一般セッション | III. 核分裂工学：301-1 炉物理，核データの利用，臨界安全

2024年9月12日(木) 16:55 ~ 17:45 D会場(講義棟A棟1F A106)

[2D18-20] 臨界実験計画

座長:三澤 毅(京大)

16:55 ~ 17:10

[2D18]

Exploring critical experimental configurations in the STACY facility based on a phenomenological parametrization of the Keff sensitivity profiles.

*Benjamin Dechenaux[1], Mariya Brovchenko[1], Satoshi Gunji[2], Shouhei Araki[2] (1. Institut de Radioprotection et de Sûreté Nucléaire (IRSN - France), 2. Japan Atomic Energy Agency (JAEA), Nuclear Safety Research Center)

17:10 ~ 17:25

[2D19]

TEX-MOX experiments: final design of critical experiments to mimic MOX fuel in low moderation conditions

*Mariya Brovchenko[1] (1. Institut de Radioprotection et de sûreté nucléaire (IRSN), France)

17:25 ~ 17:40

[2D20]

不確かさ低減に有効な積分実験の特定方法

*方野 量太[1]、福島 昌宏[1]、卞 哲浩[2] (1. JAEA、2. 京大複合研)

17:40 ~ 17:45

座長持ち時間

Exploring Critical Experimental Configurations in the STACY Facility Based on a Phenomenological Parametrization of the Keff Sensitivity Profiles

*Benjamin Dechenaux[1], Mariya Brovchenko[1], Satoshi Gunji[2], Shouhei Araki[2]
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In the context of a longstanding collaboration between JAEA and IRSN, an innovative methodology, devised at IRSN, has been transposed to the design of critical experiments. Providing a parametrization of Keff sensitivity energy profiles to nuclear data, it is shown how the methodology proposed can serve as a powerful companion for the design of critical experiments, in the new STACY facility to validate neutronic simulations with heterogeneous moderation repartition.
Keywords: criticality safety, critical experiment, new STACY facility, missing fuel rods

1. Introduction

A methodology has recently been devised [1], that allows for a phenomenological description of the reactivity variations found for a fuel assembly in which fuel rods are removed at random positions. It has indeed been shown that for an (isolated) fuel assembly, a pair of variables is sufficient to completely describe the reactivity variations introduced by the random nature of the problem. This pair (N,S) is constructed as follows,

- N is the number of fuel pins withdrawn from the fuel assembly and corresponds to a measure of the global moderation ratio of the problem;
- S is constructed by counting the number of edges on the fuel assembly's lattice that marks the boundary between a lattice mesh element containing fuel and one that's empty (i.e. containing only water).

Subsequent work [2] has shown that this parametrization of the reactivity is accompanied by (and therefore can be explained by) a parametrization of the Keff sensitivity energy profiles to nuclear data associated of the problem.
These sensitivity profiles are important data in the realm of integral experiments, and this latter result therefore point towards a new and unforeseen application of the method initially proposed for criticality safety assessments, namely the design of critical integral experiments.

2. Application to the design of critical experiments in the new STACY facility

The new STACY facility [3] is a particularly adapted candidate to benchmark the applicability of the method developed at IRSN in the context of the design of critical experiments. Because the experiment is composed of a rectangular lattice of fuel rods, the pair of variables (N,S) introduced above form an adapted coordinate system to describe and pave the space of all of the possible experimental configurations. As such, they prove a convenient and powerful companion to help the design of integral experiments. The present work will therefore aim at showing how the coordinates (N,S) form an interesting asset to design critical experiment that match the need for validation of simulations codes and methods, in particular for systems with heterogeneous repartition of the moderation.

References

[1] B. Dechenaux et al., *Criticality Safety of Fuel Assemblies with Missing Fuel Rods*, Annals of Nuclear Energy, 198, 110273 (2024).
[2] B. Dechenaux, *Sensitivities of Configurations with Missing Fuel Rods*, Proceedings of the PHYSOR Conference, San-Francisco, USA (2024).
[3] S. Gunji et al., "Study on the Basic Core Analysis of the New STACY," Proceedings of the ICNC2023 Conference, Sendai, Japan (2023).

TEX-MOX experiments: final design of critical experiments to mimic MOX fuel in low moderation conditions

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Abstract

The critical experiments with uranium-plutonium fuel in the intermediate energy range are needed to validate neutronic simulation for criticality safety for instance of the wet MOX powder. Three experiments using available ZPPR fuel plates at NCERC were designed to represent industrial configurations and minimize expected experimental uncertainties.

Keywords: MOX fuel, critical experiments, intermediate energy range, cooling system

1. Introduction

In the French MOX fuel cycle, several configurations considered in criticality safety are lacking in experimental validation. The goal of the TEX-MOX experiments [1] is to fill these gaps using existing fuel plates on the Planet vertical lift machine at the NCERC (National Criticality Experiments Research Center) in USA. First, a neutronic optimization allowed to maximize the representativity of these experiments compared to criticality safety configurations. Then, the thermo-mechanical issues of the design were addressed to ensure the feasibility and allowing to minimize the expected experimental uncertainties.

2. Representativity of industrial cases using the k_{eff} sensitivity to nuclear data

Three experiments were designed to provide a high k_{eff} sensitivity to ^{239}Pu and ^{240}Pu in the intermediate energy range, comparable to the sensitivities corresponding to the criticality safety validation needs in French nuclear facilities. This analysis was based using global and partial representativity coefficients C_k, using nuclear data covariance data, and SSR (Shared Sensitivity Ratio) [2], using only the sensitivity vectors, for specific target isotope-reaction couples identified as the most important in the validation of the industrial cases simulations.

