Contribution ID: **426**

Type: **ORAL**

Design of a nitride-fueled lead fast reactor for MA transmutation

Thursday, 29 June 2017 10:40 (20 minutes)

Research and development of fast reactors have been carried out in several European nations with mixed oxide fuel and sodium coolant as reference materials. In addition, the transmutation of Minor Actinides (MAs) in fast reactors has been investigated extensively from the viewpoint of reducing the environmental burden of long-lived radioisotopes.

Nitride fuel and lead as coolant represent possible alternative options for reactor design, which can bring substantial advantages as compared to oxides and sodium, respectively. Nitride fuel exhibits a higher thermal conductivity and a higher heavy nuclides density than oxide fuel, which would both enhance the core safety performance and improve the neutron balance in favor of MA burning due to the harder neutron spectrum. As a consequence, the amount of MAs that could be loaded in the core could be increased.

In this work, the core design of a 600 MWe lead-cooled, nitride-fueled fast reactor aimed at transmuting MAs is presented. The core design was performed aiming at accomplishing the following major goals: (i) obtaining a unitary conversion ratio; (ii) achieving a 6 kg/TWeh specific Am consumption after 6 years of cooling in a homogeneous transmutation scenario, while (iii) respecting the fuel cycle constraints for fuel maximum thermal load of 7.5 kW per assembly after 5 years cooling and of 3 kW per fresh assembly.

In addition to the core transmutation performance, safety analysis was performed in order to predict the core transient behavior following postulated accident initiators. Three reference accidents were considered in this study: an inadvertent control rod ejection leading to an Unprotected Transient OverPower (UTOP), a pump coast-down causing an Unprotected Loss Of Flow (ULOF), and a steam generator failure, resulting in an Unprotected Loss of Heat Sink (ULOHS). Reference safety criteria, such as margins against cladding failure, fuel melting and nitride dissociation were assessed.

Neutronics parameters were calculated by means of the Monte Carlo code Serpent, whereas transient simulations were performed using BELLA, an in-house code for the safety analysis of Generation-IV innovative lead fast reactor systems, currently under development at KTH.

Country/Int. Organization

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Session Classification: 1.8 INNOVATIVE REACTOR DESIGNS

Track Classification: Track 1. Innovative Fast Reactor Designs