Sub-group method applied to Iso Geometric Analysis calculation code

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We are developing a simulation code based on IsoGeometric Analysis (IGA) to resolve neutron transport equation for any geometrical domains with the multi-group "Sn" formalism. It is necessary to treat the cross section resonances with self-shielding calculation. The goal is to develop a self-shielding method for any arbitrary geometrical domains.

Keywords: Self Shielding Calculation, Sub-group Method, Cross Section, SCALE6.2, NJOY21, Probability Table, CALENDF2011

1. Introduction: There are two main self-shielding method : the equivalence method (and/or Bondarenko model) and the sub-group method. With the IGA approach, the goal is to perform calculations for any kind of geometrical domains so the equivalence method which relies on specific shapes (plate, sphere, cylinder, ...) could not be applied. That's why we chose to use the sub-group method [1] as basis because it can be used directly with any transport calculations formalism.

2. Sub-group validation: Before implementing the sub-group method in our IGA code, the first step was to validate our probability table and self-shielding calculation. To do that we calculated self-shielded cross section for a reference case, an homogeneous system with a resonant isotope (Pu^{239}) and a non-resonant isotope (H^1):

$$[N_{H^1}\sigma^g_{t,H^1} + N_{Pu^{239}}\sigma^g_{t,Pu^{239}}]\Psi^g = F^g + S^g + Q^g \tag{1}$$

where F^g is the fission source, S^g is the scattering source, Q^g is the external source
For our sub-group calculation we need different types of cross section :

- Multi-group cross section coming from SCALE6.2
- Scattering matrix from NJOY21 (not possible to get it from SCALE6.2), then adjust the matrix to have the same scattering group cross section than SCALE6.2.
- Probability Table (PT) from CALENDF2011 [2], adjusted similarly as the scattering matrix.

To perform the sub-group calculation, we coded a python program to resolve the transport equation and to perform the self-shielding calculation. The transport equation to solve become :

$$[N_{H^1}\sigma^g_{t,H^1} + N_{Pu^{239}}\sigma^g_{tk,Pu^{239}}]\Psi^g_k = F^g + S^g + Q^g \tag{2}$$

$$\sigma^g_{x,Pu^{239}} = \frac{\sum_{k=1}^K w_k \sigma^g_{x,k}\Psi^g_k}{\sum_{k=1}^K w_k \Psi^g_k} \tag{3}$$

where
$\sigma_{x,k}$ = discrete value for the reaction x of the probability table
w_k = discrete weight of the probability table

To compare our results we used CALENDF-2011, code that we already used to calculate our probability table, that can give self-shielded calculation using conventionnal self-shielding method. The Figure.1 shows the self-shielded effect in the resolved resonance range (22.5 eV to 3.35x10^4 eV) on Pu^{239} capture and fission cross section with the two different methods ($f = 1 - \frac{\sigma_{\chi,Sub-group}}{\sigma_{\chi,CALENDF-2011}}$, $\chi = f$ or c).

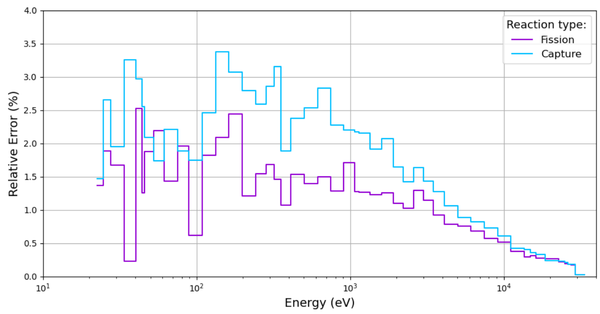

Figure 1: Self-shielded Pu239 cross section comparaison

As we can see on the Figure.1, the self-shielded cross section calculated with the sub-group method are almost the same with the cross section giving by CALENDF-2011 that uses conventional self-shielding calculation (maximum relative error < 3.4%). The difference can be explained by the fact that even if we start with the same cross section, CALENDF-2011 uses a background cross section. In our calculation we are using H^1 to play the role of background but at low and high energy H^1 cross section are not flat. However the difference is relatively low and we are satisfied with the results so we can validate the sub-group method that we are using.

3. Sub-group implementation: Since we validated the sub-group method, we started to implement it in our IGA code. To be sure that we do it in the good way, we will make calculation for a PWR system so we can compare it with some benchmark such as BEAVR. We plan to present first results in our oral presentation.

4. Conclusion: From this point we validated the self-shielding method (sub-group) and started to implement it in our IGA based code. The next steps are to perform calculation with our IGA code and to compare the results with a reference case.

References

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