A Study of the Effects of Source Sampling Methods on ARIES-RS NWL Profiles

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ARIES Pathways Project
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Outline

• Introduction
• Past NWL Work (in 1996) with approximate neutron source distribution
• Present Work with exact neutron source distribution
• Comparison with DAGMC
• Results
• Recommendations
• Publications
Introduction

- Using 3-D MCNP code, El-Guebaly* determined neutron wall loading (NWL) distribution for interim design
- Final design was later determined

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Interim (Jan ‘96)</th>
<th>Final (Aug ‘96)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>1881.5 MW</td>
<td>2167 MW</td>
</tr>
<tr>
<td>Major Radius</td>
<td>5.12 m</td>
<td>5.52 m</td>
</tr>
<tr>
<td>Minor Radius</td>
<td>1.28 m</td>
<td>1.38 m</td>
</tr>
<tr>
<td>Magnetic Shift</td>
<td>55 cm</td>
<td>33 cm</td>
</tr>
<tr>
<td>Peak NWL (midplane)</td>
<td>5.3 MW/m²</td>
<td>5.6 MW/m² (from ACS)</td>
</tr>
</tbody>
</table>

Introduction

• We reexamined the NWL for ARIES-RS

• Different source sampling methods were used
  – Effect on NWL distribution is analyzed

• FW segmented vertically (every 10-20 cm) to improve accuracy
Past Work

- Used standard MCNP source definition
- 3 regions were created in the plasma zone
- They were weighted to represent the actual source distribution, provided by C. Bathke
- Each region was sampled uniformly
- Angular distribution was isotropic

Fig. 2. Poloidal variation of neutron wall loading.

NWL results from 1997 report
Present Work

• For interim ARIES-RS design, NWL was computed using 3 source distributions:
  – one uniformly sampled region (basic)
  – 3 uniformly sampled regions (this is what was done before)
  – Sampling of actual source distribution provided by C. Kessel

• These results will be compared to assess the accuracy of each method.
Present Work (cont.)

• Plasma parameters provided by C. Kessel
  – Provided on R-Z grid in standard output format from plasma physics simulation

• Generate a source density distribution on R-Z grid, \( S(R,Z) \)

• Source probability density function (PDF) derived by volume weighting
  – PDF = \( 2\pi R \cdot dR \cdot dZ \cdot S(R,Z) \)

• Cumulative distribution function is created by summing over R and Z
• Source mesh cell is selected by:
  – Linear search through Z from distribution function
  – Linear search through R from distribution function
  – Toroidal angle is sampled randomly from a uniform distribution

• The source mesh cell is then sampled uniformly in volume; the size is obtained from the R-Z grid

• The source is emitted isotropically
Results

Comparison of Inboard NWL results by source, native geometry

Poloidal Variation of Neutron Wall Loading on Inboard

- 3 region
- uniform
- actual source
Results

Comparison of Outboard NWL results by source, native geometry

Poloidal Variation of Neutron Wall Loading on Outboard

Neutron Wall Loading, MW/m²

Vertical Distance, m

- 3 region
- uniform
- actual source
Results

Comparison of Divertor NWL results by source, native geometry
Comparison to DAGMCNPX

- Calculations repeated with DAGMCNPX
  - Previous results used “native” MCNP geometry
- DAGMCNPX was developed at UW and performs transport directly on the CAD geometry file
- The results from the native and DAGMCNPX geometries will be compared
Results

Comparison of DAGMC and native geometry for Inboard NWL, actual source

Poloidal Variation of Neutron Wall Loading on Inboard

- native geometry
- DAGMC

Neutron Wall Loading, MW/m² vs. Vertical Distance, m

0 0.5 1 1.5 2 2.5
0 0.5 1 1.5 2 2.5
Results

Comparison of DAGMC and native geometry for Outboard NWL, actual source

Poloidal Variation of Neutron Wall Loading on Outboard
Results

Comparison of DAGMC and native geometry for Divertor NWL, actual source
### Results

<table>
<thead>
<tr>
<th></th>
<th>one uniform region</th>
<th>3 uniform regions</th>
<th>actual distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Inboard Γ</td>
<td>3.2 MW/m²</td>
<td>3.8 MW/m²</td>
<td>4.1 MW/m²</td>
</tr>
<tr>
<td>Peak Outboard Γ</td>
<td>4.8 MW/m²</td>
<td>5.3 MW/m²</td>
<td>5.3 MW/m²</td>
</tr>
<tr>
<td>Average* Γ</td>
<td>3.1 MW/m²</td>
<td>3.1 MW/m²</td>
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</tbody>
</table>

*Average* Γ = Neutron Power / FW area including divertor

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<th>Native Geometry (actual source)</th>
<th>DAGMC (actual source)</th>
</tr>
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<tr>
<td>Peak Inboard Γ</td>
<td>4.1 MW/m²</td>
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</table>
Results

• Source Comparison:
  – Outboard and divertor cases:
    • the 3 region source matched the actual quite well
  – Inboard case, the 3 region source was
    • ~8% lower at the midplane
    • shallower curvature, and
    • >10% higher near the top/bottom

• DAGMC comparison:
  – For the actual source, all results within 4%
    • For 3/45 cases with >1% discrepancy had a statistical error of the same magnitude
  – Similar results for both other source types
Recommendations

• The 3 region source captures many of the effects of the real source

• However, due to the slight disagreement for the inboard results (+/- 10%), the actual source should be used

• DAGMC is also an appropriate choice for these kinds of calculations

• Sensitivity to actual source resolution should be studied
Publications
