APPLICABILITY OF COOLANT MATERIALS IN HYBRID FISSION-FUSION NUCLEAR REACTORS

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The development of future fusion and fission reactors exhibit common needs of research and development that command to optimize synergies between both types of nuclear systems. Among others, common R&D pathways include heat resisting materials, technologies of primary systems using the same coolant (helium, water or liquid metal), and design methods for fission reactor cores and fusion blankets. Such commonalities between fission and fusion nuclear systems will tend to increase with the technology developments, giving place to the so call hybrid fission-fusion nuclear reactors, that is a nuclear reactor in which high-energy neutrons from fusion reactions affect a set of fissile and fertile material, generally subcritical, thus achieving an additional multiplication of the energy and number of neutrons produced.

Regarding the analysis of refrigeration for a hybrid fusion-fission nuclear reactor, the various models of the same consider that the refrigerant must be in a gaseous state, which generates new difficulties. In this work, we analyze the characteristics that a coolant should have for different models of hybrid reactors.

INTRODUCTION

The new concepts in energy generation are characterized by tending to greater efficiency and better use of resources; so, new proposals for nuclear reactors are under evaluation, such as Gen-IV, Fusion Power Plants, Accelerator Driven Subcritical Reactors (ADS) and Hybrid Fusion-Fission Reactors (FFHR). Among those innovative reactors, it is observed a worldwide interest in the concept hybrid reactors, so there is a diversity of designs thereof. Although there is no prototype under construction, it is expected that a reactor of this style be built with the culmination of the ITER project since it will verify the limits of operation postulates for the reactor of fusion. At the same time, the evolution of physical models continues to be developed, as well as advanced complex modeling continues to improve the level of understanding of the behavior of materials by exploiting advanced microstructural characterization.

Besides, for a fusion-fission power plant, strict safety standards are required for the thermo-mechanical properties of the in-vessel components that are exposed to severe irradiation and heat fluxes; they are also an essential requirement for the economic viability of fusion.

Undoubtedly, one of the most controversial aspects of nuclear energy is the handling of spent fuel elements coming from fission nuclear power plants, which is known as nuclear waste. Among the isotopes that arouse, the principal concern in the industry are minor actinides (MAs), given their radiotoxicity. The fast neutrons generated by an FFHR could provide the appropriate spectra to burn by transmutation these isotopes.

The Hybrid Fusion-Fission Reactor (FFHR) is an arrangement formed by a nuclear-fusion device and a subcritical-fission-set [1]. In essence, an FFHS consists of three parts: a fusion reactor that acts as a source of neutrons, a subcritical system where the fissionable fuel is placed, and a tritium generating blanket that feeds the required fuel to the fusion reactor. Usually, all the system is also fitted with a neutron reflector. These parts are arranged concentrically forming a three-layer system to optimize the use of neutrons (See Fig.1)

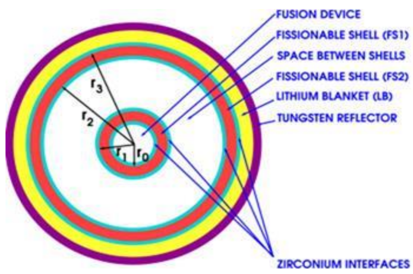

FIG. 1. Hybrid fission-fusion nuclear reactor, according to the concentric layer model. The imageis not at scale [1].

RESULTS AND DISCUSSION

Our analysis is centered on a device based on that one presented by Clause et al. [2], in which the two fuel shells are composed by metallic Uranium enriched 8%. As a starting point for our analysis of the coolants in hybrid reactors, we take the coolants studied in fusion reactors, such as ITER (International Thermonuclear Experimental Reactor), in which several different materials have been proposed for cooling:·LLCB (Lithium Lead Ceramic Breeder) uses Li2TiO3 ceramics and LiPB alloy as Tritium generating materials. There are two coolants, helium for the first wall and LiPB alloy to cool the ceramics. This concept uses ceramic coatings for the LiPb channels. Regarding the coolants for a hybrid fusion-fission nuclear reactor, the aforementioned materials must be analyzed, along with others, in this different environment. All them must be adapted to the several models of hybrid nuclear reactors, taken into account that, at the moment, the refrigerant must be in a gaseous state [3, 4], which generates new difficulties.

