CALCULATION OF FISSILE FUEL PRODUCTION IN SOME MINOR ACTINIDES BASED ON THORIUM

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ABSTRACT

In this study, a hybrid reactor with fission fusion reaction was modeled. As a fluid in design; 10% ThC_2 + 0.1-1% AmF_3 + 89.9-89% $Li_{20}Sn_{80}$ and 10% ThC_2 + 0.1-1% NpF_4 + 89.9-89% $Li_{20}Sn_{80}$ molten salt was used. In the first liquid wall, second liquid wall and shield regions of the reactor, the fissile fuel production was calculated using the MCNPX-2.7.0. ENDF/B-VII.0 nuclear reaction cross section library was used for numerical calculations.

Keywords: Hybrid Reactor, Minor Actinide, Fissile Fuel

INTRODUCTION

About 11% of the world's electricity is produced by existing reactors in the world. In order to obtain the energy provided, approximately 8500 tons of fuel is consumed and 23 tons/MW of radioactive waste is generated, annually. The storage of such a large amount of radioactive waste and their long half-life is an important problem for human and environmental health. Therefore, a hybrid reactor has been designed to obtain energy, to process the trans-uranium elements in the fuel used and to reuse them as fuel, and to convert long-lived fission products into harmless forms. Hybrid reactor is a subcritical safe system in which fusion-fission reactions occur together (Günay, 2015a; Düz, 2021; Düz and İnal, 2020;IAEA, 2009; Doligez et al., 2017; Günay, 2014a; Günay, 2014b).

The hybrid reactor uses mostly abundant deuterium-tritium as fuel. As a result of the fusion reaction of this fuel, 3.5 MeV Helium and 14.1 MeV fusion neutrons are released. Fusion neutrons collide with the liquid wall. Thus, with the hybrid reactor, both energy, fuel and short-lived wastes are generated (Şahin, 2007; Nygren et al., 2004; Hill et al., 2009; Günay, 2013; Günay, 2014c; Günay and Bardakçı, 2017).

The reason for using carbon (graphite) in fuels (ThC_2) in this study; because it has reflective properties. The particles coming out of the plasma make an inelastic collision with the carbon and return to the core region. Thus, it reduces neutron leakage and increases neutron efficiency. Carbon; it is an element that has a high retardation rate, is resistant to radiation, has a low melting temperature, a high boiling temperature, and does not cause corrosion on the structural material.

In addition to energy production, nuclear reactors used today also generate nuclear (U, Pu, Am, Cm, Np). Minor actinides (MAs) are long half-life, radioactive and good energy sources. Because of these properties, consumption of MAs as fuel is important for the environment and human health. MAs are in mixture oxide (MOX) or fluoride compositions (OECD-NEA, 2013; IAEA, 2009; Lu et al., 2013; OECD-NEA, 2015; Van Rooijen et al., 2015; Dolan, 2017; Vigier et al., 2018). In this study, we used the minor actinidine fluoride components AmF_3, CmF_3 and NpF_4 as fuel in the designed reactor to reduce the amount of MA. AmF_3, CmF_3 and NpF_4; fast neutrons can undergo fission. Since fluorine (F) is also a reflector, it collides with the particles coming out of the plasma.

The aim of this study is to examine the fissile fuel production in relevant regions with mixture of selected fluids (ThC_2, AmF_3, CmF_3, NpF_4 and $Li_{20}Sn_{80}$) in different ratios in the designed hybrid reactor. Three-dimensional design and calculations by using MCNPX-2.7.0 were made for temperature at 300 °K.

MATERIALS and METHODS

In this study was used APEX fusion technology as a hybrid reactor design. The liquid wall has been used to regulate the performance of the APEX hybrid reactor, energy transfer and tritium production (Christofilos, 1989; Günay, 2015b; Abdou et al., 2001; Abdou, 1999; Ünalan, 1998; Abdou, 2004; Şarer et al., 2007; Moir, 1997; Günay, 2014d). The large radius of hybrid reactor is 552 cm. The reactor is shaped like a torus and shown in Figure 1.

