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Basic Information

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Position: Postdoctoral Research Associate

Research

Ongoing Research	Multi-Physics Coupling with Monte Carlo and Thermal-Hydraulics, Fuel Performance and Crud Simulation in Soluble Boron, SA and UQ Analysis and Covariance Data Processing with Implicit Effect, On-The-Fly cross section treatment in Monte Carlo simulation, Multi-physics code development and analysis for Spent Nuclear Fuel Cask
Specialized experience	Methods and Development of code systems in Monte Carlo Neutron Transport and Nuclear Data Evaluations, Processing and Applications, Radiation Transport, and Criticality Safety Analysis

Education

Ph.D.	Tsinghua University, Beijing, China **Ph.D. in Nuclear Engineering**, July 2015
Visiting Scholar	University of California at Berkeley, California, USA **Visiting Ph. D. Student in Nuclear Engineering**, 2013.9 –2014.5
BA	Nanjing University of Aeronautics and Astronautics, Nanjing, China **B.Sc. in Applied Physics**, June 2010

Dissertation Work

Title	Research on the Key Methods of Evaluation, Processing and Application of Important Nuclear Data for Reactor and Code Development
Supervisor	Professor **Kan WANG** in Reactor Engineering Analysis Lab. at Tsinghua University
Abstract	See **Appendix C.**

Participated Projects

Principal Researcher

- Multi-Physics Coupling Project (L17S018000) supported by Korea Hydro & Nuclear Power Co. Ltd..
- Monte Carlo Multi-Physics Coupling Project (NRF-2017M2B2A9A02049916) Funded by the Korean government.
- Research on Evaluated Nuclear Resonance Parameters Library for Key Isotopes in Thorium Cycle and Neutronics Applications Algorithms in Nuclear Reactors, Supported by National Natural Science Foundation of China
- Research on Key Approaches and Code Development Used in Nuclear Data Processing, Supported by Tsinghua University Initiative Scientific Research Program
- Study on Key Techniques used in Thorium-Based Fuel Applications，Supported by National and International Scientific and Technological Cooperation Projects
- Study on Extension of MCNP-used ACE-Formatted Nuclear Data Library

Collaborative Researcher	• Advanced Reactor Technologies for Thorium Utilization，Supported by Tsinghua University-Berkeley Funding • Multi-group Depletion Module Development and Data Library Generation for Pebble Bed Molten Salt Cooled Reactor • Reactor Monte Carlo Code Development，Supported by the fund of National Science and Technology Major Project of Large Advanced PWR Nuclear Power Plant in China • Group-wise Nuclear Data Library Generation Code Development, Supported by the fund of National Science and Technology Major Project of Large Advanced PWR Nuclear Power Plant in China

Outstanding Experience

Analysis & Design	• MCNP, SCALE, NJOY, SAMMY • OpenMC, SERPENT, RXSP, RMC • DRAGON, CITATION, CASMO/SIMULATE • ALPAH/PARAGON/ANC • WIMS-AECL, RFSP
Programming	• C/C++, Fortran77/90, OpenMP/MPI, Python, Matlab
Accomplishments	• Monte Carlo Neutron Transport code -MCS Coupling with Sub-channel T/H code-CTF • Coupled Fuel Performance Code-FRAPCON within MCS • Fully Coupled FRAPCON, CTF within MCS code • Development of Resonance Parameters Evaluation code (similar to SAMMY) based on the R-Matrix Limited formula with Levenberg-Marquardt nonlinear least squared Method • Improvement of resonance parameters evaluation for ^{232}Th and ^{233}U • Development of Resonance Reconstruction module based on R-Matrix Limited formula in RXSP code • Development of probability tables generation module from unresolved resonance parameters in RXSP code • Development of KERMA & DPA cross sections calculation module in RXSP code • OpenMP/MPI-based Parallelism Optimization for RXSP, RMC code • Modernization and Maintenance of RXSP code • Validation &Verification of RXSP code • Generation and Testing of nuclear data libraries in ACE format used in Monte Carlo calculations • Generation and Testing of multi-group covariance data libraries for S/U Analysis by using NJOY code • On-The-Fly Doppler Broadening coupling with RMC code • Criticality Safety Analysis of AP1000 spent fuel storage rack • Nuclear Design for PWR, FBR and CANDU

Scholarship & Awards

2014	• Xuanyuan academic scholarship, First Class, Tsinghua University
2013	• Friends of Tsinghua University-Zhang-Mingwei Scholarship, First Class, Tsinghua University

