Investigation of neutron transport calculation using Iso-Geometric method: (2) 3-dimensional analysis

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A neutron transport calculation code based on IGA theory is being developed to perform neutron transport calculations in two or three dimensional spatial domains. In this paper, the code features are introduced and results of 3D calculations are presented. Calculated results have good accuracy but the calculation time is unacceptable.

Keywords: Iso-Geometric Analysis, Neutron Transport Theory, S_N method, Finite Element Method

1. Introduction In neutronic calculations the spatial domain is usually represented in a simplified manner, e.g. Cartesian, cylindrical or Hex-Z geometry. In order to analyze more general geometries, for example to take into account effects of thermal expansion or deformation due to mechanical stress, the theory of Iso-Geometric Analysis (IGA) can be used. In our work, IGA is used for S_N neutron transport calculations in 2D and 3D arbitrary geometry.

2. Theory In our work the conventional S_N method and a Finite Element Method based on Iso-Geometric Analysis (IGA) [1] are used to solve the neutron transport equation. In the IGA method the theory of NURBS [2] is used to describe the geometrical domain, and the same basis functions are also used to solve the neutron transport equation. In comparison to conventional method, the IGA method has 2 special features: first, the theory of NURBS allows to describe arbitrary geometrical domains in a mathematically exact way, and second, the basis functions are automatically adapted to the geometrical domain.

3. Code design and implementation In the present work, a completely new calculation code was developed, using the theory from [2] regarding NURBS functions, and based on the work in [1] and [3] for S_N calculations. The code is designed with the following features: multi-group S_N calculations in 2 or 3 dimensions, anisotropic scatter, fixed source calculations, λ-mode calculations, α-mode calculations, and time-stepping calculations.

4. Results The new 3D version of our code was tested in two ways: the Method of Manufactured solutions was used to confirm that the convergence properties are as expected from theory. As a first attempt for 3D eigenvalue calculations, the first problem of the Takeda-benchmarks [4] was calculated: a small, cube-shaped thermal reactor with control rod in/out. Results are given in Table 1. Adequate results were found but the calculation time is excessive at the moment. Investigations have shown two causes: the treatment of boundary conditions at internal boundaries, and the sweep-order through the mesh. Both aspects are currently under development.

3. Conclusion We are developing a new S_N neutron transport code based on IGA theory. 3-D benchmark calculations have given good results. The calculation time of the present code is unacceptable and improvements are underway.

Table 1: Results for Takeda-1 benchmark (KUCA-type core)

	This work	KENO6	Benchmark
CR up	0.9788	0.9775 ± 0.00013	0.9765
CR down	0.9636	0.9626 ± 0.00012	0.9621
CR worth	0.0152	0.0149	0.0144

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