3. Thermo-mechanical design

The decay heat produced by the mixed uranium-plutonium metallic plates that will be used in the experiments challenged the mechanical design that was optimized to handle this issue. An air intake cooling system was integrated in the aluminum support plates under each fuel layer. To maintain the temperature as low as possible (<40°C) and to have a small thermal gradient within the configurations, an active cooling system was designed and will be tested in September 2024. Additionally, the temperature distribution within the stack will be measured with fiber Bragg grating. Finally, the number of fuel layers (up to 24) and its large dimensions (> 50cm), challenged the mechanical solutions of the support plates and Planet table to minimize vertical gaps and ensure a good alignment of the stack. The experiments are planned to be executed in 2025 at NCERC, and the following experimental evaluation will undergo the ICSBEP review. In this paper will be presented the final design of the experiments along with their main characteristics as expected uncertainties, k_{eff} sensitivities to nuclear data, mechanical design of the cooling system and temperature measurements.

References

[1] M. Brovchenko, J. Bez, M. Daury, J.-C. Latche, Design of TEX-MOX critical experiments varying neutron spectrum, ICNC 2023 – The 12th International Conference on Nuclear Criticality Safety, October 1-6 in Sendai, Japan

[2] M. Brovchenko, N. Arphant, Similarity of the PMM-2 critical experiments and criticality safety cases based on the k_{eff} sensitivity analysis, ANS Winter Meeting 2021, November 30–December 3, 2021, Washington, USA

不確かさ低減に有効な積分実験の特定

Method for identifying integral experiments effective for uncertainty evaluation.

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拡張バイアス因子法とスパースモデリングに着目し、データベースから核データ検証および設計値の核データ起因不確かさ低減に有効な積分実験を特定する方法を考案した。本提案手法を用いると少数で重要な積分実験を効率的に選択できることが期待される。

キーワード：拡張バイアス因子法, スパースモデリング, Lasso, 核データ起因不確かさ, 積分実験

1. 緒言　断面積調整法は、積分実験データを活用して設計対象システムの予測値の核データに起因する不確かさの低減を図る方法である。より多くの積分実験データを活用することで不確かさの改善が期待できる一方、どの積分実験データが有効かは理論式からは特定できない。設計で着目すべき実験はどれか、あるいは核データ検証に重要な実験はどれかを説明するためには、本質的に有効な積分実験データの特定が重要となる。ここで、将来的に実施すべき積分実験のうち、より有効な少数の実験が特定できれば、効率的な実験計画が立案できる（図 1）。本研究では、拡張バイアス因子法に Lasso 推定と呼ばれるスパースモデリング手法を組み合わせ、そのような特定を行う方法を提案する。

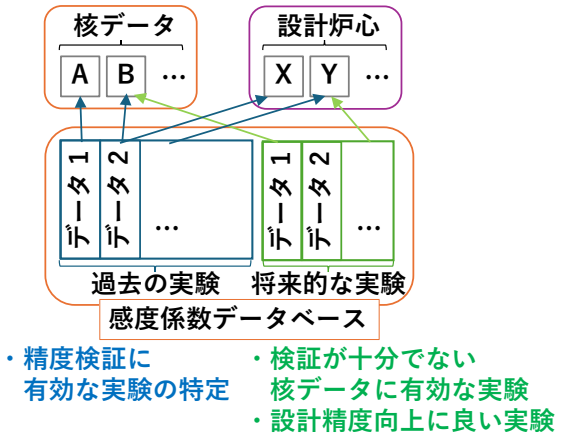

図 1 提案手法活用例

2. 手法　上述の問題は、多数の中からいくつかを選ぶ組み合わせ最適化問題となり、膨大な計算が必要になる。そこで本検討では、次のような方法を提案する。まず、断面積調整法を適用したときに得られる設計対象パラメータの不確かさが、拡張バイアス因子法によるそれと等しいことを示す。拡張バイアス因子法では、複数の積分実験データを結合した仮想的な単一の積分実験を考え、設計対象パラメータの不確かさ低減効果が最大となる結合係数を求める問題を解く。この問題はある目的関数の最小化問題として定式化できるが、Lasso 推定の援用（式(1)）によってスパースな結合係数が得られ、非ゼロ要素に対応する積分実験が不確かさの低減に有効であることが特定される。以上の方法により、複雑な組み合わせ問題をある目的関数の最小化問題に変換することができる。α は非ゼロ要素数を調整するパラメータであり、 α を大きくするほどより少数の実験が有効なものとして選択される。

$$J(x) \equiv -gMG^T x + \frac{1}{2}x^T(GMG^T + V_{e+m})x + \alpha \sum_k w_k |x_k| \quad (1)$$

g: 設計対象感度係数ベクトル,
x: 結合係数ベクトル,
k: 積分実験インデックス,
w_k: 適当な重み(詳細は発表時),
α: ハイパーパラメータ,
他の記号は典型的なそれと同じ

3. 応用例　相対感度係数の定義は、核データの相対変化量に対する設計パラメータの相対変化量として定義される。したがって、ある核データに対応する要素に 1 を持つベクトルを式(1)のg に取れば、核データ自体を設計対象パラメータとみなすことができ、提案方法によって核データ検証に有効な積分実験データの特定が可能となる。発表では、^{237}Np 捕獲断面積などのいくつかの核データに対する提案方法の応用例を示す予定である。

謝辞　本研究は JSPS 科研費（24K08301）の助成による。

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