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Simulation of loss-of-flow transient in water cooled fission blanket of Fusion-fission Hybrid Energy Reactor (FFHER)

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ABSTRACT

Fusion-fission hybrid reactor takes advantage of the best of both domains, fusion and fission, without needing a full development of fusion reactor, and without critical safety issues of fission reactor. However, decay heat still exists in fission blanket of hybrid rector in shutdown state, which will menace the safety of rector if it cannot be smoothly carried out. To testify the passive safety characteristics of fission blanket, the reactor coolant pump shaft seizure accident in fission blanket of FFHER, a fusion-fission hybrid reactor, is simulated. The model of passive residual heat removal system, as well as reactor coolant system, are built using software SCDAP/RELAP5 4.0. The analysis shows that the simulated system response is reasonable. In the SG domination stage, the peak fuel temperature keeps always below the limiting value. In the PRHR domination stage, three cases are simulated and compared to choose appropriate parameter. It is found that PRHR circulation can be rapidly established and transfer enough heat from blanket. The transition from SG domination to PRHR domination is smooth. From the simulation results, it can be concluded that PRHRS can provide sufficient blanket cooling capability in LOFA.

1. Introduction

Fusion-fission hybrid reactors have been studied for many years [1] since they may be potential tools to exploit the natural nuclear resources in an optimized way. In hybrid reactor, neutrons generated by fusion are provided to subcritical fission blanket to sustain a subcritical fission chain reaction. Therefore, reactor can generate energy in the subcritical blanket, breed fissile nuclei and transmute radioactive waste at the same time. Hybrid reactor reduces the technical difficulty of fusion reactor, and eliminates the critical safety issues of fission reactor. Therefore, many researches have been carried out and some conceptual designs have been presented recently [2–10].

One of the advanced fusion-fission hybrid reactor design is FFHER (fusion-fission hybrid energy reactor) proposed by China Academy of Engineering Physics [11–14]. In this design, the fusion part is similar to ITER (International Thermonuclear Experimental Reactor) and the subcritical fission blanket is fueled with UZr alloys of natural uranium cooled by pressurized light water.

Overall structure of the subcritical blanket is similar to the blanket of ITER and comprises inner blanket and outer blanket. The inner blanket is the straight part and outer blanket is the curved part of the D shape as shown in Fig. 1. The subcritical blanket is divided into 32 identical subparts respectively along the hoop direction. The cross section of the blanket is shown in Fig. 2 and its structure includes first wall, fuel zone, tritium producing zone and shield along the radial direction. Most of fission energy is generated in the fuel zone (31.3% is in inner blanket and 68.7% is in other blanket), which is removed by the pressurized water flowing through the coolant pipe inside the fuel. There is zirconium barrier between fuel zone and tritium producing zone. This barrier is hollow and there are pipes inside it. These pipes are dry in the normal condition. The water will be injected into these pipes to remove the decay heat in the case that the passive blanket cooling system fails. The structure of barrier between moderator and Li4SiO4 of tritium producing zone is similar to that of barrier between fuel zone and tritium producing zone. The water flows in the flow passages locating inside the barrier to cool the tritium producing zone in the operation condition. The coolant system of tritium producing zone is independent to that of fuel zone since there are big differences between their operation parameters. Since the power density in tritium producing zone is very low (Fig. 2b), its safety characteristics is not the objective of this study.

Compared with pure fusion rector, one disadvantage of hybrid rector is that the existing of decay heat in the fuel zone of fission blanket, which will menace the safety of rector if it cannot be smoothly carried out. The passive safety becomes a key trend for nuclear power plants after Fukushima nuclear accident, which means that decay heat

