

Features of the Supercritical Water-cooled Reactor (SCWR) and the Reactor Physics Issues/超臨界圧軽水冷却炉の特徴と炉物理に関連する課題

Supercritical Water-cooled Reactor (SCWR) is the only water-cooled reactor among the six Generation IV reactor concepts. It is the logical evolution of the current Light Water-cooled Reactor (LWR) as it follows the historical development of fossil fuel-fired power plant, which has been operating at the supercritical pressure of water since 1970s. The SCWR plant concept may be characterized by low capital cost and high flexibility. The single-phase cooling nature of SCWR realizes the once-through direct cycle plant system, which has the potential to dramatically reduce capital (construction) cost of the plant by simplification and elimination of components. Moreover, the large temperature and density changes of the coolant allow designing of flexible cores with outlet temperature ranging from 500 to over 600 C and neutron spectrum ranging from thermal to fast. The existing SCWR design concepts include both the pressure vessel type (China, the EU, Japan, Russia) and pressure tube type (Canada) reactors. For the pressure vessel type, most design concepts adopt the PWR-like Reactor Pressure Vessel (RPV) and control rod drive together with the BWR-like containment with suppression chamber and safety systems. Passive safety systems and Small Modular Reactor (SMR) design concepts have also been proposed and analyzed.

Generally, the thermal and fast reactors are loaded with enriched uranium and plutonium fuels, respectively. The fuel enrichments tend to be higher than those of the current LWRs, because of larger neutron absorption cross sections of candidate cladding materials. The major reactor physics issues may include, but not limited to accurate evaluations of the core power distributions and the coolant density reactivity feedbacks. The core power distribution directly influences the core average outlet temperature, while the coolant density changes by about ten times from the core inlet to the outlet. Such issues may be more important for the fast reactors, which have the following characteristics. Namely, the pseudo-fast neutron spectrum; the large heterogeneity with the seed and blanket fuels; use of solid moderator (ZrH) in some designs to achieve negative void reactivity characteristics.

Currently, at Waseda University, the concept of fast reactor concept of SCWR is further being developed with multi-level physics modeling, which covers from the core design (including fuel performance modeling), transient and accident plant behavior, and severe accident management. The unique and challenging issue of the water-cooled fast reactor is preventing re-criticality of the fuel debris, when total loss of coolant must be assumed.

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