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Abstract

This paper documents the results obtained in an adjustment study of cross-section parameters as well as k_{eff} responses of 19 spherical plutonium critical assemblies, utilizing the new TSURFER (Tool for Sensitivity/Uncertainty Analysis of Response Functionals Using Experimental Results) module in the SCALE 5.1 sensitivity and uncertainty analysis methodology to be released in CY 2006. Special attention was devoted to the sensitivity of the results to the available variance-covariance data and supplements for the responses and parameters.

KEYWORDS: Adjustment, variance-covariance matrices, uncertainties, plutonium critical assemblies

1. Introduction

The Generalized Linear Least Squares Methodology (GLLSM) is implemented in the TSURFER module of the SCALE 5.1 system [1] to be released in CY 2006. The methodology utilizes the measured values of **responses, *r*,** such as k_{eff}, and reaction rates, as well as their respective uncertainties, given as a variance-covariance matrix, C_r. Also used is a series of **parameters, *p*,** such as cross sections, number of neutrons emitted in fission, and fission spectra, as well as their respective uncertainties, given as a variance-covariance matrix, C_p. Both the responses and the parameters are represented as vectors of different dimensions corresponding to the respective number of responses and the number of parameters, and the uncertainties are square matrices of corresponding dimensions. The methodology combines the information and results in the reduction of the uncertainties of both responses and parameters. These modified parameters, having a smaller uncertainty, are used in turn to predict k_{eff} values in criticality safety applications and provide an estimate for the bias in the computations.

The modified parameter and response values [2] are

$$p' = p - C_p S^{\dagger} C_d^{-1} d \ , \quad r' = r + C_r C_d^{-1} d \ , \tag{1}$$

where $d = \bar{r}(p) - r$ is the deviation vector of the calculated response values from their respective measured values. The matrices denoted by C are the respective variance-covariance matrices or "uncertainties," where

$$C_d = C_{\bar{r}} + C_r - C_{\bar{r}r} - C_{r\bar{r}} = S\,C_p S^{\dagger} + C_r - S\,C_{pr} - C_{rp} S^{\dagger} \ . \tag{2}$$

The matrices S are the sensitivities of the responses to the parameters, while the matrix C_{rp} and its transpose C_{pr} represent possible parameter-response correlations. Usually such a priori correlations are not present in reality and can be omitted.

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The new uncertainties in the modified (i.e., adjusted) parameters and in the adjusted responses and the resulting new correlations (this time also between adjusted parameters and adjusted responses) are given by

$$C_{p'} = C_p - C_p S^{\dagger} C_d^{-1} S C_p, C_{r'} = C_r - C_r C_d^{-1} C_r, C_{p'r'} = C_p S^{\dagger} C_d^{-1} C_r \quad . \tag{3}$$

Since the uncertainty matrices are, by their definition as variance-covariance matrices, positive definite, the uncertainties are reduced in such a campaign. The consistency of all data used is given by chi square, which in our case reduces to the simple form of $\chi^2 = d^{\dagger} C_d^{-1} d$.

The work described here is the analysis of the dependency of the adjustment results on various features and assumptions in such a process utilizing the TSURFER module. The analysis involves 19 bare and reflected benchmark metallic spherical plutonium cores. In particular, the sensitivity of the results to the representation of the response uncertainty correlations was checked, as well as to the procedures used to supplement missing parameter uncertainties. In this extended summary we present only results of the sensitivity of the k_{eff} responses to the supplemented parameter uncertainties.

