Self-shielding calculations based on the IGA-method

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A calculational method for self-shielding calculation is described. This method is developed to perform calculation for any arbitrary geometrical domains. The objective is to implement it in an innovative calculation code based on IsoGeometric Analysis, developed in our laboratory. The method is based on sub-group method to treat resonances and "Sn" theory to resolve the neutron transport equation.

Keywords: Neutron transport theory, Self-shielding calculation, IGA method, Sub-group method

1. Introduction In our laboratory, we are developing an innovative simulation code based on IsoGeometric Analysis (IGA), which allows to resolve neutron transport equation for any geometrical domains with the multi-group "Sn" formalism. With multi-group calculation, it is necessary to treat the resonances of cross section with self-shielding calculation. Thus, the goal is to develop a self-shielding calculation method for any arbitrary geometrical domains and we chose to use the sub-group method as basis.

2. The Subgroup Method For self-shielding calculation, integrals such as $\int_{\Delta u_g} \sigma_x(u)\varphi(u)du$ and $\int_{\Delta u_g} \varphi(u)du$ need to be evaluated, in which the flux φ(u) is a function of the total cross section $\sigma_t(u)$, under appropriate assumptions, such as isolated resonances, absence of resonance interaction, and the narrow resonance approximation. In that case, we have decided to use the sub-group method as a basis and to extend it to our IGA code [1]. One of the main features is it can be used with any flux solution technique, such as "Sn" theory, and it is not limited to any geometrical domains. The sub-group method is used to calculate the multi-group self-shielded cross section by using the probability density. Indeed, with sub-group method every $\sigma_t(u)$ dependent function can be discretized by:

$$\frac{1}{\Delta u_g}\int_{u_{g-1}}^{u_g} f[\sigma_t(u)]du = \sum_{k=1}^{K} w_k f(\sigma_k)$$

If we consider a heterogeneous system described in the "Sn" formalism, where the direction of movement is discretized into a set of directions n and where a resonant isotope N^* is in a non-resonant background N^+, the transport equation is given by: $\hat{\Omega}_n \nabla \Phi^g(r,\hat{\Omega}_n) + [N^*\sigma_t(u) + N^+\sigma_t^+]\Phi^g(r,u,\hat{\Omega}_n) = Q^g(r,\hat{\Omega}_n)$

In the case we have a calculation code that is based on the "Sn" theory, it is possible to resolve the previous equation and obtain the flux that will be a function of $\sigma_t(u)$ so we can apply the sub-group method:

$$\Phi^g(r,\hat{\Omega}_n) = \mathrm{f}[Q^g(r,\hat{\Omega}_n),\sigma_t(u)] \Rightarrow \sigma_{x,i}^g = \frac{\sum_{k=1}^{K}\sigma_{x,k} f_k Q^g(r,\hat{\Omega}_n),\sigma_{t,k}}{\sum_{k=1}^{K} f_k Q^g(r,\hat{\Omega}_n),\sigma_{t,k}}$$

When we speak about sub-group method, we have to mention the probability table which consist of a quadrature set $\{\sigma_k, w_k;\ k=1, K\}$ that represents a probability density. There are different methods to calculate the probability table. We chose to use the method of moment and the mathematical probability table, because of his consistency and stability [2].

3. Conclusion We have started to improve this neutron transport code based on IGA method to take into account self-shielding effect. At the moment, we have found the self-shielding model to implement in our code. This model will have to be improved: to be compatible with arbitrary geometrical domain and with the discrete ordinates method "Sn"

References

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