Possibility of Sodium Cooled Breed and Burn Fast Reactor with Rotational Fuel Shuffling

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The performance of small-size sodium cooled Breed and Burn Fast Reactor with rotational fuel shuffling was investigated. The thermal hydraulic analysis and burnup performance were conducted with Comsol-Multiphysics and MVP3.0 respectively. The results showed that sodium allowed for a reduced reactor radius while still capable of reaching and maintaining criticality while not exceeding the materials' temperature safety limits.
Keywords: Breed and Burn reactor, Sodium coolant, SMR, Burnup analysis, Thermal-hydraulic analysis

1.Introduction:

Previous studies [1] have discussed the feasibility of LBE cooled Breed & Burn (B&B) Reactor design that involved the use of a rotational fuel shuffling pattern where low reactivity assemblies are loaded into the core and periodically moved to a position increasingly towards the center region after a set amount of time. LBE coolant is relatively new in the nuclear industry and sodium presents some chemical and thermal advantages that could make it a feasible replacement for LBE. Sodium coolant is more efficient at extracting heat from the reactor. This allows the fuel pin pitch to be reduced, making the reactor more compact. The nuclear industry also has much more experience with using sodium as coolant compared to LBE. Sodium coolant does not corrode the reactor's pipelines the same way LBE does, such compatibility allows the Sodium coolant flow to reach speeds higher than 2 m/s limit usually imposed to LBE.
The purpose of the study is to assess the performance of sodium coolant paired with the rotational fuel shuffling pattern.

2. Methodology

In this study MVP3.0 was used for neutron transport calculation while MVP-BURN was used for the burnup analysis with nuclear data library JENDL-4.0 and COMSOL Multiphysics was used for the thermal hydraulic analysis. The fuel pin was axially divided into 11 tally regions of equal size and composition (Natural Uranium). The study observed the performance of both "Ideal" ODS and realistic HT9 claddings. The rotational fuel shuffling was performed by a Python code which would create a new input file after each step and restart the simulation until the pre-set amount of shuffling steps had been reached.

3. Results and Conclusion

Figure 1 shows the temperatures reached in the reactor's hottest channel by the fuel, cladding and coolant in the 1.03 cm Pin Pitch scenario. All three parameters were within the 923K safety limit with a coolant flow limited to 10 m/s. In the preliminary analysis, the maximum keff values reached in the equilibrium condition was 1.0383 with a 5% error.

Table 1. Reactor Design

Parameter	Value
Thermal Power	800 MWth
Core Height	220 cm
Core Equivalent Radius	115.4 cm
Fuel Composition	U-10 wt% Zr (Natural Uranium)
Bond Material	Sodium
Cladding	ODS and HT9
Coolant	Sodium
Number of Pins per Assembly	271
Number of Assemblies	168
Sodium Plenum Height	40 cm
History Number/Batch	21600/30

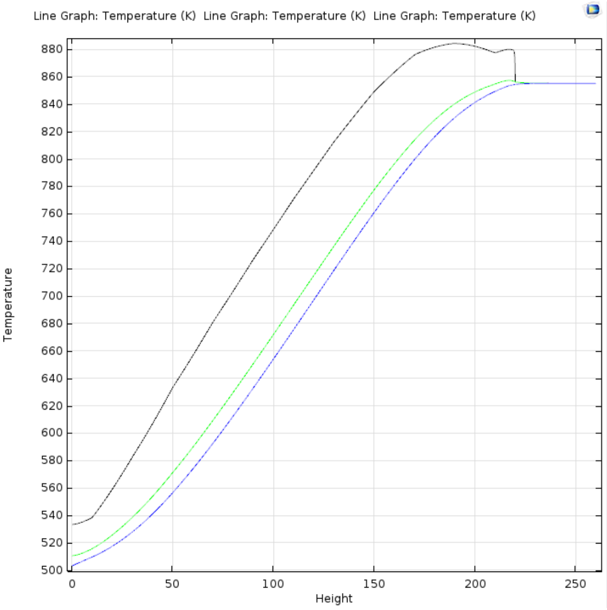

Figure 1. Figure 1. Fuel, Cladding and Coolant Temperature graph.

References: [1] Kazuki Kuwagaki, Jun Nishiyama & Toru Obara (2018) Concept of Stationary Wave Reactor with Rotational Fuel Shuffling, Nuclear Science and Engineering, 191:2, 178-186,