2. Parameter Uncertainty Information

The parameter uncertainty information is obtained by the TSURFER module from a filename specified in the input. Our analysis used the covariance files generated by PUFF-III from ENDF/B-V and supplemented by ANL files. The TSURFER module looks for the uncertainty files needed according to the sensitivities of each response. When the sensitivity is greater than a given threshold value, 0.001 in our case, and there is no variance-covariance matrix available in the parameter uncertainty file, TSURFER generates its own covariance matrix with a given uniform **D**efault relative **S**tandard **D**eviation, DSD, and a **D**efault **CO**rrelation for adjacent groups, DCO. The uncertainty file used in this work does not have covariance matrices for quite a few nuclide-reaction pairs. For instance, the file is missing elastic scattering covariance matrices for various plutonium isotopes and for carbon, as well as fission spectrum covariance matrices for the higher plutonium isotopes. Since the fission spectra, being normalized to one, have strong anticorrelations and the elastic scattering may have a positive correlation with neighboring energy groups, the DCO parameter was set to zero (i.e., no correlations). The sensitivity of TSURFER results to the DSD value was tested and is depicted in Figs. 1 and 2. The DSD values of 10, 5, and 0% (i.e., the standard deviations of the cross sections or the fission spectra are 10, 5, or 0) vary the adjusted k_{eff} values only slightly. In Fig. 1, the adjusted k_{eff} values for all 19 systems are given for the three DSD values. Since three systems with high k_{eff} values that deviated significantly from one had to be rejected from our analysis, as will be explained in the full paper, Fig. 2 zooms in on the adjusted k_{eff} values for the first 15 systems (the last system is not plotted). It was decided that a DSD value of 5% will be used for the rest of the analysis since this value is still reasonable for fission spectra and also for the elastic scattering and because the results do not deviate by much from the 0% case.

3. Conclusion

An adjustment study of 19 plutonium benchmark critical assemblies indicated that the parameter (cross-section) data base and response (k_{eff}) data base are not consistent. The rejection of the least-consistent assemblies from the campaign resulted in a consistent set of critical assemblies on which the importance of the correlations of the responses was tested.

Figure 1: The sensitivity of adjusted (k_{eff}-1) values to DSD.

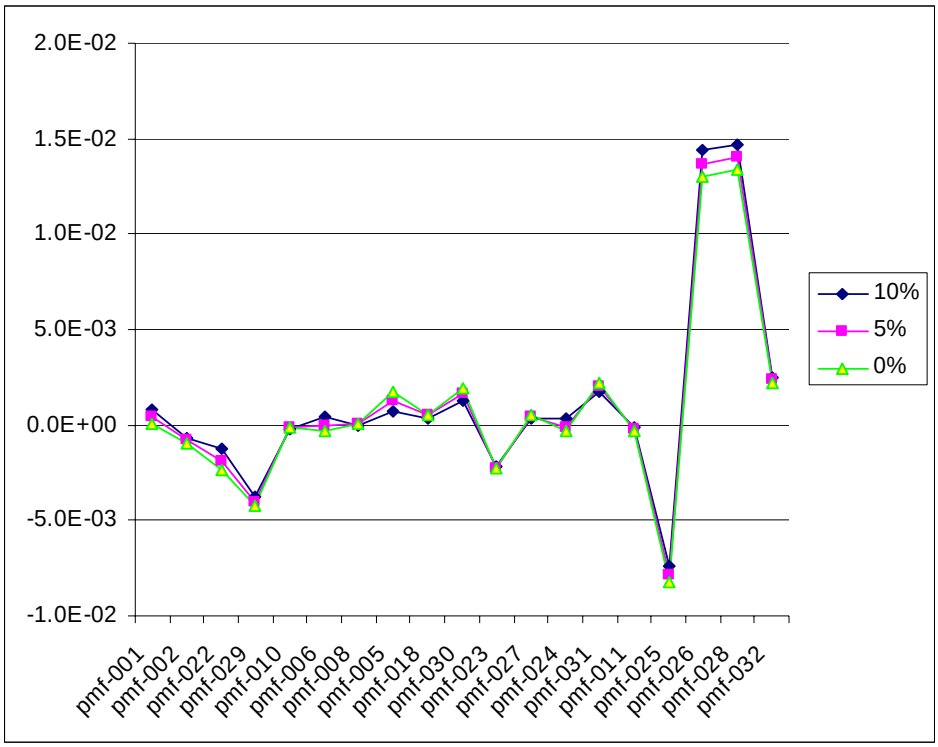

Figure 2: The sensitivity of adjusted (k_{eff}-1) values to DSD (zoom).

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