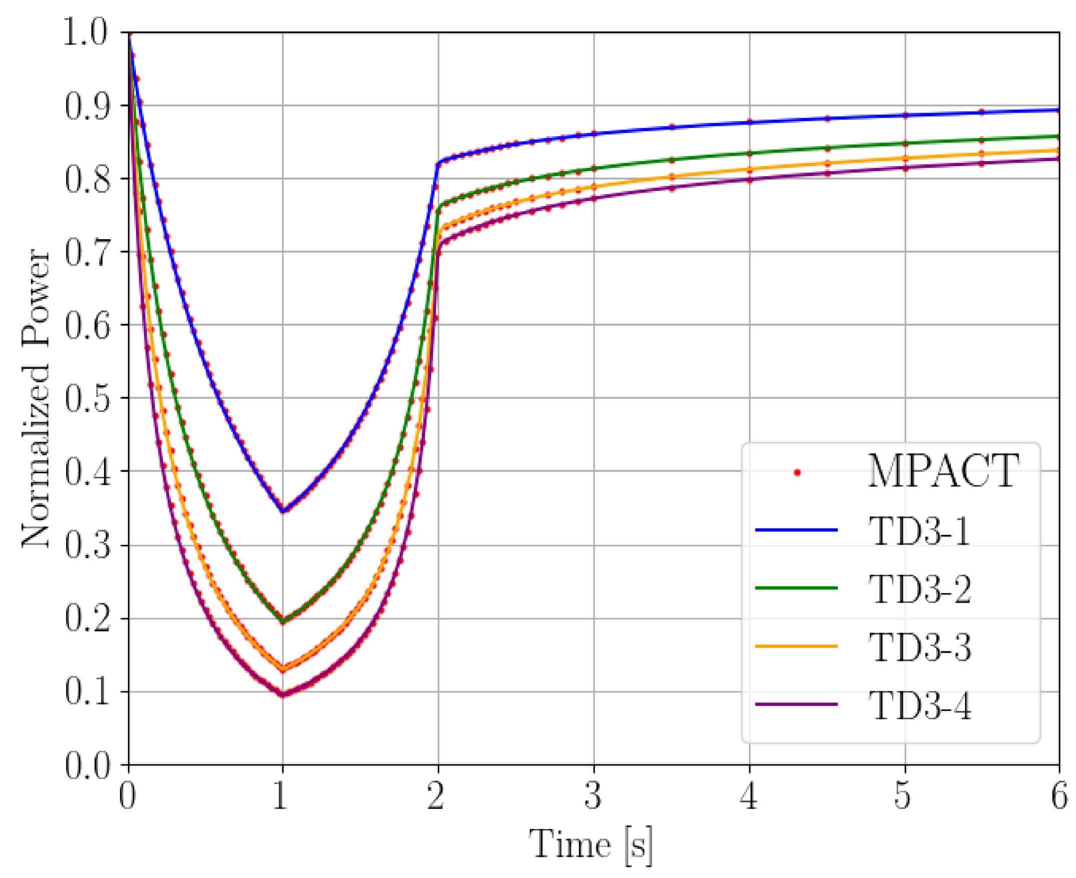
The results were compared with the MPACT code [5].

