IMPROVEMENTS OF CROSS SECTION LIBRARIES FOR KASKAD-S

Young-Sik CHO, Young-Ouk LEE and Jonghwa CHANG
Korea Atomic Energy Research Institute
P.O.Box 105 Yusung, Daejon, KOREA
yscho@kaeri.re.kr ; yolee@kaeri.re.kr; jhchang@kaeri.re.kr

ABSTRACT

The nuclear data preparation system for KASKAD-S is improved. KASKAD-S is the deterministic code which is used for ADS-related calculations along with the Monte Carlo code LAHET. The multigroup high-energy cross sections and stopping powers for KASKAD-S are generally prepared by the code FOROS. The calculation results using the nuclear data generated by FOROS show good agreements with the experimental data except below a few hundreds MeV where the large discrepancies are observed. Some nuclear data including the transfer matrices are currently built into the source code of FOROS, and hence the updates of nuclear data in FOROS require the elaborate modification.

The new method for generating the coupled proton-neutron data without using FOROS is developed. The processed data from NJOY and TRANSX are fed into the newly developed codes LIBBER and ANIFM to generate the coupled proton-neutron cross section libraries for KASKAD-S. With the help of these codes, up-to-date cross section data can be easily used in KASKAD-S calculations. Several benchmark calculations are performed using the newly generated data and compared with the experimental data. Our results for 30 MeV protons are in good agreement with the experimental data, which shows that our method to prepare the cross section libraries for KASKAD-S from the recently evaluated libraries is sufficiently effective for the calculation of ADS-related problem.

1. INTRODUCTION

Growing interest in the accelerator-driven system (ADS) is accompanied with development of a code system to simulate the elementary production of particles in spallation reactions and transport of these particles in the target. In the ADS, a high-power particle accelerator produces energetic protons that interact with a heavy metal target to produce neutrons. The source neutrons are generated by direct impingement of the accelerator proton beam onto a target material in a process called spallation. The spallations are subsequently multiplied in the surrounding subcritical blanket. Currently both Monte Carlo (such as LAHET[1]) and deterministic codes are taken into consideration for analyses of the static and dynamic behaviour of the system.

As a deterministic method, the discrete ordinate method gives an additional merit in comparison with Monte Carlo codes, to perform both neutronics and shielding calculations in spallation target design by decreasing computing times and memory requirements in calculation of energy, angular and spatial distributions of the spallation source and in deep penetration target shielding calculations.

KASKAD-S[2] is a deterministic two-dimensional neutral and charged particle transport code which is suitable for high-energy coupled proton-pion-neutron-photon transport simulation in the ADS. It was originally developed in Keldysh Institute of Applied Mathematics, Moscow, and transferred to the Korea Atomic Energy Research Institute (KAERI), and is currently being improved and updated for the ADS-related applications.

The multigroup high-energy cross section libraries for KASKAD-S are generally prepared by FOROS code which is a part of SADCO-2 system[3]. The FOROS code prepares multigroup cross-sections for protons, pions and neutrons in high-energy region above 20MeV in FMAC-M format[4] for KASKAD-S. It was finally updated in 1995 and our benchmark calculations showed that it gives rise to an explicit disagreement with measured data below a few hundreds MeV. Some nuclear data including the transfer matrices are currently built into the source code of FOROS, and hence the updates of nuclear data in FOROS require the elaborate modification and recompilation of the source codes. The more flexible and reasonable method for improving the nuclear data library system of KASKAD-S is a use of the code which can directly convert ANISN format, which is prepared by NJOY[5] and TRANSX[6], to FMAC_M format.

