5 - 22 Conceptual Design of Subcritical Reactor for China Initiative Accelerator Driven System CiADS

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Nuclear power is an important part of energy source for human-beings, but the treatment and disposal of nuclear waste is the bottleneck which has been restricting the sustainable development of nuclear power. At present, the Accelerator Driven Subcritical System (ADS) is considered to be the most promising technological approach to solve the problem of nuclear waste.

In ADS, the accelerator is used to provide high-energy high-current proton beams, which bombard heavy nuclei to produce spallation neutrons. as exogenous driving and maintaining subcritical reactors, translating long-lived high radionuclides into short-lived or nuclidestable nuclide. ADS regulates the intensity and fast neutron spectrum of the neutron source by adjusting the operating parameters of the accelerator, then regulates the rate of transition of the fissionable/transmissive nuclide in the subcritical reactor, and achieves good neutron economy and transmissive support ratio.

At the end of 2015, the National Major Scientific and Technological Infrastructure project named "China Initiative Accelerator Driven System (CiADS)" was formally approved by the National Development and Reform Commission. in the CiADS project, the technical route of "superconducting linear accelerator + high power spallation target + subcritical reactor" is determined. Aiming at the construction requirement of CiADS, a conceptual design of subcritical reactor has been finished.

The subcritical reactor is a Lead-bismuth cooled fast neutron reactor, and the semi-pool semi-loop type special-shaped vessel is used to realize the structure coupling with the spallation target. The relatively mature fuel scheme is adopted, the unique Lead-bismuth coolant auxiliary system is designed, the fuel operation without opening the head is achieved by the remote operation system, a variety of engineering safety systems are set up to ensure the safety of the reactor. The subcritical reactor consists of core, reactor coolant system, engineering safety systems, reactor auxiliary system, nuclear island common support system.

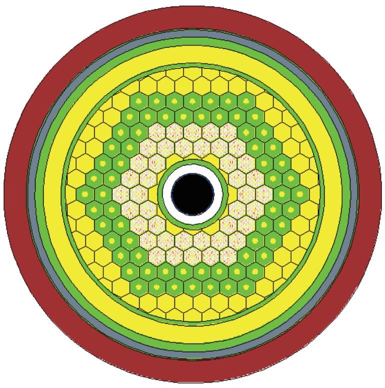

Fig. 1 (color online) Layout of Reactor core

The CiADS subcritical core consists of 42 hexagonal fuel assemblies and 66 dumb assemblies. There is a circular channel in the middle of the core for the scatter of the target tube. The layout of CiADS subcritical reactor core is shown in Fig. 1, the core parameters is shown in Table 1.

The CFD program and subchannel program are used to design the CiADS subcritical core. The main parameters are shown in Table 2, which meet the design criteria and the overall design requirements.

Table 1 Main parameters of core.

Item	Value
ADS power/MW	10
Reactor power (BOL/EOL)/MW	7.86/7.81
Spallation neutron yield/(n/p)	1.76
Total mass of fuel/t	2.4
$K_{\rm eff}$	0.850 63
$K_{\rm s}$	0.879 05
Burnup at EOL/(MWd/tU)	3 584
Number of fuel assemblies/box	42
Number of dumb assemblies/box	66

The semi-pool semi-loop type reactor coolant system of CiADS subcritical reactor is driven by forced circulation. It is mainly composed of main vessel, primary pump, primary heat exchanger and auxiliary heat exchanger, as shown in Fig.2. The main coolant system transports the heat generated in the core to the secondary loop through the primary heat exchanger, heats the secondary loop water into high temperature water which discharge heat into the atmosphere in cooling tower.

Table 2 Core thermal-hydraulic parameters.

Item	Value	Remark
Inlet mean temperature/℃	280	Higher than the design limit 200 ℃
Core temperature rise/℃	100	
Export average temperature/℃	380	
Core total mass flow/(kg/s)	541	
Effective core mass flow/(kg/s)	520	4% bypass
Coolant average velocity/(m/s)	0.316	
Coolant max velocity/(m/s)	0.355	Lower than the design limit 2 m/s
Fuel center max temperature/℃	534.29	Lower than the design limit 2 00 ℃
Max temperature of the cladding outer surface/℃	460.02	Lower than the design limit 5 50 ℃
Max temperature of the coolant/℃	456.45	Lower than the design limit 1 550 ℃

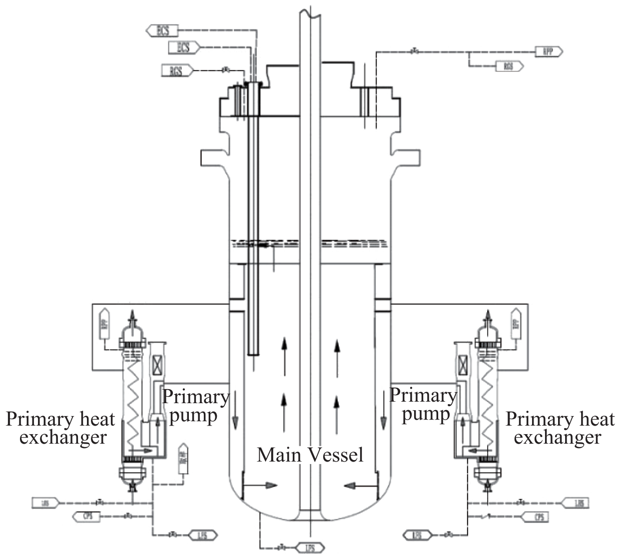

Fig. 2 Scheme of main coolant system.