Eigenvalue Results for the C5G7-TD Benchmarks

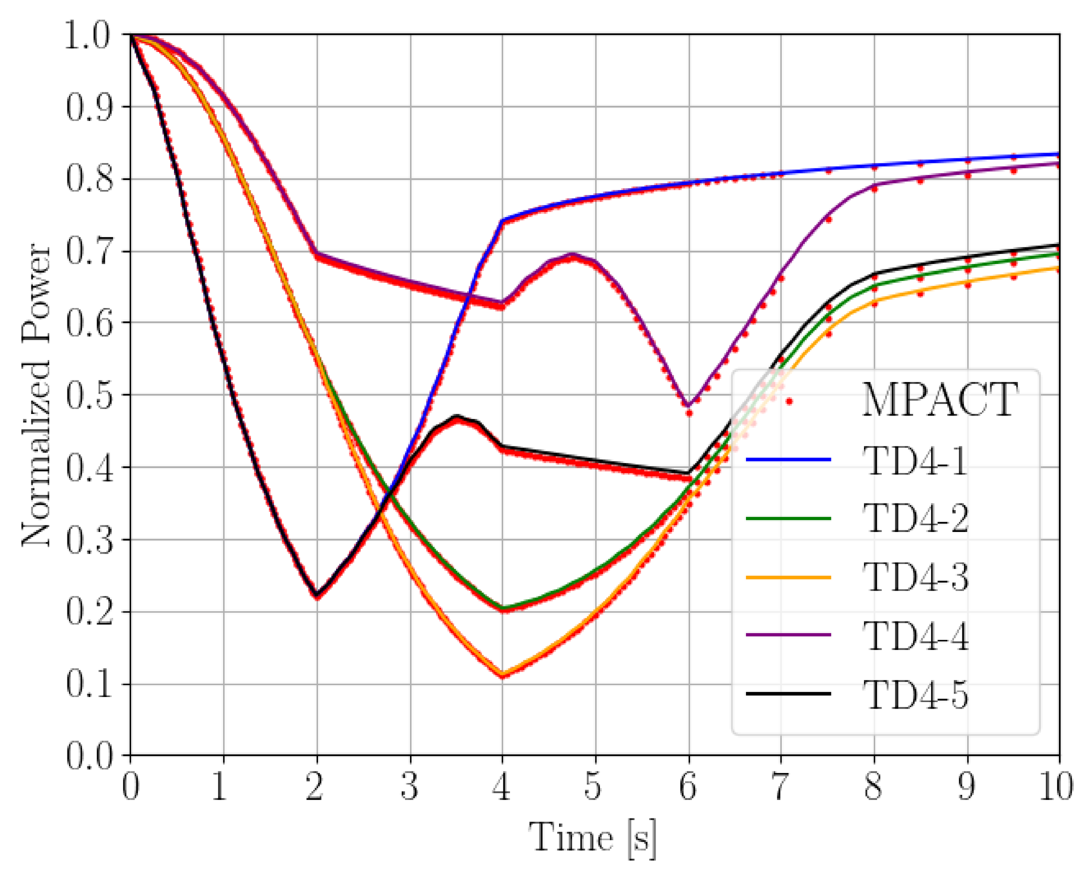
Exercise	MPACT	AZTRAN	Difference
2D	1.18666	1.18336	278 pcm
3D	1.16351	1.16603	216 pcm

Core power differences between AZTRAN and MPACT

Exercise	Max. Diff(%)	RMS(%)	Exercise	Max. Diff(%)	RMS(%)
TD3-1	0.43	0.25	TD4-1	0.65	0.25
TD3-2	0.54	0.34	TD4-2	1.90	0.93
TD3-3	0.61	0.40	TD4-3	1.84	0.90
TD3-4	0.64	0.43	TD4-4	1.51	0.64
—	—	—	TD4-5	1.75	0.83



C5G7-TD3 exercises



C5G7-TD4 exercises

Conclusions

- The results obtained by AZTRAN achieve good agreement and consistent results compared with the well-known MPACT code.
- Increasing the spatial-angular resolution can minimize the differences observed in the 3D case, but this will increase the computational burden (A powerful workstation is required).
- The Flux Weighting method can mitigate the cusping effect efficiently without significant compuational effort.
- The verification demostrates AZTRAN´s capability to simulate transient calculations with acceptable accuracy, making it a reliable tool for nuclear analysis.

References

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[2] S. Van Criekingen, F. Nataf, and P. Have. “PARAFISH: A parallel FE–PN neutron transportsolver based on domain decomposition.” Annals of Nuclear Energy, 38(1), pp. 145-150(2011).
[3] J. (Jia) Hou, K. N. Ivanov, V. F. Boyarinov, and P. A. Fomichenko. “OECD/NEA benchmark for time-dependent neutron transport calculations without spatial homogenization.” Nuclear Engineering and Design, volume 317, pp. 177–189 (2017).
[4] J. C. Gehin. A quasi-static polynomial nodal method for nuclear reactor analysis. Ph.D. thesis, Massachusetts Institute of Technology (1992).
[5] Q. Shen, Y. Wang, D. Jabaay, B. Kochunas, and T. Downar. “Transient analysis of C5G7-TD benchmark with MPACT.” Annals of Nuclear Energy, volume 125, pp. 107–120 (2019).