Characterization of Carbon Nano-Particles from the Clad of Nuclear Fuel in HTGR with Inherent Safety (I) - Qualitative Analysis

H. Nishida[1], G. Iwanaka[1], H. Takano[1] and M. Itoh[1]

[1]Department of Chemical Engineering and Materials Science, Doshisha University, Kyoto 610-0321 JAPAN
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Presenting author email: dum0748@mail4.doshisha.ac.jp

High Temperature Gas-cooled Reactor (HTGR) with the absolute inherent safety is one of the Generation-III+ (Gen-III+) and -IV (Gen-IV) nuclear reactors. The absolute inherent safety means safety self-shutdown system inherency without any support from outside even in the case of electric power loss and/or mechanical breaks of the core control system of the reactor. The inherent safety of the reactor is ensured by the specific nuclear core design and the heat exchange system with He Gas. Although thus high inherent safety and wide industrial applicability using its very high temperature operation were installed even in the Gen-II HTGR, such types of nuclear reactor were not adopted for commercial nuclear power plants because of the higher costs both for construction and running than the current light water nuclear reactors as used in Fukushima and all others.

After the accident on 3.11 at the site-**I** of Fukushima, Topco, the situations drastically shifted from economics to safety in worldwide, and the new HTGR based on the thorium cycle will be emerging as a new solution on the several arguments concerning future energy safety. In HTGR, carbon graphite and He are used for the moderator and nuclear clad and the coolant, respectively. The inherency works well to prevent the meltdown of the nuclear core, however, the loss of cooling accident (LOCA) may cause severe radioactive contamination by the radio-activated carbon particles in the coolant generated from the carbon of the moderator and nuclear clad.

In this research, several characteristics of such carbon nano-particles were examined for the particles thus generated under very high temperature from the same type of carbon graphite used in HTGR for the designing an inline particle removal system of the primary cooling system in Gen-III+HTGR.

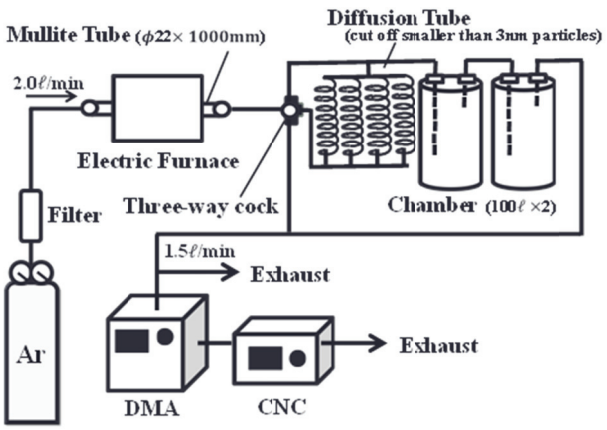

Fig. 1 The schematic diagram of experimental apparatus.

In the particle generation, two mechanisms were assumed: nucleation process after the sublimation of carbon and fragmentation of carbon graphite by thermal shock under very high temperature. **Figure 1** shows the schematics of experimental apparatus. Three alternating sampling paths were installed: (a) direct path, (b) particle growth one in chambers after via diffusion tube (3nm cut) and (c) simple particle growth one in the plenum chambers. The particles were measured by a CNC with DMA (TSI). To prevent the electric breakdown in DMA by carrier gas, Ar was applied as the gas instead of He. Ar was flowed into a Mullite™ tube heated at 1470K with the rate of 2.0ℓ/min. Carbon three pebbles (ϕ10mm, Toyo Tanso) made of IG-110 carbon, the same type of carbon used in HTGR and PBMR (Sumita, et al, 2006), were set at the center of the Mullite tube.

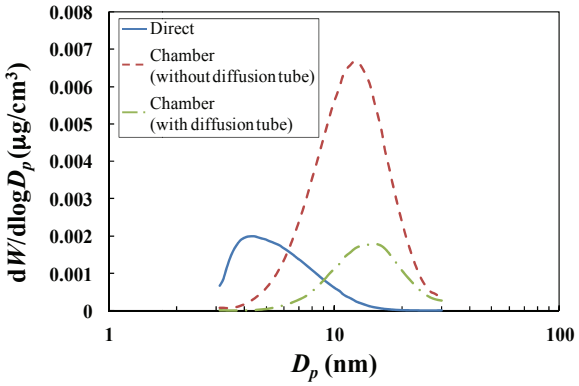

Fig. 2 Moving averaged mass size distributions of generated from carbon pebble heated at 1470K.

Figure 2 shows the mass concentration distribution of the three alternating paths; the data were modified with the moving averaged method of 5 points to avoid unconditional ambiguities. The total mass of carbon particles of the paths were (a) 5.771μg/cm^3, (b) 10.76μg/cm^3 (c) 47.13μg/cm^3. The mass of (b) and (c) became larger than that of (a). It was because the carbon vapor and the particles smaller than the sensing range of CNC (3nm) grew up to the range after condensation and coagulation in the chambers (residence time: 5000s). The mass difference of the two cases through chambers shows the true mass of the vapor and the small particles. From the comparison of the three mass data, it was made clear that major mass fraction of the particles was the fragmentation rather than the nucleation via sublimation, and the design of particle removal system should be focused in the mechanism of around 10nm in diameter.

Sumita, J. et al., (2006) JAEA-Technology, **48** (1), 1-19.