Editorial

Supercritical Water-Cooled Reactors

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Supercritical water-cooled reactor (SCWR) is the water-cooled reactor using supercritical pressure water as coolant [1]. It is considered as one of the promising Generation IV reactors, due to its advantages of plant simplification and high thermal efficiency [2, 3].

Several design concepts of SCWRs have been proposed: (a) supercritical water-cooled thermal neutron reactor; (b) supercritical water-cooled fast neutron reactor; (c) supercritical water-cooled mixed neutron spectrum reactor; (d) supercritical water-cooled pebble bed reactor; (e) supercritical heavy-water-cooled reactor. The detailed design parameters of some typical SCWR concepts around the world are summarized in Table 1 [4]. Recently, the use of thorium in the SCWRs has been investigated [5, 6].

The advantages of the SCWRs are shown as follows [1].

- (i) Supercritical water has excellent heat transfer properties allowing a high power density, a small core, and a small containment structure.
- (ii) The use of a supercritical Rankine cycle with its typically higher temperatures improves efficiency (would be ~45%).
- (iii) This higher efficiency would lead to better fuel economy and a lighter fuel load, lessening residual (decay) heat.
- (iv) SCWR is typically designed as a once-through, direct cycle, whereby steam or hot supercritical water from the core is used directly in a steam turbine, which makes the design simple.
- (v) Water is liquid at room temperature, cheap, nontoxic, and transparent, simplifying inspection and repair (compared to liquid metal cooled reactors).

- (vi) A fast SCWR could be a breeder reactor which could burn the long-lived actinide isotopes.
- (vii) A heavy-water SCWR could breed fuel from thorium (4x more abundant than uranium), with increased proliferation resistance over plutonium breeders.

Some challenges in SCWRs are the subjects of research work which need us to research, among which are the following [4–7].

- (i) Lower water inventory (due to compact primary loop) means less heat capacity to buffer transients and accidents (e.g., loss of feedwater flow or large break loss of coolant accident) resulting in accident and transient temperatures that are too high for conventional metallic cladding.
- (ii) Higher pressure combined with higher temperature and also a higher temperature rise across the core result in increased mechanical and thermal stresses on vessel materials that are difficult to solve.
- (iii) The coolant greatly reduces its density at the exit of the core, resulting in a need to place extra moderator there.
- (iv) Extensive material development and research on supercritical water chemistry under radiation are needed.
- (v) Special start-up procedures are needed to avoid instability before the water reaches supercritical conditions.
- (vi) A fast neutron SCWR requires a relatively complex reactor core design in order to achieve a negative void coefficient.

TABLE 1: Some typical SCWR concepts around the world.

Name	Proposed by	Design concept	Moderate	Rated power (MW)	Outlet temperature (°C)	Pressure (MPa)	Net efficiency (%)
W21	Tokyo University	Thermal neutron spectrum SCWR	H ₂ O	1570	508	25	44
TWG1	Water TWG (Japan)	Fast neutron spectrum SCWR	H ₂ O	1728	Alternative	Alternative	38~45
W6-1	AECL (Canada)	CANDU-X-MARK1	D ₂ O	910	430	25	41
W6-2		CANDU-XNC		370	400	25	41
W6-3		CANDU-ALX1		950	450	25	40.6
W6-4		CANDU-X-ALX2		1143	650	25	45
—	Europe	HPLWR	H ₂ O	1000	500	25	44
—	INEL (USA)	Thermal neutron spectrum SCWR	H ₂ O	1600	500	25	44
B500SKD1	Russia	Integrative SCWR	H ₂ O	515	381	23.6	38

In order to help readers understand the development of the SCWRs in the world, we sponsored a special issue on the supercritical water-cooled reactor and hoped to get some papers from the topics which include but are not limited to the following:

- (i) reactor core and fuel designs,
- (ii) materials, chemistry, and corrosion,
- (iii) thermal-hydraulics and safety analysis,
- (iv) plant systems, structures, and components,
- (v) computational fluid dynamics (CFD) and coupled codes,
- (vi) neutronic properties,
- (vii) balance of plant,
- (viii) other applications.

Now the special issue is published, which includes 5 papers. The contents include a new concept of core design, like “A simplified supercritical fast reactor with thorium fuel,” calculation code development, like “Preliminary development of thermal power calculation code H-power for a supercritical water reactor,” “Code development in coupled PARCS/RELAP5 for supercritical water reactor,” and flow distribution, one of the important issues of thermal hydraulics in the nuclear reactor, like “Core flow distribution from coupled supercritical water reactor analysis.” It also contains some experimental results, like “Experimental investigation on flow-induced vibration of fuel rods in supercritical water loop.” We hope that readers of this special issue will find not only the development status of SCWRs and updated reviews on SCWRs, but also the formulation of important questions to be resolved such as how to develop the codes for SCWRs.

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