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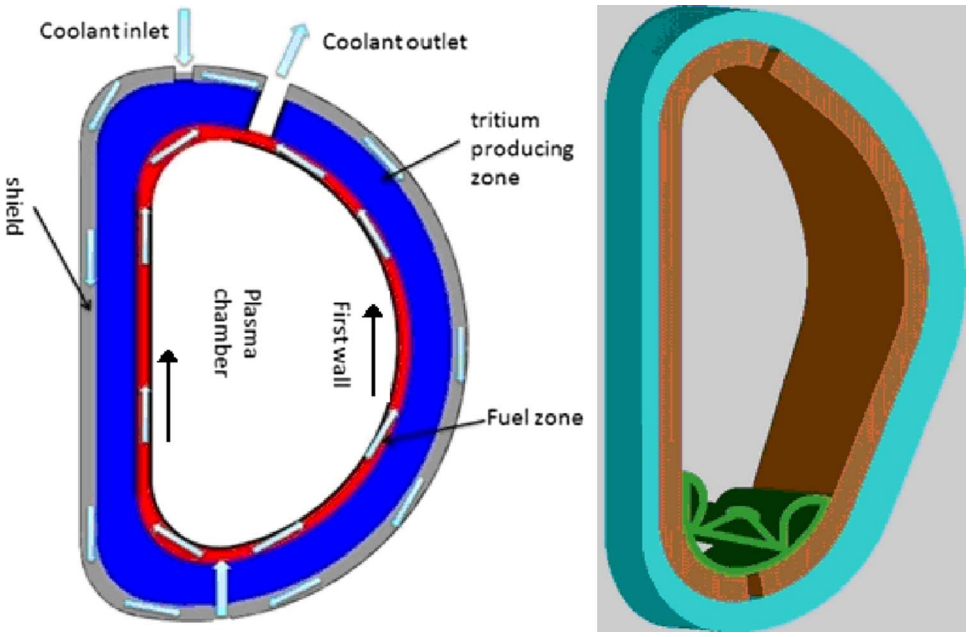
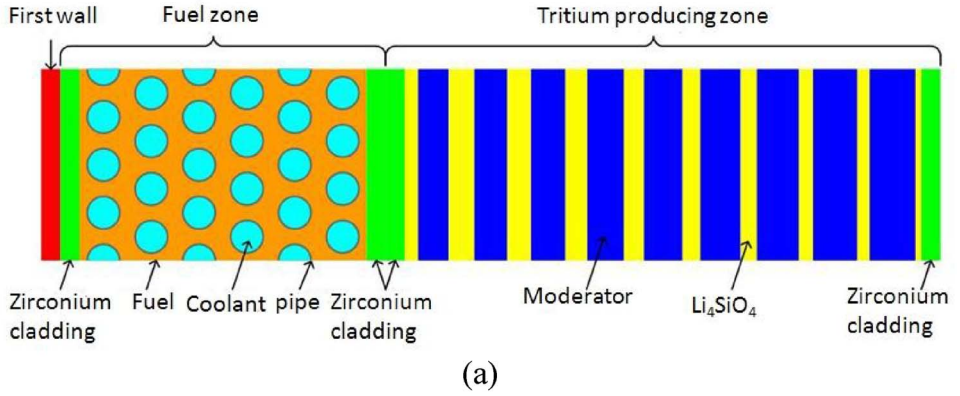
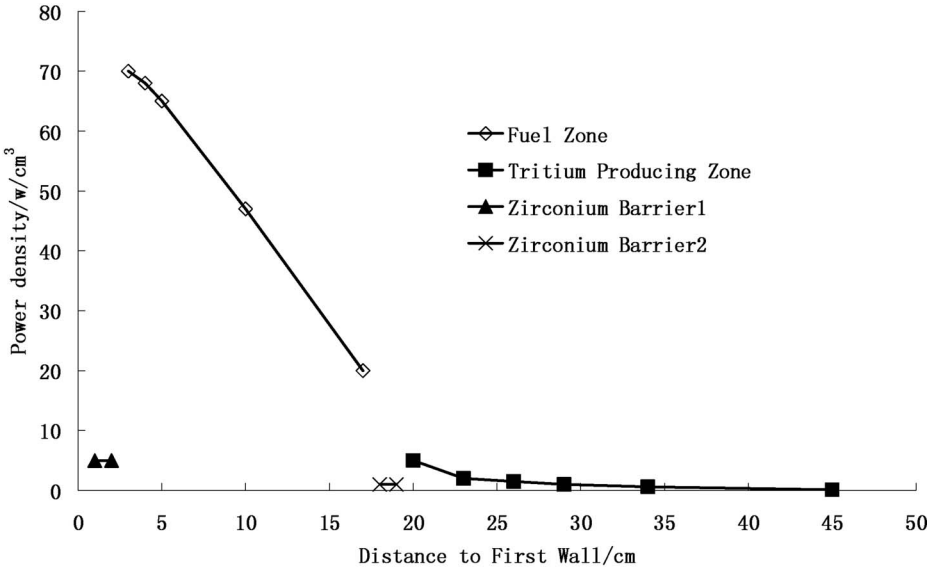


Fig. 1. Schematic diagram of the subcritical blanket.



(a)



(b)

Fig. 2. Cross section of the blanket.
a: Configuration; b: Average power distribution