2. IMPROVEMENTS OF CROSS SECTION LIBRARIES

The code ARVES[4] is currently included in KASKAD-S package as a complementary tool of KASKAD-S to convert ANISN format to FMAC-M format. It is basically designed for the coupled neutron-photon and electron-photon libraries and is not applicable to the coupled proton-neutron libraries. We developed the code ANI2FM based on ARVES for converting the coupled proton-neutron cross section libraries in ANISN format to FMAC-M format. Stopping powers of protons are taken into account in the code ANI2FM. The auxiliary code LIBBER was also developed to post-process the TRANSX output. LIBBER can be used to edit the ANISN-formatted files. For example, stopping powers of charged particles can be easily inserted into an ANISN-formatted file with LIBBER. With these two codes, the cross section libraries for KASKAD-S can be prepared from the recently evaluated cross section libraries in ENDF format.
We prepared the cross section libraries of C-12, Fe-56, Cu-63 and Pb-208 for KASKAD-S. Those libraries were generated from ENDF/B-VI release 6 which was originally known as LA150 high energy libraries. LA150 libraries generated by Los Alamos National have nuclear data for about 30 important isotopes extending the neutron and proton energies up to 150 MeV. After processing the evaluated libraries using NJOY99 and TRANSX, stopping powers of protons calculated by SRIM2000 were added using LIBBER. The resultant ANISN file was fed into ANI2FM to generate the cross section library in FMAC-M format.

3. CALCULATION

To validate the newly prepared cross section libraries for KASKAD-S, several benchmark calculations were performed by KASKAD-S. The calculation includes the estimation of neutron production and angular distribution of secondary neutrons for thick target bombarded by 30- and 52-MeV protons. The targets were represented as cylinders in r-z geometry. The thickness and density of target are shown in Table 1. The thickness of the targets is about twice of the range of the incident proton. The proton sources were assumed to be normally incident on the bottom of cylinder. As discrete ordinates method, adaptive weighted diamond difference scheme (AWDD) was used.
The total neutron yields from our calculations together with experimental results and FOROS calculations are shown in Table II. The experimental data were obtained from the paper by T. Nakamura et al.[7] The authors pointed out that the experimental results for 52 MeV are estimated values with the assumption that the neutron flux in the backward direction is the same as that measured at $\theta = 75$ deg., since the neutron spectrum emitted into the backward direction was not

measured. For 30 MeV, It is evident that the calculation results from the newly prepared cross section libraries give better results than FOROS. For 52 MeV, the calculated values are larger than the experimentally estimated ones except that of carbon. It is not certain from where the large discrepancies resulted. Currently, the further benchmark calculations are being performed to verify the new procedure for preparing the cross section libraries for KASKAD-S.

Table I. Thickness and density of target

Target	Target Thickness		Density (g/cm^3)
	30-MeV proton (mm)	52-MeV proton (mm)	
Carbon	9.0	31.45	1.7
Iron	3.0	6.0	7.86
Copper	3.0	8.2	8.93
Lead	3.0	10.0	11.34

Table II. Total neutron yield

	30 MeV			52 MeV		
	NJOY/ TRANSX/ ANI2FM/ KASKAD-S	FOROS/ KASKAD-S	Experimental results	NJOY/ TRANSX/ ANI2FM/ KASKAD-S	FOROS/ KASKAD-S	Experimental Results (Estimated)
Carbon	2.62 x 10^{-4}	4.52 x 10^{-3}	1.14 x 10^{-3}	7.53 x 10^{-3}	1.82 x 10^{-2}	~7.58 x 10^{-3}
Iron	9.32 x 10^{-3}	7.45 x 10^{-3}	9.90 x 10^{-3}	4.85 x 10^{-2}	4.33 x 10^{-2}	~2.04 x 10^{-2}
Copper	1.12 x 10^{-2}	2.86 x 10^{-3}	1.21 x 10^{-2}	6.76 x 10^{-2}	1.08 x 10^{-2}	~2.45 x 10^{-2}
Lead	1.84 x 10^{-2}	9.47 x 10^{-3}	1.73 x 10^{-2}	1.12 x 10^{-1}	8.00 x 10^{-2}	~3.05 x 10^{-2}

Figures 1, 2, 3 and 4 show the calculated energy spectra of neutrons at 0^{o} emission angle along with the experimental ones for carbon, iron, copper and lead respectively. The discrepancy between the calculations and experimental data is large at lower energies, but it decreases at higher energies except carbon. The comparison for carbon shows the discrepancy increases at higher energy contrary to other results. The large disagreement at total neutron yield for carbon is attributed to the large discrepancy of neutron flux at higher energies. By overall comparison, it is evident that this work gives a better result than FOROS/KASKAD-S calculation. The agreement between the calculated and measured data is relatively good especially for copper.

