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ADJUSTMENT OF IRON CROSS SECTION USING AN INTEGRAL EXPERIMENT

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Abstract: Adjustment of iron cross sections to the integral data of the pulsed sphere experiment at LLNL was carried out by the least square method. The SUSD code system was used for generating sensitivity coefficients and covariances including the effects of the secondary neutron energy distribution. The adjustment of both excitation functions and secondary neutron energy distributions gave successful results. The method is very useful for deriving quantitative accuracy of microscopic data from the integral experiment.

(adjustment, iron, neutron cross sections, integral experiment, secondary neutron energy distribution, covariance)

Introduction

Integral experiments are very important for assessing the accuracy of the cross sections. A large numbers of integral experiments were carried out, but the results were not well utilized by the evaluators of data libraries. The reason would be that only qualitative information on the accuracy of the cross sections had been given from the analysis of the experiments. It is necessary to derive quantitative accuracy of the microscopic cross sections from the analysis.

For the purpose, we proposed the method and carried out adjustment of iron cross sections to an integral experiment data using the SUSD code system.

SUSD code system

SUSD is the computer code system for cross-section sensitivity-uncertainty analysis including the effect of SED (secondary neutron angular distribution) and SAD (secondary neutron angular distribution)/1/. The code calculates sensitivity coefficients for one and two-dimensional transport problems based on the first order perturbation theory. Variance and standard deviation of detector responses or design parameters can be obtained using the cross section covariance matrix. The structures of the SUSD code system is depicted in Fig.1.

Covariance of Li-6 and Li-7 neutron cross sections of JENDL-3PR1 were eveluated including SED and SAD/2/. Covariances of Fe and Be were also evaluated.

The uncertainty of tritium breeding ratio (TBR), fast neutron leakage flux and neutron heating were analysed on four types of blanket concepts for commercial tokamak fusion reactors. The collective standard deviation was 2-4% in TBR, 10-20% in the fast neutron leakage flux and 2-3% in the neutron heating. Contributions from SAD/SED uncertainties were found to be significant. The types of the reactions contributing to the uncertainty were also identified/3/.

The SUSD code system was used for generating the sensitivity coefficients and the covariance matrices for the present study.

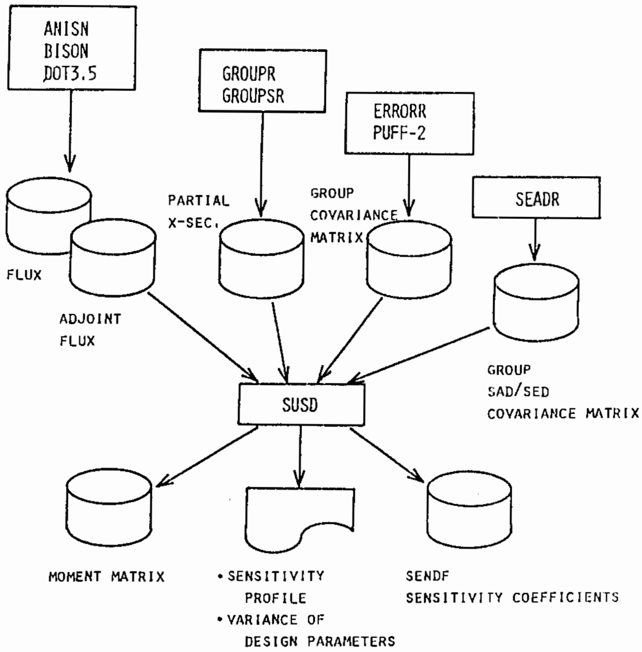

Fig.1 SUSD code system

Method of Adjustment

Least square method was used for the adjustment. The following quantity, Q is minimized to obtain the adjusted quantity.

$$Q = \sum_i \sum_j (\sum_k S_{ik}\Delta x_k - \Delta I_i) V_{ij}^{-1} (\sum_k S_{jk}\Delta x_k - \Delta I_j) + \sum_i \sum_j \Delta x_i \rho_{ij} \Delta x_j$$

where

ΔI_i is the differnce between experimental and calculated response,
V_{ij} is the covariance of response, I_i and I_j,
ρ_{ij} is the covariance of the cross sections, x_i and x_j,
S_{ik} is the sensitivity coefficient of the response I_i to the cross section of type k,
Δx_k is the adjusted quantity of the cross section of type k.

