APPLICATIONS OF "CANDLE" BURNUP STRATEGY TO SEVERAL REACTORS

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A new reactor burnup concept CANDLE (Constant Axial shape of Neutron flux, nuclide densities and power shape During Life of Energy producing reactor) is proposed [1, 2], where shapes of neutron flux, nuclide densities and power density do not change along burnup but move in the axial direction of a core with a constant velocity for a constant power operation during the whole reactor life. If this concept is feasible, a long life reactor can be designed, whose life is easily set by adjusting its core axial length. The change of excess reactivity along burnup is theoretically zero for ideal equilibrium condition, and shim rods will not be required for this reactor. The configuration of the succeeding core is easy for this burnup strategy. The burning zone at the end of reactor life can be used as the ignition zone of the succeeding core.

The CANDLE burnup strategy can be applied to several reactors, when the infinite neutron multiplication factor of fuel element of the reactor changes along burnup as the followings. It starts from the value less than unity, and increases with burnup, and becomes more than unity after certain amount of burnup, and then takes its maximum value at a certain value of burnup, and then decreases with burnup, and becomes less than unity, and continues to decrease with burnup. The spatial regions before and behind the burning region, where the neutron multiplication factor is less than unity, are inevitable to fix the shape of burning region by shifting both front and back ends of the shape to the same direction with the same speed. The condition that infinite neutron multiplication factor for some interval should be more than unity is also inevitable for keeping the system critical. The amount of the surplus of infinite neutron multiplication factor above unity should be large enough to supply excess neutrons to the front region for fissile nuclide production.

To satisfy this condition an excellent neutron economy should be satisfied in the equilibrium state. Even for fast reactors it is not easy to realize this scenario when only natural uranium is charged in the front region. Only fast reactor with excellent neutron economy can realize it. A lead-bismuth-eutectic (LBE) cooled metallic fuel fast reactor, whose fuel volume fraction is 50%, is such a reactor. When the fuel starts from the natural uranium, the number of neutrons is large required for the infinite multiplication factor becoming larger than unity, and a large number of neutrons are also absorbed by the well-burned fuel. Therefore, the spent fuel burnup becomes large. For the above case, it becomes about 400GWd/t, which is equivalent to efficient energy utilization of about 40% of natural uranium. The moving speed of burning region is slow for realizing this high burnup and about 4 cm/year.

Using the natural uranium as the fresh fuel is interesting, since either enrichment or reprocessing is not required after second core. However, its neutron economy is just marginal, and it is very difficult to realize the CANDLE burnup with this condition. Adding some fissile materials in the fresh fuel makes realization of the CANDLE much easier. In this case the number of neutrons absorbed in fertile materials and fission products is decreased and the burnup of spent fuel decreases.

The CANDLE burnup strategy can be applied even to thermal reactors. For this case the infinite neutron multiplication factor usually decreases with burnup monotonically during its whole history. However, by adding burnable poisons the behavior of infinite neutron multiplication factor can be changed such that it increases at the beginning of the core life, and it satisfies the condition for CANDLE burnup. The block-type high temperature gas cooled reactor is good for this idea. The core construction of the succeeding reactor is easy, since the fuels are axially separated.

References

[1] H. Sekimoto and K. Ryu, Demonstrating the Feasibility of the CANDLE Burnup Scheme for Fast Reactors, Trans. American Nuclear Society, 83, 45 (2000).
[2] H. Sekimoto, K. Ryu and Y. Yoshimura, A New Burnup Strategy CANDLE, Nucl. Sci. Engin., (2001, to be published).