4. CONCLUSION

In designing the ADS, it is important to get accurate information on the neutron yields and energy distributions. The development of the new procedure to prepare the cross section libraries for KASKAD-S from the evaluated libraries aimed at the improvement of an accuracy of KASKAD-S calculations by making use of the recent developments of high-energy cross sections libraries.

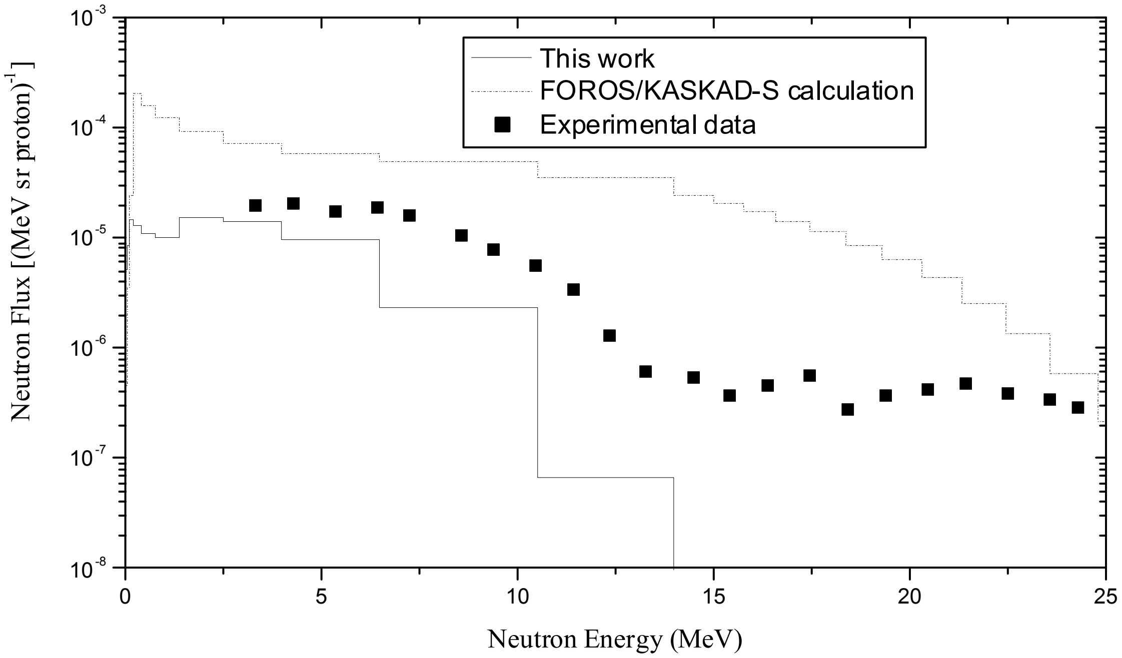

Fig. 1. Energy spectra of neutrons for the carbon target bombarded by 30 MeV protons at 0^o emission angle.