Adjustment of iron cross section

As an integral experiment for the analysis, we used the pulsed sphere experiment of iron which was carried out at LLNL/4/. The radius of the sphere was 22.30 cm, 4.76 mfp. The DT fusion neutrons were generated at the center of the sphere. The leakage neutron spectrum was measured between 2 MeV and 15 MeV by the time of flight method using the detectors located at 30 and 120 degrees from the beam line.

In the present study, the spectrum at the detector position (120 degrees from the beam-line) was analysed by the continuous energy Monte Carlo code, MCNP and the cross section from JENDL-3PR1. Point detector estimator was used. The angular dependence of the source neutron energy and yield was taken into account. The spectrum was bunched in 26 energy groups and used as the calculated response. The measured spectrum was also bunched in 26 groups and the difference between the calculated and experimental responses was used for the adjustment.

The procedure of the adjustment is described in Fig.2. The forward and adjoint flux were calculated by the one-dimensional BISON code which was incorporated in SUSD. The sensitivity coefficients were obtained based on the first order perturbation theory. MCNP was not used for the calculation of the sensitivity coefficients, because it did not have the adjoint calculation capability. In the BISON calculation, the leakage flux from the sphere surface was used as the response instead of the current flux, in order to improve the convergence. The difference of the sensitivity coefficients due to this approximation was found to be less than 15%.

The reaction types which had high sensitivity to the responses were as follows,

a. 14 - 12 MeV flux
   elastic(15-13.4 MeV, 13.4-11.8 MeV) and 0.85 MeV level inelastic
b. 12 - 10 MeV flux
   elastic(13.4-11.8 MeV),0.85,1.40,2.08,2.66, 2.94,3.12,3.35,3.45,3.60 MeV level inelastic
c. 9 - 7.5 MeV flux
   3.80,4.50 MeV level and continuum level inelastic
d. 7 MeV - flux
   continuum level inelastic

The covariances of the responses and the cross sections were necessary for the adjustment. Only the variances were used in this study. This assumption relaxed the restraints and gave the largest adjusted quantity. The statistical uncertainty of the MCNP calculation was used for determining the variance, V of the response, because it was larger than the uncertainty of the measured spectrum. The variance of the iron cross section was calculated using SUSD and the covariance file which was evaluated by us. The variances were 10% for elestic, 15% for inelastic (both discrete and continuum) and 20% for (n,2n) reactions.

The adjustment was carried out using the variances, the sensitivity coefficients and the experimental and calculated responses. The adjusted cross sections which showed large change were summarized in Table.1. Almost all cross sections were increased between 15 and 13.4 MeV.

The experiment was analysed again by MCNP based on the adjusted cross sections. For the purpose, it was necessary for preparing the point-wise cross sections from the group-wise adjusted cross sections. They were generated as follows.