2012	• Graduate Students Social Practice Scholarship, Second Class, Tsinghua University
2012	• Social Practice Scholarshio, Second Class, Tsinghua University
2011	• Graduate Students Social Work Scholarship, Second Class, Tsinghua University
2011	• Friends of Tsinghua University-Guanghua Scholarship, Second Class, Tsinghua University
2008	• National Scholarship, First Class, NUAA
2007	• National Scholarship, First Class, NUAA

Appendix A：

Summary of Research Experiences

Development of Multi-Physics Coupling System within MCS code

- **MCS** code is being developed by CORE group in UNIST (Ulsan National Institute of Science and Technology) for the purpose of nuclear reactors design especially for PWRs with very good performance in efficiency and accuracy, which applies many advanced methodologies and techniques, such as Modified Power Method, Coarse Mesh Finite Difference, whole core pin-by-pin depletions, large scale parallel implementation, internal 1-dimesonal single-channel T/H solver – TH1D, multi-physics coupling interface, and Multi-poles based directly On-The-Fly Doppler broadening and so on.
- **CTF** is a sub-channel Thermal/Hydraulic (T/H) simulation code, which is designated for Light Water Reactor (LWRs) vessel analysis. It uses a two fluid, three-field (fluid film, fluid drops and vapor) modeling approach. With the implementation of MPI based parallel, boron tracking model and a developer-friendly coupling interface, these features of accuracy and efficiency of CTF can be guaranteed. Currently, the sub–channel Thermal/Hydraulics code – CTF is coupled within MCS to provide T/H feedback of very accurate coolant temperature and coolant density.
- **FRAPCON** is a code for calculation of steady-state, thermal-mechanical behavior of oxide fuel rod for high burnup in LWRs, where it has these capabilities for cladding elastic and plastic deformation, fuel-cladding mechanical interaction, fission gas release, as well as cladding oxidation. A steady-state fuel performance prediction code – FRAPCON is also coupled to provide detailed fuel performance information.
- However, CTF coupling is separate from FRAPCON coupling, which means there is no interactive between CTF and FRAPCON This papers analyzes some drawbacks including fuel thermal conductivity, gap conductance in CTF, and single closed channel enthalpy model in FRAPCON. Aftermath, the **full coupling** has been implemented into MCS code to overcome the above mentioned drawbacks, and make full use of good features including transverse cross flow between neighboring sub-channels in CTF and burnup-dependent fuel thermal conductivity formulation, and iterative determined fuel pellet-cladding gap thermal conductance in FRAPCON. Posterior to code development of this CTF plus FRAPCON coupling interface, a simpler single rod case has been tested to verify the accuracy and efficiency of this full coupling system. Besides, the application of this MCS based multi-physics coupling system in BEAVRS whore core model with 3-D pin-by-pin power density and T/H feedbacks exchange between neutronic solver and T/H solvers has been performed, which proves the practical capability of this Monte Carlo based steady-state multi-physics coupling code system.
- **Cobra-SFS** is a Thermal/Hydraulic analysis code especially for fuel storage and transportation casks. Derived from the COBRA family of codes, COBRA-SFS retains all the important features of the COBRA codes for single-phase analysis, and extends the range of application to problems with two-dimensional radiative and three-dimensional conductive heat transfer. With these added capabilities, COBRA-SFS has been used to analyze various single- and multi-assembly spent fuel storage systems containing unconsolidated and consolidated fuel, with a variety of fill media. Therefore, Cobra-SFS has been also coupled within MCS code to accomplish the capability of multi-physics coupling system intended to SNF (spent nuclear fuel) **cask**.

