Results of Nuclear Data S&U Analysis for Benchmark Exercises Using DANTSYS/SUSD3D with COMMARA-2.0

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- Results for Benchmark Exercises
- Status of V&V Activity
- Summary
I. Introduction

Preparation of Cross Section Data

- Source ENDF
  - ENDF/B-VII.0

- NJOY99 Code Processing
  - Same NJOY processing options as KAFAX-libraries (NEA-1815, -1816, -1817) except for energy group structure (150 groups)
  - MATXS-format
  - Energy group structure: 33 groups of SG33 standard
  - Weighting function: KALIMER-150 core spectrum
Preparation of JENDL-4.0 Covariance Data

- Source Covariance Data
  - JENDL-4.0

- NJOY99 (ERRORRR) Code Processing
  - COVFIL-format
  - Energy group structure: 33 groups of SG33 standard

- Nuclides included
  - Non-Actinides: B-10, B-11, O-16, Na-23, Mn-55, Fe-56, Co-59, Ni-58, Ni-60
Preparation of **COMMARA-2.0 Covariance Data**

- **Source Covariance Data**
  - COMMARA-2.0

- **Modified ANGELO Code from I. Kodeli**
  - Data conversion of COMMARA-2.0 to COVFIL-format
  - Verification of covariance matrices by LAMBDA code
  - Energy group structure: 33 groups of SG33 standard

- **Nuclides included**
  - Non-Actinides: B-10, B-11, O-16, Na-23, Mn-55, Fe-56, Co-59, Ni-58, Ni-60
Comparison of U-235 Fission Covariance Data

< JENDL-4.0 >

< COMMARA-2.0 >
Comparison of Pu-239 Fission Covariance Data

< JENDL-4.0 >

< COMMARA-2.0 >
Comparison of **U-238 Capture Covariance Data**

< **JENDL-4.0** >  

< **COMMARA-2.0** >
Sn Transport Calculation by DANTSYS

- Geometry
  - 1-D Sphere model: JEZEBEL-Pu239, JEZEBEL-Pu240, FLATTOP-Pu
  - 2-D Cylinder (R-Z) model: ZPR-6/7, ZPR-6/7 High-Pu240, JOYO Mk-I

- Angular Quadrature Sets
  - S16, S8, S4: Traditional built-in Pn constants given by DANTSYS (IQUAD=1)
S&U Analysis by SUSD3D

< JENDL-4.0 >

ENDF/B-VII.0

JENDL-4.0

NJOY

ISOTXS(33g)

DANTSYS

GENDF (33g)

SUSD3D

Φ, Φ⁺

(33g)

< COMMARA-2.0 >

ENDF/B-VII.0

COMMARA -2.0

NJOY

TRANSX

ISOTXS(33g)

COVFIL

(33g)

SUSD3D

Φ, Φ⁺

(33g)

GENDF

DANTSYS

NJOY

(ERRR)

ANGELO
II. Results for Benchmark Exercises

This Study

- Benchmark calculations have been carried out for 7 benchmark exercises of WPEC SG33.
- Validation of Integral Parameters
  - $k_{\text{eff}}$, spectral indices, Na void reactivities (ZPPR-9)
  - DANTSYS calculations
    - ENDF/B-VII.0-based MATXS-format libraries
    - Options: P1-S4, P1-S8 (JEZEBEL-Pu239, ZPR-6/7), P3-S16
    - Same meshing and isotopic compositions as SG33 standard
    - Different angular quadrature sets (S4) from SG33 standard
  - Corrective Factors for homogeneous deterministic calculations (P1-S4, 33 groups)
This Study

- Calculation of Nuclear Data Uncertainties to $k_{eff}$
  - Forward & Adjoint Fluxes: ENDF/B-VII.0
  - Covariance Data: JENDL-4.0 vs. COMMARA-2.0
  - Considering
    - most of nuclides with covariance data
    - most of nuclear reactions of covariance file
    - inelastic scattering reactions (MT=4)
    - normalized to sum of total nu sensitivities (MT=452) for all actinides

- Comparison of Uncertainty Contributions
  - by nuclides & by dominant reactions of major nuclides
  - for JENDL-4.0 vs. COMMARA-2.0 covariance data
## Summary of DANTSYS/SUSD3D S&U Results

<table>
<thead>
<tr>
<th>No.</th>
<th>Core</th>
<th>Parameter</th>
<th>Experiment</th>
<th>DANTSYS w/ ENDF/B-VII.0 (P1-S4) C/E</th>
<th>SUS3D w/ COMMARA-2.0 Cov. Uncertainty (%)</th>
<th>SUS3D w/ JENDL-4.0 Cov. Uncertainty (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>JEZEBEL-Pu239</td>
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<td>1.005</td>
<td>0.348</td>
<td>0.852</td>
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</tbody>
</table>

COMMARA-2.0
✓ produce smaller k-eff uncertainties than JENDL-4.0 covariance data
✓ due to smaller ND uncertainties for dominant reaction covariances
Comparison of Criticality Results

**ENDF/B-VII.0 vs. JENDL-4.0**

- **Criticality**
- **C/E Values of $k_{\text{eff}}$**
- **ENDF/B-VII.0 vs. JENDL-4.0**
  - ENDF/B-VII.0 tends to be larger than JENDL-4.0 for 1-D models.
  - ENDF/B-VII.0 tends to be smaller than JENDL-4.0 for 2-D models.