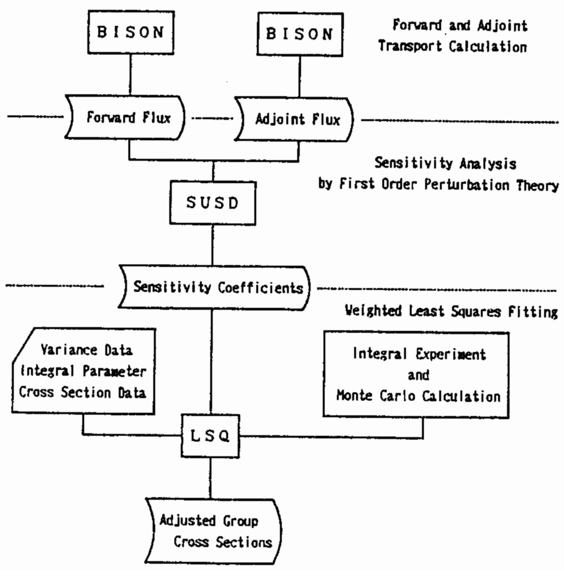

Fig.2 Flow chart of cross section adjustment

Table 1 Change of cross sections after adjustment

Reaction type	Energy (MeV)	ΔX/X (%)
elastic	15.0 - 13.4	+ 1.5
	13.4 - 11.8	+ 5.3
inelastic (level)		
0.8 MeV	15.0 - 13.4	+ 7.8
	13.4 - 11.8	+ 4.8
2.1 MeV	15.0 - 13.4	+ 15.0
2.6 MeV	15.0 - 13.4	+ 10.0
2.9 MeV	15.0 - 13.4	+ 8.0
3.6 MeV	15.0 - 13.4	+ 10.0
3.8 MeV	15.0 - 13.4	+ 8.8
4.1 MeV	15.0 - 13.4	+ 9.1
4.2 MeV	15.0 - 13.4	+ 9.0
4.4 MeV	15.0 - 13.4	+ 7.5
4.5 MeV	15.0 - 13.4	+ 64.6
	13.4 - 11.8	+ 1.0
inelastic (continuum)	15.0 - 13.4	+ 3.0

(1) The cross section values of JENDL-3PR1 at 14 MeV and 15 MeV were changed uniformly according to the results of Table 1. The data at 12 and 13 MeV were also changed for the elastic, 0.85 MeV and 4.5 MeV level inelastic and continuum level inelastic reactions.
(2) In order to conserve the value of the total cross section, the sum of the adjusted values were subtracted from the (n,alpha) cross sections, which seemed to have the largest uncertainty.

The calculated spectrum after the adjustment was compared with that before the adjustment in Fig.3. The experimental spectrum was also shown in the figure. Improvement of the spectrum was observed at 9-11 MeV. This verified that the discrete and the continuum level inelastic scattering cross sections were properly adjusted. The disagreement was still observed between 8.5 and 6 MeV. The sensitivity of the 4.5 MeV level and continuum inelastic cross sections was high in this energy. The change of the 4.5 MeV level cross sections reached to 64%, but there still remained large discrepancy. This indicated that it was necessary to adjust the secondary neutron energy distributions (SED).

We carried out the adjustment again, including the SED of the continuum level inelastic scattering cross sections together with the excitation functions, the cross section values. The adjusted SEDs for the incident energies of 14 MeV and 15 MeV are depicted in Fig.4 and Fig.5 respectively. The experiment was analysed again using the adjusted data and MCNP. The result is shown in Fig.6. The spectrum after the adjustment agrees well with the experimental one within the calculational and experimental errors. This indicates the validity of the adjustment procedures.

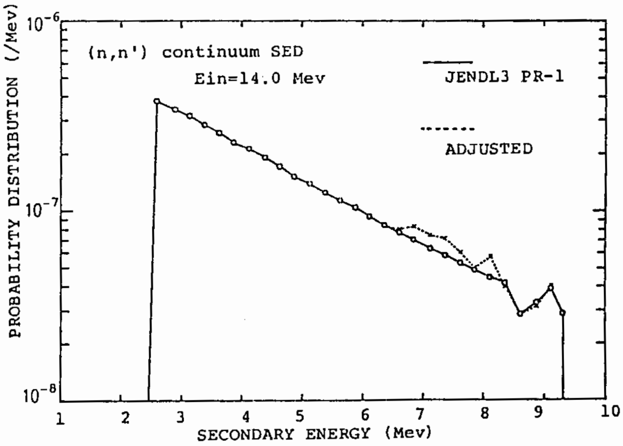

Fig.4 Comparison between original and adjusted SED of continuum(n,n')

