PREVENTIVE WAY OF RELATIVELY LOW RADIACTIVE WASTE ENERGY PRODUCTION BY THORIUM-URANIUM FUEL CYCLE APPLICATION

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Abstract

Analysis of possible ways of reduction of radioactive wastes by transmutation of radioactive long-lived fission products such as ^{99}Tc, ^{129}I and ^{135}Cs and by burning up of transuranic nuclides implies that the reactor core should consist of three zones with fast, epithermal and thermal neutron spectra. High flux thermal neutron environment ($\geq 10^{16}$ n/cm^2·s) is expected as the best way for the transmutation of most of the radioactive waste to stable or short-lived nuclides and for increasing the probability for fission such actinides as ^{237}Np and ^{238}Np.

Since we are not able to construct such a reactor core with the three zones and we are not able to reach such an intense thermal neutron flux ($\geq 10^{16}$ n/cm^2·s) in terms of technical feasibility and in view of the inefficiency of actinides incineration for a low intensity thermal neutron flux, we focus our attention on the thorium-uranium fuel cycle as a prophylactic way of energy production where the radio-toxicity of the wastes is about three orders of magnitude smaller than in the case of classical PWR reactors.

^{232}Th is a better fertile material than ^{238}U in thermal reactors because of the three times higher thermal neutron absorption cross-section of ^{232}Th (7.4 barns) as compared to ^{238}U (2.7barns). Thus, conversion of ^{232}Th to ^{233}U is more efficient than that of ^{238}U to ^{239}Pu in thermal neutron spectrum though the resonance integral of ^{232}Th is one third of that of ^{238}U. The values of cross sections in brackets refer to the thermal neutrons.

While the uranium 238-plutonium 239 fuel cycle requires fast neutrons to be sustainable, the thorium 232-uranium 233 fuel cycle is sustainable with either thermal neutrons or fast neutrons.

The ^{232}Th – ^{233}U fuel cycle let us obtain breeding of fissile atoms both in fast, epithermal and thermal neutron spectra.

As thorium based fuels have benefits in terms of radio-toxicity there are however challenges in terms of reprocessing the spent thorium based fuel. The database and experience of thorium fuels and thorium fuel cycles are very limited , as compared to UO_2 and $(U,Pu)O_2$ fuels, and need to be augmented before large investments are made for commercial utilization of thorium fuels and fuel cycles.

That is why, as the first step of studying the thorium application feasibility, once through thorium based fuel cycle analysis for energy production and radioactive waste transmutation was undertaken, which does not require the technically difficult reprocessing of the spent fuel. Justification for such a study direction is the relatively small amount of radioactive wastes during exploitation the thorium based fuel in the process of energy production and that the natural thorium is about 3.5 times more abounded than the natural uranium in the earth.

Moreover the thorium based fuel enables to increase burn-up of the fuel due to breeding of fissile atoms.

The idea is to analyze the thorium based fuel application in the open cycle feasibility study in the existing light water reactors with minimal modifications in order to exploit them.

Preliminary analysis of thorium based fuel application in the EPR reactor have shown that once through thorium fuel cycle can be reached with difficulty. It is inferred that the ^{233}U concentration tends to saturation value which does not depend on power density while the kinetics of reaching the saturation value depends on it.

Whereas the available neutron numbers for breeding in the thorium-uranium fuel cycle is only a little above zero (0.1 – 0.3, the value is not given precisely in the open literature) we have focused on the accelerator driven system (ADS) where the effect of breeding can be easier utilized in more flexible way for higher burn-up of the fuel giving impact on economy improvement. Review of available literature concerning the ADS let us include to the analysis determination of optimal spallation neutron target sizes which enables to obtain the required ion beam current of the value achievable with today’s technology.

Monte Carlo methodology calculations for the contribution to the analysis of thorium based fuel application in the EPR reactor and in the accelerated driven systems (ADS) were used.