論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Study on Burnup Performance of Small Pebble Bed Reactors with Accumulative Fuel Loading Scheme
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10649号, 授与年月日:2017年9月20日, 学位の種別:課程博士, 審査員:小原 徹,高橋 実,千葉 敏,赤塚 洋,相樂 洋
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10649号, Conferred date:2017/9/20, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	NUCLEAR ENGINEERING 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 (Engineering) Doctor of
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

Pebble bed reactor (PBR) is one of the promising nuclear power plants in the future. It has high thermal efficiency compared to LWRs. The accumulative fuel loading scheme is the simplest fueling scheme in PBR. The main purpose of this study was to make clear the potential of small PBR with accumulative fuel loading scheme for several fuel materials. The potential is defined as to achieve high burnup performance with long operation time. Several fuel materials such as UO_2, MOX, U-ROX, and Pu-ROX was investigated in this study.

The Monte Carlo MVP/MVP-BURN code was used to calculate the burnup calculation with JENDL-4.0 as nuclear data library. A new code based on FORTRAN language has been developed to treat the accumulative fuel loading scheme during the burnup calculation. The optimum fuel composition of each fuel material was obtained to achieve high discharge burnup with long operation period.

In UO_2 fuel, the optimum fuel composition was 6-g HM/pebble with 20% of ^{235}U. The results showed that the operation time was 10.2 years. The maximum and average burnups were 223 GWd/t and 182 GWd/t, respectively. However, high excess reactivity occurred in the initial condition due to a significant amount of fuel in the initial condition. This problem was solved by introducing low enriched uranium and burnable poison (BP) material at BOL condition. In the case of low enriched uranium, fuel enrichment was reduced from 20% to 3.42%. In the case of utilizing BP material, Combinations of B_4C and Gd_2O_3 were used to suppress the high initial excess reactivity. Therefore, there were two primary results for PBR with accumulative fuel loading scheme with UO_2 fuel. By applying the low enriched uranium at BOL condition, the initial excess reactivity can be reduced effectively but the core lifetime became shorter about eight years with the maximum burnup about 199 GWd/t. By utilizing BP material, the operation period and maximum burnup were 10 years and 224 GWd/t, respectively. However, the initial excess reactivity could not be decreased as small as using low enriched uranium.

The MOX fuel which is mixed of plutonium from the nuclear-spent fuel with depleted uranium was introduced to enhance the use of plutonium in the thermal reactor. It is one of the strategies to stabilize the amount of plutonium in the nuclear-spent fuel. Therefore, 5g HM/pebble of MOX fuel, which contains 30% plutonium from the spent fuel of PWR and 70% of depleted uranium was introduced as the optimum fuel composition. The results showed that the maximum discharge burnup and operation period were 172 GWd/t and 5 years, respectively. Initial excess reactivity was quite low and no additional treatment required to suppress the initial excess reactivity. However, MOX fuel cannot significantly reduce the amount of plutonium because another plutonium is generated from the depleted uranium.

A new fuel concept, rock like oxide (ROX) fuel was introduced. This fuel has been developed by JAEA for the annihilation of excess plutonium and the direct disposal of spent fuel. The ROX fuel is a kind of inert matrix fuel, and the fuel matrix is composed of the single phase of inert matrices yttria stabilized zirconia (YSZ). In this study, U-ROX fuel contains about 81.75% of YSZ and 18.25% of UO_2 with 20% of ^{235}U enrichment. The fissile density of ROX is about five times lower than that of UO_2 fuel. The optimum fuel composition was 5g HM per pebble. The results showed that the maximum discharged burnup was 218 GWd/t with the core lifetime about 8.4 years and high excess reactivity occurred in the initial condition. The solution to overcoming the high excess reactivity at BOL condition was the same as in the case of UO_2 fuel, using low enriched uranium and burnable poison material. In this study, 4.65% of ^{235}U was used to reduce the initial excess reactivity. The results showed that the consequences of implementing the low enriched uranium in the initial condition were the reduction of operation time and burnup performance. The operation time decrease from 8.4 to 6.6 years and maximum burnup became 198 GWd/t. In the case of using BP material, B_4C was used to suppress the initial excess reactivity. The results showed that the operation period and maximum discharge burnup were almost similar to the ROX fuel without BP material, but the initial excess reactivity could not be reduced as much as in the case of using low enriched uranium. The last part of this study was to introduce Pu-ROX fuel for the annihilation of excess plutonium. In this study, plutonium is diluted with inert matrix fuel instead of UO_2 fuel. Therefore, the Pu-ROX fuel contains about 81.75% of YSZ and 18.25% of PuO_2 with 3g HM/pebble. The results showed that operation period about 11 years was achieved with 550 GWd/t of maximum discharge burnup.

Burnup performance is a way to measure how much the fuel is burned. High burnup performance means to get more power out of the fuel before replacing, and the reactor can be operated longer between refueling outages. Therefore, less fuel consumption and reduce the spent fuel production. According to the results of each fuel types, it showed that each fuel types could achieve high discharge burnup with long operation period in PBR with accumulative fuel loading scheme.