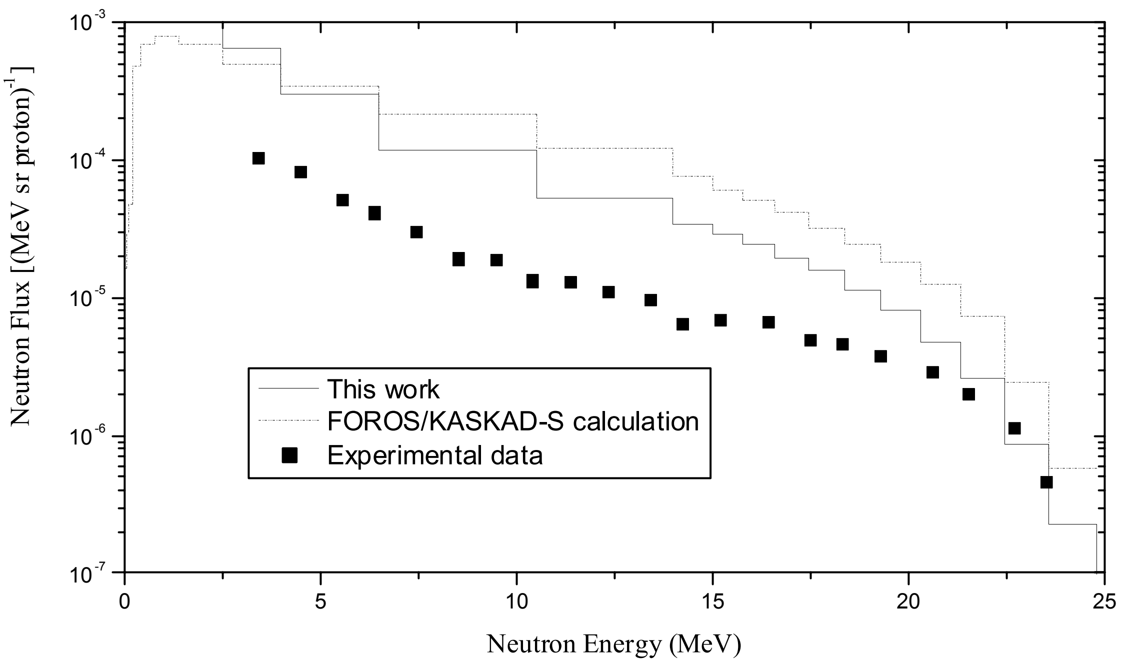

Fig. 2. Energy spectra of neutrons for the iron target bombarded by 30 MeV protons at 0^o emission angle.

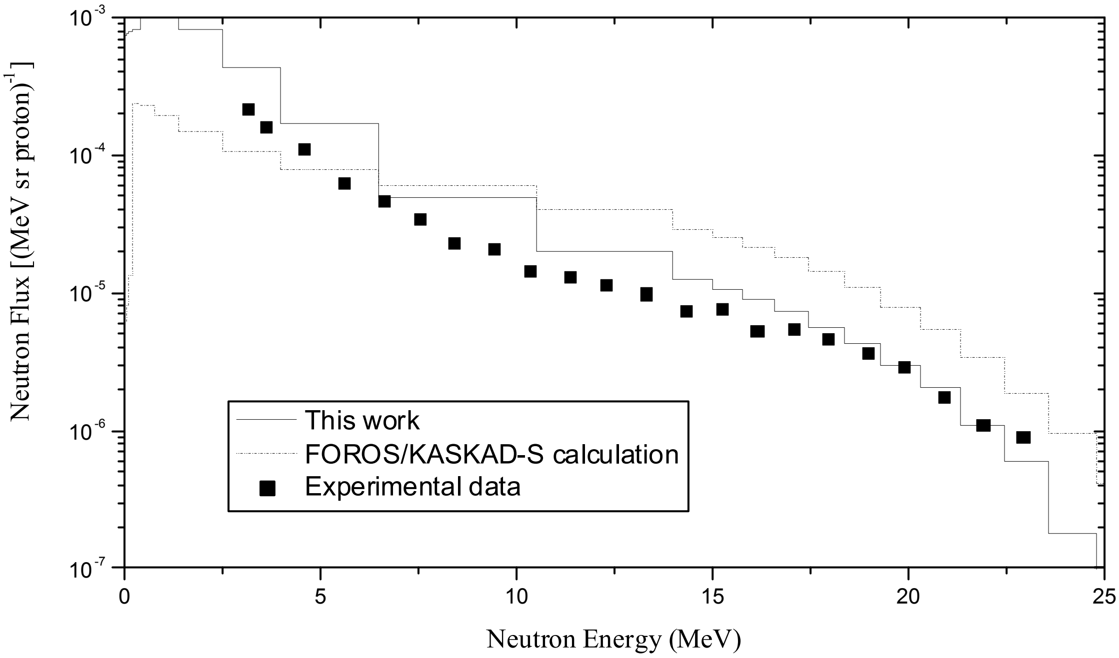

Fig. 3. Energy spectra of neutrons for the copper target bombarded by 30 MeV protons at 0^o emission angle.