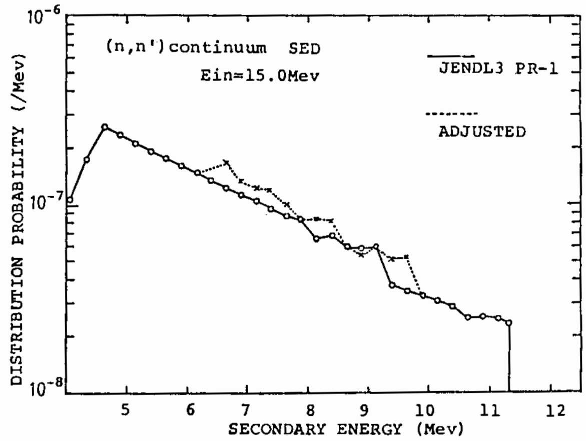

Fig.5 Comparison between original and adjusted SED of continuum(n,n')

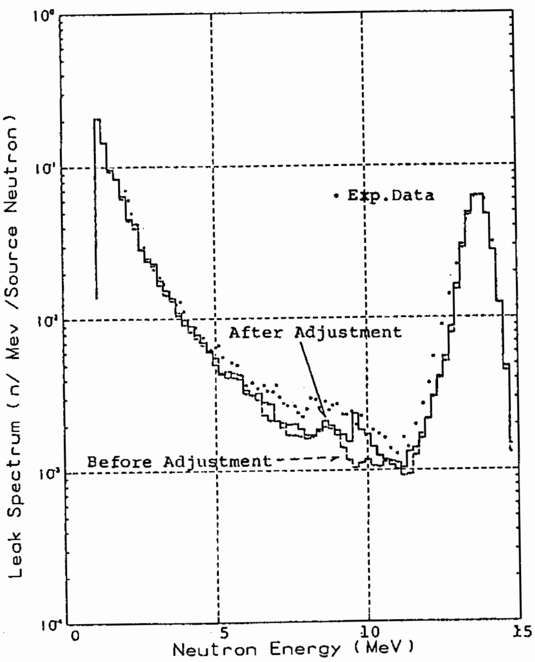

Fig.3 Comparison of calculated specta using original and adjusted data(only excitation functions adjusted)

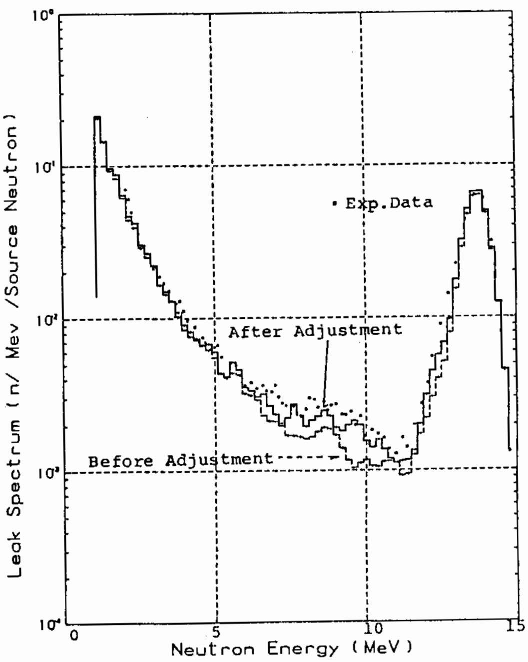

Fig.6 Comparison of calculated spectra using original and adjusted data(both excitation functions and SED adjusted)

Summary

Adjustment of the iron cross sections was carried out for deriving quantitative accuracy from the analysis of the integral experiment. The adjustment of only excitation functions was not successful, but the adjustment of both the excitation functions and the secondary neutron energy distributions gave successful agreement with the experiment. The method is useful for deriving the change of the microscopic cross sections from the integral experiement data which have not been well utilized by the evaluators of the present cross section libraries. For more elaborate adjustment, the utilization of chi-square examination will be remained for future study.

REFERENCES

1. K.Furuta et al.,UTNL-R-0185(1986)(Japanese),ORNL-RSIC-CCC501(1987)(English).
2. K.Furuta et al.,UTNL-R-0167(1984).
3. K.Furuta et al.,Nucl.Eng.Design/Fusion 3, 287(1986).
4. L.F.Hansen et al.,Nucl.Sci.Eng.51,278 (1973).