Development and Maintain of RXSP code

- A code-**RXSP** has been developed by REAL group in Tsinghua University to process the Evaluated Nuclear Data File (ENDF) in order to generate the pointwise energy nuclear data library in ACE format which is then used by Reactor Monte Carlo code.
- The research on resonance reconstruction methods including both all types of resonance parameters storage format in ENDF/B-6 and their calculation formula to generate point-wise cross sections are carried out. The resonance reconstruction module developed by myself were integrated with others developing Doppler Broadening module and thermal cross sections interpolation module, forming the Bete-1.0 version of RXSP code, which was released in China Nuclear Society Meeting on Reactor Physics in 2012.
- The Probability Table method is a natural and effective approach to treat with neutron transport in unresolved resonance region. I successfully developed the Probability Table Generation (**PURC**) module embedded in RXSP-Beta1.0 code system. In addition, the ladder sampling approach which is also applied in NJOY code was improved by using several techniques, the generation efficiency was improved a lot as well. After the OpenMP-based parallelism algorithm was applied in it, the probability tables' generation efficiency achieved as much as 70 times compared with the PURR module in NJOY code. The RXSP-Beta2.0 code package was released in China Nuclear Society Meeting on Reactor Physics in 2013.
- **R-Matrix Limited** is the most strongly recommended resonance formula by CSEWG for calculating point-wise cross section from resonance parameters, which capability can be realized in the latest version of NJOY (NJOY2012) code. Based on the resonance reconstruction module in RXSP-Beta2.0, my research on the updated and extend the capability for using R-Matrix Limited formula was performed. The validation of accuracy and efficiency of this module proved that it is feasible to be utilized in reactor simulations.
- The **ERRORC** module for covariance data processing has been developed recently based on RXSP code framework, which has better performance in the capability in the covariance data processing for multi-group cross sections, nu-bar, fission spectrum and resonance parameters compared with ERRORR module of NJOY code. It is noted that the implicit uncertainty of resonance parameters has been firstly considered in covariance data processing code, which is caused by the changed of weighting flux during the sensitivity calculation of multi-group cross sections to resonance parameters.

Development of New Modules of RMC code

- It is one of the efficient approach to reduce the memory consumption in Monte Carlo based reactor physical simulations by using the On-the-fly Doppler broadening for temperature dependent nuclear cross sections. To meet the dual requirements of both accuracy and efficiency during the Monte Carlo simulations with many materials and many temperatures in it, this work enables the capability of on-the-fly pre-Doppler broadening cross sections during the neutron transport by coupling the Fast Doppler Broaden module in RXSP code embedded in the RMC code also being developed by REAL team in Tsinghua University.
- Additionally, the original OpenMP-based parallelism has been successfully converted into the

MPI-based framework, being fully compatible with neutron transport in RMC code, which has achieved a vast parallel efficiency improvement. This work also provides a flexible approach to solve Monte Carlo based full core depletion calculation with many temperatures feedback in many isotopes.

- According to the new capability for On-The-Fly Doppler broadening, the compatible format of key parameters in the input file was designed for RMC code.

Standardized Development of RMC & RXSP

- By using the Unstructured Markup Language modeling toolkit-IBM Rhapsody, some re-factory work and research on RMC& RXSP code packages were conducted, and some important documents, i.e. Requirements Specifications, Program Specifications, were written as well.
- Base on the GIT-a code version control system in our group, some organizations and coordination with other group members to develop RMC&RXSP code packages are performed, some historical versions records of code package are managed as well.
- Automatic testing scripts for the validation and verification of RMC&RXSP code package are written in Python-based programming language. Additionally, a series of benchmark including over 400 isotopes and 3 types of neutron spectrum were carried out.

Evaluations of Resonance Parameters For Isotopes in Thorium Cycle

- The research on Levenberg-Marquardt nonlinear least square fitting method are conducted to develop the resonance parameters evaluation code—RRPE(R-matrix limited Resonance Parameters Evaluation code) by improving the classic R-Matrix theory used in the evaluation of resonance parameters for some key isotopes in uranium cycle. The MPI-based parallelism algorithm was also used in point-wise cross sections computation in resolved resonance region and Doppler broadening and measurements resolution broadening as well. The accuracy of RRPE code was validated and the efficiency was improved a lot compared to the SAMMY code which is also developed for resonance parameters evaluations by Oak Ridge National Laboratory.
- Base on the self-developed resonance parameters evaluation code for the isotopes in uranium cycle—RRPE, the evaluations of parameters in resolved resonance region for ^{232}Th、^{233}U are carried out, with the assistant of experimental cross sections from EXFOR database. It is proved that RRPE code has the capability of resonance parameters evaluation to meet the demand of accurate cross sections in reactor physical simulations and some other applications.

Appendix B.

Summary of Research Achievements

- **Software Copyrights**

1. Copyright of Reactor Cross Sections Processing code-RXSP (#0597885). The developer in second place, and my adviser is the first one.

2. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, XSLINK-Fuel Assembly XS Processing, C-2018-008346, Korea Copyrights Commission (2018)

3. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, MCS-Depletion Calculation, C-2018-008347, Korea Copyrights Commission (2018)

4. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, MCS-Multigroup Transport, C-2018-008345, Korea Copyrights Commission (2018)

5. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, MCS-Photon Transport, C-2018-008350, Korea Copyrights Commission (2018)

6. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim,

Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, MCS-VHTR calculation, C-2018-008344, Korea Copyrights Commission (2018)

7. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, MCS-PWR calculation, C-2018-008348, Korea Copyrights Commission (2018)

8. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, MCS-Time-dependent Simulation, C-2018-008349, Korea Copyrights Commission (2018)

9. Deokjung Lee, Peng Zhang, Matthieu Lemaire, Jiankai Yu, Sooyoung Choi, Hyunsuk Lee, Chidong Kong, Jiwon Choe, Hanjoo Kim, Bamidele Ebiwonjumi, Wonkyeong Kim, Jinsu Park, Yunki Jo, Kiho Kim, Jaerim Jang, Tung Dong Cao Nguyen, Khang Hoang Nhat Nguyen, Woonghee Lee, Tuan Quoc Tran, Yongmin Jo, Sanggeol Jeong, Eun Jeong, Khassenov Azamat, Vutheam Dos, U-SNF, C-2018-008343, Korea Copyrights Commission (2018)

- **Publications**

10. China Power Investment Nuclear Power Co. Ltd., **Talk on Nuclear Power- The Blog for A Nuclide**, Popularization of Science Press, ISBN 978-7-110-07785-6/TL·4, **Text Written Group Leader.**

- **Awards**

  - The Winner in the ICONE-22 Student **Best Poster** Competition – China at 22nd International Conference On Nuclear Engineering, Prague, Czech Republic, July 7-11, 2014.

- The Winner in the ICONE23 Student **Best Poster** Competition-China at the 23rd International Conference On Nuclear Engineering, Makuhari Messe, Chiba, Japan, May 17-21,2015.

- The Winner of **Best Poster Prize** in the KNS2018 Spring Meeting, Jeju, Republic of Korea, May 17-18, 2018.

- **Journal Papers**

[1]. Jiankai Yu, Hyunsuk Lee, Hanjoo Kim, Peng Zhang, Deokjung Lee, Preliminary Validation of MCS Multi-Physics Coupling Capability with CTF, Annals of Nuclear Energy, 118, 317-335, 2018.

[2]. Jiankai Yu, Hyunsuk Lee, Hanjoo Kim, Peng Zhang, and Deokjung Lee, Coupling of FRAPCON for Fuel Performance Analysis in the Monte Carlo code MCS, under review by Computer Methods in Computer Physics Communications.

[3]. Jiankai Yu, Hyunsuk Lee, Hanjoo Kim, Matthieu Lemaire, Peng Zhang, and Deokjung Lee, MCS Based Neutronics/Thermal-Hydraulics/Fuel-Performance Coupling with CTF and FRAPCON, under review by Computer Physics Communications.

[4]. Jiankai Yu, Hyunsuk Lee, Hanjoo Kim, Peng Zhang, Deokjung Lee, N/TH analysis of 3-D BEAVRS Cycle 1 Depletion with MCS/CTF Coupling System, in draft

[5]. Jiankai Yu, Hyunsuk, Hanjoo Kim, Peng Zhang, Sooyoung Choi, Deokjung Lee, Fuel Performance analysis of 3-D BEAVRS Cycle 1 Depletion with MCS/FRAPCON Coupling System, in draft.

[6]. Jiankai Yu, Hanjoo Kim, Sooyoung Choe, Peng Zhang, Deokjung Lee, Mutli-Physics Coupling Analysis 3-D BEAVRS Cycle 1 Depletion by MCS/CTF/FRAPCON Coupling System, in draft.

[7]. Jiankai YU, Songyang LI, Kan WANG, Development and Validation of Nuclear Cross Section Processing Code for Reactor-RXSP, *Nuclear Power and Engineering*, 34 (s1), 10-13, 2013. (EI, Accession number: 20133816763123)

[8]. YU Jiankai, LI Wanlin, WANG Kan, Validation of Updated Resonance Reconstruction Module of RXSP code Based on R-Matrix Limited Formula, *Transactions of the American Nuclear Society*, 111,1240-1243, 2014. (EI, Accession number: 20153301172068).

[9]. YU Jiankai YU, LI Wanlin, WANG Kan, The Validation of In-Line Doppler Broadening Cross Sections Capability in RMC code, Accepted by *Nuclear Power and Engineering*.