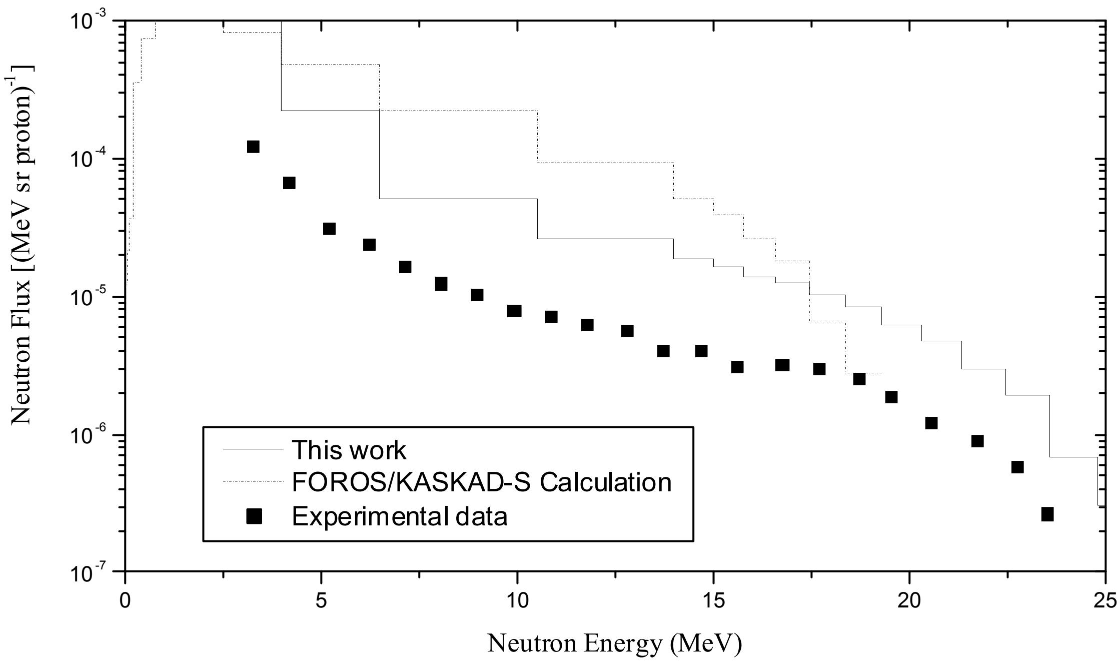

Fig. 4. Energy spectra of neutrons for the lead target bombarded by 30 MeV protons at 0^o emission angle.

Calculated total neutron yields and the neutron spectra for C-12, Fe-56, Cu-63 and Pb-208 for energies up to 52 MeV with the updated libraries were compared with the experimental data. The calculations show that the new libraries give a much better agreement with the experimental data for 30 MeV, while the discrepancy between the calculation and experiment is large for 52 MeV. Currently, the further improvement of nuclear data preparation system along with the benchmark calculations is being performed and compared with the experimental data above 30 MeV.

REFERENCES

1. R. E. Prael and H. Lichtenstein, "User Guide to LCS: The LAHET Code System," LA-UR-89-3014, Los Alamos National Laboratory (1989)
2. A. M. Voloschenko and A. V. Shwetsov, "KASKAD-S-2.0 – Tow-Dimensional Discrete-Ordinates Neutron, Photon and Charged Particles Transport Code," User's Guide, Report No. 7-2-2000, Keldysh Inst. of Appl. Math., Moscow (2000).
3. D. V. Gorbatkov and V. P. Kryuchkov, "SADCO-2: A Modular Code System for Generating Coupled Nuclear Data Libraries to Provide High-Energy Particle Transport Calculation by Multigroup Methods," *Nucl. Instr. & Meth. in Phys. Res.*, **A 372**, pp. 297 (1996).
4. A. M. Voloschenko, S. V. Gukov and A. V. Shwetsov, "ARVES-2 - a Package of Utilities for FMAC-M Format: a Multigroup Macroscopic Cross-section Format for Discrete-ordinates Transport Codes," User's Guide, Report No. 7-3-2000, Keldysh Inst. of Appl. Math., Moscow (2000)
5. R. E. MacFarlane and D. W. Muir, "The NJOY Data Processing System Version 91," LA-12740-M (1994).
6. R. E. MacFarlane, "TRANSX 2: A Code for Interfacing MATXS Cross-Section Libraries to Nuclear Transport Codes," LA-12312-MS (1992).
7. T. Nakamura, M. Fujii and K. Shin, "Neutron Production from Thick Targets of Carbon, Iron, Copper, and Lead by 30- and 52-MeV Protons," *Nuclear Science and Engineering*, **83**, pp. 444-458 (1983).