Development of Conceptual Proposal for a Nuclear Facility with the Gas Cooled Fast Reactor BGR-1000 Using Coated Microfuel and Technologies of Light Water Reactors

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Abstract

The paper presents the status in elaboration of a reactor facility with a Gas Cooled Fast Reactor named BGR-1000 on the initial stage of developments. In the present time, general formulation of the concept is given and analysis of possible design decisions for the active core and first circuit equipment is performed.

The design of a reactor facility with the fast helium cooled reactor 1000 MWe is based on the active core with fuel assemblies containing the fixed bed of coated fuel microparticles directly cooled by cross flow of helium coolant with moderate (750^{o}C) outlet temperature.

The neutron-physics characteristics of this reactor and their connection with the parameters of the core layout and fuel cycle options are preliminary evaluated. Preliminary assessments are performed for thermal-hydraulic characteristics, fuel behavior analysis, etc.

KEYWORDS: Gas Cooled Fast Reactor, helium coolant, coated fuel microparticles, conceptual design

1. Introduction

The paper presents the status in elaboration of a reactor facility (RF) with a Gas Cooled Fast Reactor (GCFR) named BGR-1000 on the initial stage of developments [1]. The design of a reactor facility with the fast helium cooled reactor 1000 MWe, which is proposed for development, is based on the active core with fuel assemblies containing the fixed bed of coated fuel microparticles (CP) directly cooled by cross flow of helium coolant of moderate temperature.

Lately in Russia a known impetus to the initiation of works on the proposed reactor facility was given by RD&D on substantiation of opportunities to use coated microfuel particles in light-water reactors [2]. Sufficiently high corrosion resistance of CP with silicon carbide (SiC) outer coating in water, steam and steam-water media, presented in several publications, allows consideration of using the flooding of a gas cooled reactor core with the cold water in accidental conditions (in LOCA) in the same way as it is foreseen in LWR-type reactors.

Taking this into account, it is also possible to use for a fast gas cooled reactor facility a

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standard metal reactor vessel, e.g. that is similar to VVER-type reactors of Russian design, as well as the loop-type layout of the primarily circuit. The latter also allows to hope that specific capital initial costs for such gas cooled fast reactor will be comparable to LWR facilities.

2. General description

2.1 Basic requirements

Basic requirements to a reactor facility with the BGR-1000 are the following:

- use of the known and largely proven technical decisions making it possible to avoid significant expenditures for conducting of the in-depth RD&D with high degree of the risk of the investments recovery.
- exclusion of essential radiation consequences of emergencies, accidents or diversions due to the application in the microfuel elements with multilayer protective coatings, corrosively resistant in the aqueous medium and preserving integrity at temperatures up to 1600^{o}C;
- emerging neutron-physics of the core: ensuring core breeding ratio about 1.05 (and necessary reactor breeding ratio with optional use of axial and radial blankets), maximum reactivity margin for burnup about beta effective, small void reactivity effect, negative reactivity effect caused by flooding of the core by the cold water, possibility of achievement of the specified characteristics also working in the closed cycle with the recycling of actinides.
- ensuring initial capital costs of a power unit with BGR-1000 facility comparable with a VVER-1000 light-water reactor of Russian design;
- ensuring thermal efficiency of the BGR-1000 reactor facility would be around 50% due to the use of efficient decisions for steam turbines.

2.2 Reactor layout

The design of reactor facility with the fast helium cooled reactor 1000 MWe is based on the active core with fixed CP bed directly cooled by cross flow of gaseous coolant of moderate (750^{o}C) outlet temperature.

An opportunity is consider using fuel assemblies with various design solutions for providing of radial coolant flow profile through a layer of CP bed, which is distributed along the fuel assembly height to ensure necessary performance and temperatures.

Different fuel types could be considered in the core concept. The basic design assumes the use of dense mixed uranium-plutonium carbide fuel composition. As a backup option, conventional dioxide could be considered; however, the noticeable decrease of core performance characteristics should be expected in this case because of relatively low fuel fraction in the core.

3. Performed studies

In the present time, the general formulation of a concept is given, the qualitative analysis of possible design decisions for the active core and first circuit equipment is performed.

The neutron-physics characteristics of this reactor and their connection with the parameters of the core layout and fuel cycle options are preliminary evaluated (calculations of the reactor and the simulation refueling are performed with design codes used in calculational studies of fast reactors; calculations with a Monte Carlo code were carried out for a full-scale model of the fuel assembly). Among other important findings is the confirmation of possibility to reach core subcriticality in the flooded state.

Preliminary assessments are performed for thermal-hydraulic characteristics, analysis of the fuel behavior, etc.

4. Conclusion

The development of a reactor facility with a Gas Cooled Fast Reactor named BGR-1000 is considered as implementation synthesis of the proven technological decisions of high-temperature and light-water (VVER-type) reactors.

In the present time, the general formulation of a concept is given, the qualitative analysis of possible design decisions for the active core and first circuit equipment is performed.

The main directions of future investigations are the sensitivity analysis that should reveal possible issues requiring further qualification.

In comparison with any reactor GCFR concept with traditional container-type fuel elements, the concept of the reactor BGR-1000 with fixed CP bed possesses the potential to eliminate essential radiation consequences of any severe accident or diversion (if they occurred), and also ensures the additional level of protection from the propagation of the fissile materials - coated particles, especially with carbide fuel, practically cannot be effectively reprocessed with the purpose of extraction of plutonium by the traditional aqueous methods, such as PUREX. At the same time, for the reprocessing of CP one can use the high-temperature non-aqueous methods, for example, the method of volatile gas fluorides, developed in RRC Kurchatov Institute.

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References

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