Preface

The more than five decades of nuclear energy utilization has shown significant advantages of nuclear power respect to environment protection, economic competitiveness and power supply stability. Due to fast economic development, the demand on energy and especially on electricity production in China has grown rapidly. The present electricity production is dominated by coal fired power plants. Serious problems in environmental pollution and limitations in renewable energy emphasize the importance of nuclear power in the future Chinese energy mix.

One of the key factors guaranteeing a sustainable development of nuclear power is the achievement of self-reliant technology and development of innovative technology. Nearly all nuclear reactors in operation today are second generation nuclear reactors. Based on more than twenty years intensive research and development (R&D) work, third generation reactors (GEN-Ⅲ) have been developed with high standard of safety. In China, water-cooled reactors (WCRs) of GEN-Ⅲ have been selected as the main reactor type for the next decades.

Although GEN-Ⅲ reactors have a high standard of safety, the sustainability and economic competitiveness become bottlenecking problems for long-term development. WCRs of GEN-Ⅲ have low thermal efficiency, about 35%. Due to the measures to enhance safety, high requirements on components and system reliability lead to complicated system and high system costs which impact the economic competitiveness. Furthermore, WCRs of GEN-Ⅲ are operated under thermal neutron spectrum, which gives extremely low fuel utilization, i.e. less than 1.0%. To ensure a long-term sustainable development of nuclear power, new generation of reactors, i. e. generation Ⅳ (GEN - Ⅳ), needs to be developed and introduced. In year 2002 the GEN - Ⅳ international Forum was established, recommended six reactors as GEN - Ⅳ concepts and issued the roadmap for GEN - Ⅳ nuclear system development.

Supercritical water cooled reactor (SCWR) is the only one GEN - Ⅳ reactor concept with water as coolant. One of the main advantages of SCWR is its enhanced economics due to high thermal efficiency (up to 45%) and system simplification. Supercritical water at high temperatures has low density, which enables the realization of a reactor with high neutron energy spectrum and subsequently high conversion ratio and the potential of waste transmutation.

In China, WCRs are and will be the main reactor concepts for the nuclear power generation. The experience gathered and technology developed in the design, manufacture, construction and operation of nuclear power plants are mainly concentrated in WCRs. Therefore, the development of SCWR is a smooth extension of the existing nuclear power generation park in China. From the technologic point of view, SCWR is a combination of WCR technology and the technology of supercritical fossil-fired power generation. Therefore, a good technologic availability is ensured.

In spite of the merits mentioned above, SCWR also shows significant challenges. Compared with conventional WCRs, the operating pressure and temperature are much higher, which result in challenging issues in structural material, heat removal and safety. Since 1990's of the last century extensive R&D works have been performed worldwide. In China, the most important milestone in this subject is the initiation of the National Basic Research Program (973 Program) performed during 2007 - 2011, financed by the Ministry of Science and Technology and coordinated by Shanghai Jiao Tong University (SJTU). Since 2006 SJTU has been intensively working on various aspects of SCWR technology, including plant system, safety systems, reactor core, thermal-hydraulics and material performance. Large amount of results were gathered and significant international recognition were achieved. The reactor core concept of SJTU with mixed spectrum, SCWR - M, was well accepted by the international community.

This book summarizes the research results achieved mainly at SJTU. It covers both design analysis and fundamental studies. The first three chapters deal with design analysis of SCWR - M which focus on safety system and reactor core, whereas the last two chapters concentrate on two key scientific and technologic issues, i. e. basic phenomena of thermal-hydraulics and material performance at SCWR - M conditions. Documentation of results and experiences into this book will provide valuable information for future R&D studies in China, and also worldwide.

The research works related to the results documented in this book were carried out by many colleagues and graduates of the School of Nuclear Science and Engineering of SJTU. Dr. Fu Shengwei and Dr. Xu Zhihong's effort for the system code development and safety system design and analysis contribute to Chapter 3. Prof. Xiong Jinbiao makes significant contribution to the numerical part of Section 4.2.2, Mr. Zhao Meng and Dr. Zhang Siyu performed experimental studies in supercritical water and supercritical Freon R134a, respectively, and make important contribution to Section 4.2.3 and Section 4.2.4. Dr. Zhou Chong investigated the dynamic behavior of supercritical water cooled systems and contributes to Section 4.4. The authors would also like to express their thanks to all partners of the 973 Program for their fruitful collaboration and valuable technical discussion.