Preface

Nuclear reactor design is based on knowledge and data from many nuclear engineering fields including nuclear reactor physics, nuclear thermal hydraulics, and nuclear safety.

In nuclear reactor design, reactor performance is evaluated by numerical analysis for requirements of nuclear and thermal limitations, stability, controllability, and safety, referred to as conceptual design. To approximate reactor performance, the design then proceeds to hardware design of reactor facilities using knowledge from mechanical engineering, electrical engineering, and nuclear structural engineering. The consequent reactor power plant facilities are mainly described in another textbook of this series titled Nuclear Plant Engineering. Knowledge of nuclear reactor fuel and materials is referenced in the conceptual design for reactor performance and in the hardware design which include in particular the fuel assemblies, reactor vessel, and its internal structures. The conceptual and hardware designs may be repeated if necessary.

To understand nuclear reactor design, it is necessary not only to be aware of the structures and compositions of the facilities constructed by the conceptual and hardware designs but also to comprehend the processes and methods used to reach the nuclear reactor design. This book describes an approach to design and calculation methods, focused on core design. Many pages have been devoted to core calculation methods and light water reactor core design. We hope that this book will help professionals as well as beginners understand and review the methods and core design.

Features of each chapter are summarized as follows.

"Fuel Burnup and Reactivity Control" of Chap. 1 is not only a key component of nuclear reactor physics but also of core design, reactor operation management, and safety. Details, including calculation methods, are described. Because the textbook of this series titled *Nuclear Reactor Physics* does not cover the topics in this chapter, it is recommended that readers interested in nuclear reactor physics read Chap. 1.

Section 2.1, "Nuclear Design Calculation," first describes nuclear data and neutron cross sections and their processing methods for the nuclear calculation.

Next, the lattice calculation, lattice burnup calculation, core diffusion calculation, nuclear and thermal-hydraulic-coupled calculation, core burnup calculation, and space-dependent kinetics calculation are described. From this description, readers will be able to understand the nuclear design calculation methods used in practice. Section 2.2, “Reactor Core, Plant Dynamics and Safety Calculations,” is intended to provide an understanding of the key points of plant dynamics and safety calculation methods as well as core calculation methods. Core design calculations are performed to determine core characteristics at normal conditions in combination with nuclear and thermal-hydraulic calculations. The single-channel thermal-hydraulic calculation model with fuel rods and its hydraulic equivalent coolant path provides the simplest model for heat transfer flow of the core beyond the fuel rods. The three-dimensional nuclear and thermal-hydraulic-coupled core burnup calculation, in combination with nuclear and heat transfer calculations, is used in core management as well as core design. The plant dynamics calculation is concerned with plant control, stability, and safety analysis. First, the node junction model, which is a basic model for the heat transfer calculation in the plant system including the reactor, coolant pipes, valves, and pumps, is described and then reactor control system design, plant startup analysis, and reactor stability analysis methods are treated. The basic concept of reactor safety analysis methods is also touched upon. Supercritical light water-cooled reactors are introduced as an example, and the nature of consideration and analysis methods is the same as that of light water reactors. The actual facilities and systems of light water reactors are complex. We believe that the descriptions in this book, rather than focusing on details, are better suited to understanding the general nature of reactors. More detailed analysis models and large-scale conventional codes are used in practical safety analysis. Their explanations are left to books for professionals; this book is expected to help in understanding the basic analysis methods. At the very end of Sect. 2.2, the FEMAXI-6 code is described for fuel rod behavior analysis. Fuel rod behavior and integrity concerning pellet and cladding are associated with core characteristics as burnup and core safety from the point of view of security of fuel integrity at abnormal transients. Such a series of analysis methods in the core, plant, and fuel rod behavior should be able to be understood as their individual concepts and then in their overall connection.

Section 3.1 is “Development and Improvement of Light Water Reactors,” and Sects. 3.2 and 3.3 present core design and core fuel management of boiling water reactors (BWRs) and pressurized water reactors (PWRs), respectively. Basic core design flow, core configuration setup, fuel lattice, fuel assembly design, reactivity characteristics, power distribution control, transitions and future trends in core design, core management, fuel management, and core design of conventional light water reactor are described.

“Design of Advanced Reactors,” Chap. 4, describes fast reactors and high-temperature gas-cooled reactors, focusing on core design. Detailed descriptions of each reactor type are left to other books; this book is expected, instead, to help in understanding the core design concept of each reactor. For example, advanced reactors are characterized by single-phase flow cooling, high-temperature core cooling, and different fuel compositions. The design criteria and principles are also different from those of light water reactors. Understating the difference may lead to a deeper comprehension of reactor design. This book also describes experiences with the HTTR experimental reactor as a high-temperature gas-cooled reactor.

This book systematically describes consideration and calculation methods about nuclear reactor design, mainly core design. We hope it will be useful for readers actually working in the nuclear power industry, research and development, and safety, as well as for students.

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