[10]. Qiu, Yishu, Liang Jingang, Wang Kan, Yu Jiankai. New strategies of sensitivity analysis capabilities in continuous-energy Monte Carlo code RMC, *Annals of Nuclear Energy*, 81(1), 50 – 61, 2015. (SCI, Accession number: 20151400714837)

[11]. QIU Yishu, WANG Kan, YU Jiankai, Development of Sensitivity Analysis Capability in RMC code, *Transactions of the American Nuclear Society*, 111, 737 - 740, 2014. (EI, Accession number: 20153301172100)

[12]. Wang Kan, Li Zeguang, She Ding, Liang Jin'gang, Xu Qi, Qiu Yishu, Yu Jiankai, Sun Jialong, Fan Xiao, Yu Ganglin. RMC - A Monte Carlo code for reactor core analysis, *Annals of Nuclear Energy*, In Press. (SCI, Accession number: 20151000598926)

- **International Conference Proceedings**

[1]. Yu Jiankai, et al., The Development and Validation of Nuclear Cross Section Processing Code for Reactor-RXSP, *2013 21st International Conference on Nuclear Engineering*, Chengdu, China, July 29 - August 2, 2013, American Society of Mechanical Engineers (2013). (EI, Accession number: 20142317797340)

[2]. YU Jiankai, HUO Honglei, LI Wanlin, WANG Kan, YU Ganglin, Validation of a New PURC Module for Calculating Probability Table in RXSP code, *2014 22rd International Conference on Nuclear Engineering*, Prague, Czech Republic, July 7-11, 2014, American Society of Mechanical Engineers (2014). (EI, Accession number: 20144800240864)

[3]. YU Jiankai, LI Wanlin, WANG Kan, Jasmina Vujic, Validation Study of a Continuous Energy Neutron Cross Section Library Generated using RXSP Based on ENDFBVII.0, *PHYSOR 2014 – The Role of Reactor Physics Toward a Sustainable Future*,The Westin Miyako, Kyoto, Japan, September 28 – October 3, 2014, on CD-ROM, American Nuclear Society (2014).

[4]. Jiankai YU, Jin'gang LIANG, Ganglin YU, Kan WANG, Development and Validation of the Fast Doppler Broaden Module Coupled Within RMC code, *23rd International Conference on Nuclear Engineering*, Chiba, Japan, May 17 – 21, 2015, American Society of Mechanical Engineers (2015).

[5]. Jiankai YU, Jin'gang LIANG, Kan WANG, Development of In-Line Temperature Dependent Cross Sections Processing Capability in RMC Code, *ANS 2015 Summer Meeting*, San Antonio, June 7 – 11, 2015, American Nuclear Society (2015).

[6]. Jiankai YU, Wanlin LI, Ganglin YU and Kan WANG, Research on Resonance Parameters Evaluation Based on R-Matrix Limited Formula and Code Development, *Joint International Conference on Mathematics and Computation (M&C), Supercomputing in Nuclear Applications (SNA) and Monte Carlo (M&C + SNA + MC 2015)*, Sheraton Music City, Nashville, USA, April 19-23, 2015, American Nuclear Society (2015).

[7]. Jiankai YU, Kan WANG, Peng ZHANG, Deokjung LEE, Validation of R-Matrix Limited Based Reconstruction Capability for RXSP Code, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 27-28, 2016, Korean Nuclear Society (2016).

[8]. J. Yu, H. Lee, K. Azamat, K. Wang, D. Lee, PERFORMANCE OF ON-THE-FLY CROSS SECTIONS PROCESSING IN MONTE CARLO SIMULATION CODE, 37th Annual CNS Conference, Niagara Falls, Canada, Jun 4-7, 2017 (2017).

[9]. Jiankai YU, Azamat Khassenov, Peng ZHANG, Deokjung Lee, On the Convergence issue for Multi-poles conversion from Reich-Moore Formalism, M&C 2017 - International Conference on Mathematics & Computational Methods Applied to Nuclear Science & Engineering, Jeju, Korea, April 16-20, 2017, on USB (2017)

[10]. Jiankai Yu, Hyunsuk Lee, Hanjoo Kim, Peng Zhang, Deokjung Lee, Preliminary Validation of MCS Multi-Physics Coupling Capability with CTF, Proceedings of the Reactor Physics Asia 2017 (RPHA17) Conference Chengdu, China, August. 24-25, 2017.

