論文 / 著書情報
Article / Book Information

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（博士課程）
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The purpose of the study was to obtain the relationships among design parameters including reactor thermal power, power density and its profile, and dimension of reactor core and reactor building (RB) as well as the temperature of reactor regions at shutdown in view of passive decay heat removal for both prismatic and pebble bed types of HTGR locating above- and under-ground. One of the severest situations was assumed in the study in which the functionality of active and passive cooling systems was completely failed after depressurized loss of coolant accident with reactor scram and negligible contribution of natural convection compared to other types of heat transfer mechanism inside reactor building was considered in this situation. The major constraints for reactor design parameters were determined that they have to satisfy the safety limits of both fuel and RB temperatures after reactor shutdown.

The several steps of procedure to obtain the relationship of design parameters of HTGR for passive decay heat removal was proposed and parametric relationships were got for both types of HTGR depending on location, power density profile and irradiation period. The parametric survey analyses were performed using the fundamental heat transfer mechanisms in HTGR. The parametric relationships for above- and under-ground, prismatic HTGRs were obtained using both original (as functions of Bessel in radially and cosine in axially) and uniform power density profiles. These for above- and under-ground pebble bed type of HTGRs were also got using both linear (as considered as one of the closest to the original profile) and uniform power density profiles. It has been shown that there is a great impact of power density profile on passive decay heat removal of both types of HTGR. The results show that general behavior of parametric relationship is qualitatively similar regardless of the shape of power density profile, and however, there is possibility to enhance the safety performance of HTGR by flattening power density profile throughout the core. In other words, by flattening power density profile the allowable maximum power can be increased without changing other parameters or it is permitted to design the same reactor with large safety margin by keeping other parameters. Otherwise, the same power reactor can be designed with smaller size without degrading passive safety features so that it has great advantage in economical point of view due to reducing the total cost.

The relationships of the design parameters are the same for both above- and under-ground reactor concepts if the maximum RB temperature is ignored from the consideration. However, if it is considered, the RB size tendency related to other design parameters is different for both reactor concepts that is due to different type of final heat sink either it is soil or air. The major parameter for practical RB size for an above-ground reactor might be the core temperature at shutdown while reactor power could be the most influential consideration for a reasonable-sized underground RB.

Possible designs for a small, prismatic HTGR with power of 100 MW_t having a maximum power density of 3 W/cm^3 operating at temperature of 1123 K was proposed and its neutronic and thermo-hydraulic performances were determined by the corresponding analyses. In neutronic analyses, to suppress the excess reactivity and to flatten the reactivity swing and power peaking factor (PPF) with burnup, burnable poison particle (BPP) was introduced into the core. It was shown that the optimization for core configuration by using non-uniformly distributed fuel and BPPs of B_4C and Gd_2O_3 was done successfully to reduce the excess reactivity and PPF with burning. As a result, the maximum excess reactivity was effectively reduced from 32% to down 0.78 %Δk/k and the change in PPF during long operation of the core was flattened well. In addition, it was shown that the small amount of excess reactivity during operation was compensated by inserting control rod (CR)s into the core to avoid a prompt criticality accident and in this case, the change in PPF during operation was still maintained as flat because the neutron flux was not significantly fluctuated due to small depth of CRs insertion. The proposed reactor with optimized core has a negative temperature coefficient of reactivity and the average value of core temperature coefficient of the reactivity was −3.92 pcm/K during operation. By performing single-channel thermo-hydraulic analyses using COMSOL multiphysics software, the fuel maximum temperature and pressure drop of the proposed reactor with non-uniform core were less than the corresponding design limits during reactor operation.

In this study, systematic methodology to get the design parameters for both types of HTGR as prismatic and pebble bed for passive decay heat removal were proposed and the conditions depending on their location and the influence of power density profile on the safety performance of both types of HTGR were obtained. Therefore, the fundamental neutronic and thermo-hydraulic analyses for a small, prismatic HTGR for passive decay heat removal were performed successfully and it was determined its neutronic performance and the safety feature during operation.