[Graph showing comparison of criticality between ENDF/B-VII.0 and JENDL-4.0 for different models and calculations.]
Comparison of Integral Parameters

ENDF/B-VII.0 vs. JENDL-4.0

C/E Values of Parameters

Na Void Reactivity tend to be overestimated for JENDL-4.0
**Comparison of Total Uncertainty**

### JENDL-4.0 vs. COMMARA-2.0

**Total Uncertainty (%) due to JENDL-4.0 & COMMARA-2.0 Cov. Data**

- **JENDL-4.0**
  - P1-S4
  - P3-S16

- **COMMARA-2.0**
  - P1-S4
  - P3-S16

**Uncertainties for P1-S4**
- Tend to become smaller than P3-S16 for 1-D models
- Due to changes in elastic & inelastic scattering contributions

**Total k-eff Uncertainties due to JENDL-4.0**
- Over 3 ~ 4 times larger than COMMARA-2.0
- Except JOYO Mk-I with 2.5 times larger uncertainty.
Uncertainty Contribution by Nuclides & Reactions

JEZEBEL-Pu239
< by Nuclides >

JENDL-4.0 vs. COMMARA-2.0
✓ mainly brought about by contribution of Pu-239
JENDL-4.0 vs. COMMARA-2.0

- larger differences in fission & nutot contributions
- significant changes in elastic & inelastic scattering contributions of S8 & S16 results against S4 results
ZPR-6/7

< by Nuclides >

JENDL-4.0

COMMARA-2.0

JENDL-4.0 vs. COMMARA-2.0
✓ mainly brought about by contribution of U-238, Pu-239, Fe-56, and Na-23
JENDL-4.0 vs. COMMARA-2.0

✓ extremely large U-238 capture contributions for JENDL-4.0
✓ slight changes in elastic & inelastic scattering contributions among S4, S8, & S16 results
< by Reactions of Pu-239 >

JENDL-4.0 vs. COMMARA-2.0
✓ larger differences in Pu-239 fission, capture, & nutot contributions
< by Reactions of Fe-56 >

JENDL-4.0

COMMARA-2.0

JENDL-4.0 vs. COMMARA-2.0
✓ larger differences in Fe-56 elastic & inelastic scattering and capture contributions
JENDL-4.0 vs. COMMARA-2.0
✓ larger differences in Na-23 elastic & inelastic scattering and capture contributions
III. Status of V&V Activity at KAERI

Work flow of V&V activity

- BFS experiment (73, 75, 55)
- TRU burner physics experiment (New, BFS-76-1)
- IPPE BFS DB (ISTC, under discussion)
- ZPPR-15 (I-NERI, on going)
- Open DB (IRPhE, CSEWG)
- Data Library (ENDF/B, JEFF, JENDL)
- NJOY (ERROR) or engineering decision
- Reactor physics experiment DB
- Reactor physics experiment DB
- Sensitivity coeff., (APSTRACT)
- Cross Section Adjustment (ATCROSS)
- Adjusted Library
- Assessment of adjusted library
- Assessment of applicability
- Completed
- On going
- Plan
Development of sensitivity analysis code (APSTRACT)

- Using perturbation theory based $S_N$ transport theory
  - Forward and adjoint flux from TWODANT calculation
  - Using self-shielded cross section in ISOTXS

< Comparison of integral sensitivity coefficients of reactor physics exp. with reference core$^{1)}$>

<table>
<thead>
<tr>
<th></th>
<th>Ref. 1)</th>
<th>ZPR-3-48</th>
<th>ZPR-6-6A</th>
<th>ZPR-9</th>
<th>ZPR-3-56B</th>
<th>ZEBRA-MZA</th>
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<td>Pu239</td>
<td>Fission</td>
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<td>Nu</td>
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<td>Capture</td>
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<td>-0.0641-</td>
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<td>Fission</td>
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</table>

1) Reference core represents the TRU burner core for which BFS-76-1 experiment was performed
Development of cross section adjustment technology

- Major Topics of Research
  - Requirement of cross section adjustment
  - Determination of target accuracy and selection of reactor physics experiment from open documents

- Methodology of adjustment
  - Generalized least square method

- Development of XS adjustment code (ATCROSS)
  - Interface with sensitivity analysis code
  - Interface with NJOY code for covariance (COVFILS format)
  - Uncertainty analysis and representativeness analysis

- Major Achievements and Further Utilization
  - Requirement of cross section adjustment
  - Selection of applicable physics experiment DB from open database
  - Cross section adjustment code (ATCROSS)
  - Utilization for producing adjusted multi-group library
IV. Summary

◆ Summary
  F Generation of MATXS-format cross section libraries based on ENDF/B-VII.0 and JENDL-4.0
  F Generation of COVFIL-format covariance libraries based on JENDL-4.0 and COMMARA-2.0
  F Calculation of integral parameters for 7 benchmark exercises of WPEC SG33
  F Estimation of nuclear data uncertainties to k-eff

◆ Future Works
  F GPT Routine Development
  F Adjustment Procedure Development