Bearing in mind the model we adopted for the hybrid nuclear reactor, few high-energy neutrons must be converted into many lower energy neutrons. For this purpose we use a multiplier cascade. The multiplying properties of the cascade are expressed in their factor of amplification M [2]. These cascades have shown previously its capacity to generate a fast-spectra of neutrons [5]. CerMets (Ceramic+Metal) allow to get close to 3000 K. These materials were developed to build reactors for air and space propulsion like [6]. CERMET Samples consist of uranium dioxide (UO2) fuel particles in a tungsten metal matrix, which has been shown in previous international programs to improve the yield and retention of fission products.

Figure 2 shows the system simulated with IMPC5, where a sphere of UO_2 is embedded into a Tungsten matrix

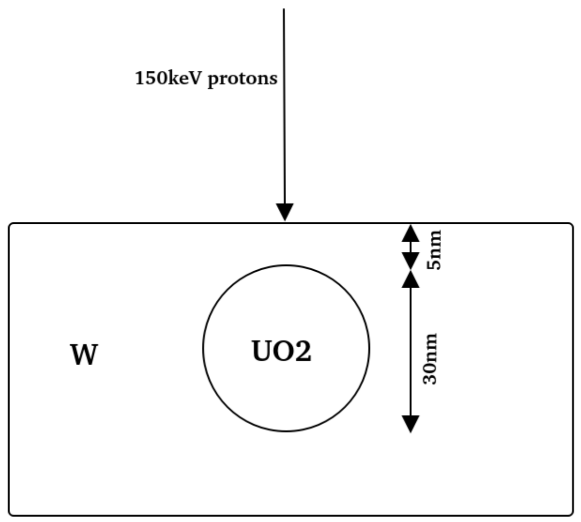

FIG. 2. Scheme of the system simulated with IMPC5.

Regarding the coolants for a hybrid fusion-fission nuclear reactor, and taken into account that, at the moment, the refrigerant must be in a gaseous state, both H and He [3, 4], we show a plot of the damage in the cermet, using the IMPC5 Montecarlo simulation; being the target a 30x30x40 nm3 W prism (the 40nm are in z, which is the average direction of the beam) with a 15nm UO2 sphere with a center in the center of the prism. The incident beam is a 150keV protons with a Gaussian distribution of impact angles, that is, on average there is normal incidence to the target surface but there are some protons that enter the cermet with a certain angle of entry. As we can see in Fig.3, at 150keV the protons are not capable of displacing W, the only displacements occur within the sphere

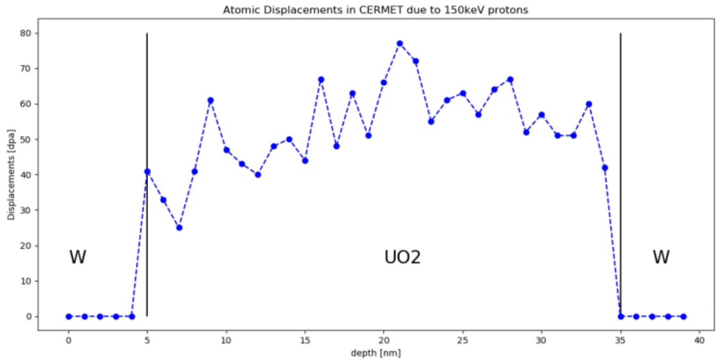

FIG. 3. *Atomic Displacement in Cermet.*

For bombarding with greater energies additional processes such as electronic sputtering contributes to surface erosion. A major part of the energy of incident ions is transferred to electrons along the ion track.

CONCLUDING REMARKS

The cermet alloys studied here,have reasonable thermophysical properties and, from irradiation experience in fast reactors to well over 100 dpa, a substantial resistance to swelling and high temperature embrittlement. From the pont of view of its behaviour with the gaseus coolant, we observe that for protons at the studied energies, there are not displacemente of ots atoms. Moreover, they have good compatibility with He coolants.

But there are several difficulties open regarding the behavior of the coolant with the cermet. In particular, for these energies, we have to study the corrosion processes involve in this interaction.

Further research would require the study of the temperature distribution around the fuel sphere, specially the properties of W as a function of T, for example, phonons, elastic constant, hardness, and so on.

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