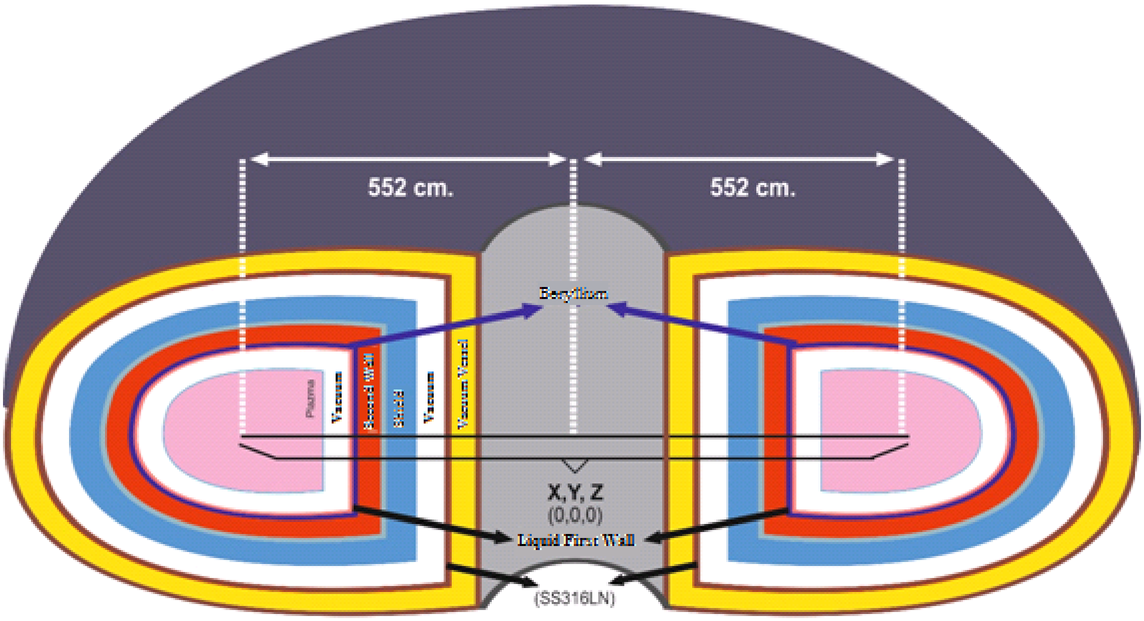

Figure 1. Representation of the APEX hybrid reactor used in calculations.

$Li_{20}Sn_{80}$ liquid layer; it is preferred because it significantly reduces the parameters that damage structural materials such as radiation and activation (Abdou et al., 1999; Abdou et al., 2005; Günay et al., 2011; Youssef and Abdou, 2000; Ying et al., 1999; Youssef et al., 2002; Günay, 2016). Beryllium was used as reflector.

MCNPX; it is a combination of MCNP and LAHET codes (Chadwick et al., 2006; Pelowitz, 2011). The latest version, MCNPX-2.7.0, was used in the study.

FISSILE FUEL PRODUCTION

The fuel material used for power generation in conventional nuclear reactors is fissile fuels. Fissile fuels are nuclei that can perform fission reactions with low-energy neutrons. These are ^{235}U, ^{233}U, ^{239}Pu. The isotopes of ^{235}U, ^{233}U, ^{239}Pu, which can fission with neutrons at low energies, are produced from ^{232}Th and ^{238}U. The ^{235}U isotope, which is used as a fuel in fission nuclear reactors, produces energy and new neutrons by generating high fission with thermal neutrons. Existing fission reactors use only a small fraction of uranium, as this fuel is very scarce in nature. The ^{238}U isotope, which is found in large quantities in nature, is converted to ^{239}Pu with a very low yield by the (n,γ) reaction. Depending on the type of reactor and its operation, some of the plutonium formed is burned and some is stored (Günay et al., 2011; Korkut and Hançerlioğulları, 2012; Şahin and Übeyli, 2005). ^{233}U fissile fuel is produced by ^{232}Th(n,γ) as the fuel raw material in the reactor.

RESULTS

In the study, ^{232}Th fertili was used for the production of fissile fuel. The (n,γ) reaction is required for fissile fuel production from ^{232}Th fertil. In this study; the fissile fuel production was calculated. Table 1 shows the production of ^{233}U fissile fuel as a result of the (n,γ) reactions of ^{232}Th fertil used in the designed reactor.

Table 1. Fissile fuel production (kg/year) obtained by using fluids in the relevant parts of the reactor.

Heavy Metal Ratio	AmF_3	CmF_3	NpF_4
%0.1	$3.99.10^{-04}$	$1.69.10^{-03}$	$4.28.10^{-04}$
%0.5	$6.05.10^{-04}$	$7.12.10^{-03}$	$7.29.10^{-04}$
%1	$8.64.10^{-04}$	$1.39.10^{-02}$	$1.15.10^{-03}$

It has been observed that the ratio of fissile fuel produced increases when the minor actinide ratio is increased and the molten salt ratio is decreased in the selected fluids. As a result, it was observed that the greatest increase in ^{233}U fissile fuel production was in 10% ThC_2+ 1% CmF_3+ 89% $Li_{20}Sn_{80}$ fluid.

DISCUSSION and CONCLUSIONS

In this study, ^{233}U fissile fuel was obtained in the first liquid wall, second liquid wall and armor regions where ^{232}Th fertil was found. In selected fluids in the study, it was observed that the ratio of fissile fuel produced increased as the minor actinide fluoride ratio increased. The best increase was observed in CmF_3.

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