[11]. Jiankai Yu, Soojin Lee, Deokjung Lee, "Fuel Performance Coupling of FRAPCON within MCS", Transactions of 2017 ANS Winter Meeting, Washington, D.C., Oct. 29 - Nov. 2, (2017).

[12]. Jiankai Yu, Hanjoo Kim, Hyunsuk Lee, Matthieu Lemaire, Peng Zhang, Deokjung Lee, Verification of Monte Carlo code MCS Coupled with CTF and FRAPCON, PHYSOR 2018:

Reactor Physics paving the way towards more efficient systems, Cancun, Mexico, April 22-26, 2018.

[13]. Jiankai Yu, Sooyoung Choi, Yongmin Jo, Peng Zhang, Wanlin Li, Kan Wang, Deokjung Lee, Verification of Multi-group Covariance Data Processing MODULE in RXSP code, ANS Best Estimate Plus Uncertainty International Conference (BEPU 2018), Real Collegio, Lucca, Italy, May 13-19, 2018.

[14]. Jiankai Yu, Sooyoung Choi, Yongmin Jo, Peng Zhang, Wanlin Li, Kan Wang, Deokjung Lee, Implicit Resonance Self-Shielding Effect of Multi-Group Covariance in RXSP code, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 17-18, 2018.

[15] Jiankai Yu, Hyunsuk Lee, Peng Zhang, Deokjung Lee, Fuel Performance Analysis of BEAVRS Benchmark Cycle 1 Depletion using MCS, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 17-18, 2018.

Appendix C.

Summary of my Ph.D. Dissertation

Title:

Research on the Key Methods of Evaluation, Processing and Application of Important Nuclear Data for Reactor and Code Development

Advisor:

Professor **Kan WANG** at Department of Engineering Physics in Tsinghua University

Abstract:

The independent reactor core physical design and simulation for advanced nuclear energy system relies on the foundation of nuclear data with high accuracy. It is important and necessary for some processing procedures to be utilized in the conversion from raw nuclear data in experimental nuclear data base into the ACE-formatted point-wise nuclear data libraries, which can be applied directly in Monte Carlo based neutronics transport calculations by RMC, MCNP and some other similar codes. The domestic researches on key algorithms are limited to the copyright and licenses of these codes developed by foreign institutes, including resonance parameters evaluations, cross sections reconstruction in resolved resonance range, Doppler broadening cross sections, and the unresolved probability tables' generation and so on.

This paper is focus on the key methodologies in nuclear data evaluation, processing and application, aiming at developing the corresponding codes system with independent intellectual property rights, which content in this study is listed as follows:

1) Study the nonlinear least squares fitting method, and the latest R-Matrix approximation formula; a code named RRPE is developed to evaluate the resonance parameters in resolved resonance range.

2) In view of the resonance reconstruction module-CSP in self-developing reactor nuclear data processing code-RXSP, the deficiency of the convergence criterion in CSP module is handled to expand the R-Matrix Limited based resolved resonance cross section reconstruction.

3) Research the approaches of unresolved probability tables' generation, and develop a PURC module in the framework of RXSP code, which solves the generation efficiency in the traditional but classic algorithm with the assistant of sorting techniques optimization and OpenMP-based parallel acceleration in it.

4) The study on inner-coupling for Fast Doppler broadening cross sections with temperature dependence and RMC code is carried out, and thus RMC code has the capability of in-line Doppler broadening cross section during the Monte Carlo based neutronics transport, and thermal cross section interpolation is included as well.

Some conclusions are drawn from these above researches, which are listed as follows:

In basis of Levenberg-Marquardt method used in data fitting procedure, RRPE code is developed to have the capability of resonance parameters evaluation as accurate as SAMMY code; The improved CSP module can process R-Matrix Limited-formatted resonance parameters from evaluated nuclear data library to produce the point-wise cross sections at zero temperature with the high accuracy as much as NJOY (v2012) code; After the optimized sorting algorithm and parallel acceleration is applied, PURC module can generate probability tables by using "Ladder Sampling" approach with the accuracy as much as NJOY code, but much higher efficiency of it;

RMC code is improved by inner coupling of Fast Doppler broadening and thermal cross sections interpolations with it, which now has the capability of rapidly processing cross sections at the problem-dependent temperatures, and has a very good prospective application in neutronics-thermal hydraulic coupling calculations with many nuclides and many temperatures feedback.