

# Wigner Energy Effect on the Storage of Irradiated Graphite Produced from KRR-2

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## 1. Introduction

Irradiated graphite arising from the decommissioning of KRR-2 (Korean Research Reactor 2) have shown to include somewhat degree of Wigner energy, specific radioactivity and the resulting radioactive chemicals/nuclides in the study of bulk mode of graphite structure[1]. Plans of annealing and disposal of the irradiated graphite stored Wigner energy in its internal matrix of rearranged carbon structures due to neutron dose might depend on whether the storage stability of the graphite is attainable or not[2]. That is, because the Wigner energy as a latent explosive energy in the graphite structure was caused by carbon atomic rearrangements or dimensional distortions in the graphite crystal lattice is very labile at higher temperature conditions than that of its formation, why it is of importance to forecast the thermal stability of the graphite in a long term storage[3]. Moreover, since the nuclide emissions are directly related to the thermal stability of the graphite at the same time in view point of graphite disposal, the control of Wigner energy content in a lower level or naught in the waste program of the irradiated graphite might be necessary in the near future.

A study on fire accident model as an emergency case analysis at a sudden external fire exposure of the irradiated graphite was proposed to assess the feasibility of the disposal storage of the graphite without any physical and/or chemical treatment of Wigner energy in the form of box disposal[4].

In this study a fire accident model of the irradiated graphite, that is to be disposed in the radioactive waste storage facility in the forthcoming time, was considered to estimate the thermal stability of graphite, whether the Wigner energy of the irradiated graphite has an effect on the storage stability or not, in front of a sudden fire accident.

## 2. Heat Flux Model

### 2.1. Energy Balance

In order to establish the heat flux for the graphite in the external firing system heat input quantity is defined by a combination of convection and radiation into the fire-exposed graphite surface. Therefore, this total heat flux can be calculated using the following equation:

$$Q = A[h(T_f - T_s)^N + V\sigma(\alpha\varepsilon_f T_f^4 - \varepsilon_s T_s^4)] \quad (1)$$

where

$A$  = surface exposed to fire

$h$  = convection coefficient

$N$  = convection power factor

$V$  = radiation view factor

$\sigma$  = Stefan-Boltzmann constant

$\alpha$  = absorption of surface

$\varepsilon_f, \varepsilon_s$  = emissivity of flame and surface

$T_f, T_s$  = fire exposure and surface temperature.

The governing equation for the transient temperature of the heat flux in a three-dimensional body of graphite without Wigner energy generation is described in the following form:

$$\rho C_p \frac{\partial T}{\partial t} + \kappa \nabla^2 T = Q \quad (2)$$

$$\nabla^2 = \frac{\partial}{\partial x^2} + \frac{\partial}{\partial y^2} + \frac{\partial}{\partial z^2}$$

where

$\rho$  = density of graphite

$C_p$  = specific heat capacity of graphite

$T$  = temperature distribution in conduction

$t$  = time

$\kappa$  = thermal conductivity of graphite.

Initial and boundary conditions are:

$$T = T_0 \text{ at } x = x_0, t > 0 \quad (3)$$

$$T = T_i \text{ for } t = 0, x \geq 0.$$

### 2.2. Treatment of Modes of Heat Transfer

In a case of internal energy generation in the irradiated graphite, as emission of Wigner energy proceeds as much as heat absorbs, the governing equation (2) becomes as the followings:

$$\alpha \nabla^2 T + \frac{\alpha}{\kappa} g(t) = \frac{\partial T}{\partial t} \quad (4)$$

where  $g(t)$  = released Wigner energy at time  $t$ .

The forthcoming interest in this heat generation problem for the transient heat conduction of the graphite body due to the external heat flux of firing accident is the energy generation mechanism. In the former study for Wigner energy generation in the irradiated graphite was modeled by the following equation:

$$\frac{dg(E,t)}{dt} = -\lambda g(E,t) \exp\left(-\frac{E}{kT}\right) \quad (5)$$

where

$$g(E,t) = g(t)$$

$E$  = activation energy, variable  
 $k$  = Boltzmann constant  
 $\nu$  = frequency factor.

### 2.3. Analytical Solution Problem

One dimensional approach to the governing equation (4) and (5), and the boundary and initial condition equation (3) can be get an analytical solution by simplification study. Thus, the temperature profile in the graphite body can be described by the following equations[5]:

$$T(x,t) = T_0 + [1 - (1 - \frac{x}{\delta})^3] F \quad \text{in } 0 \leq x \leq \delta \quad (6)$$

where  $F = (T_i - T_0) + \frac{\alpha}{\kappa} g(E,t)$ .

### 3. Results and Discussion

One dimensional and three dimensional transient heat transfer analysis for the irradiated graphite with Wigner energy at a sudden fire condition (1 hour exposure at fire) was conducted. The following figures(Fig.1, Fig.2) show the thermal behavior of the KRR-2 thermal column graphite nearby the fire.

Figure 1 describes the temperature profile at the graphite surface and at the core in case of no Wigner energy content. After one hour firing, while the surroundings are got back to normal condition, the both of temperatures of the graphite are to be stabilized to the normal states.

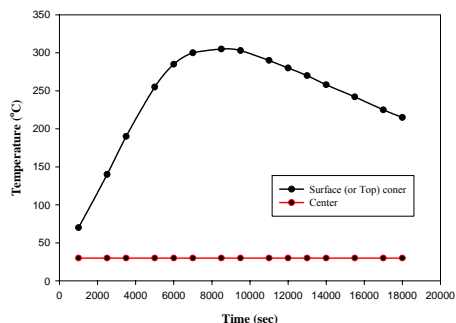


Fig. 1. Temperature vs. Time in Case of Normal Graphite at Fire

Figure 2 shows the thermal instability of the irradiated graphite due to the Wigner energy generation by external heat absorption, while it is exposed in external fire for one hour. Within one hour the outer surface of the irradiated graphite having whole Wigner energy in it reaches a very hot temperatures suitable for the graphite state deformation like sublimation or something else to ignite. In another approach, when the elimination of 80~90% of the Wigner energy from the irradiated graphite was performed, a maximum hot temperature that is endurable for a fire accident was maintained at the graphite surface.

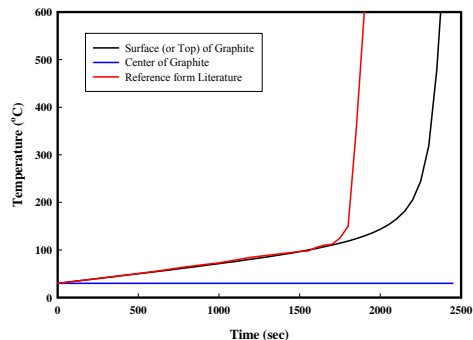


Fig. 2. Emergency Assumption of Temperature Rise of the Irradiated Graphite(#53 partition) at Fire

### 4. Conclusion

A study on the fire accident model for the irradiated graphite from KRR-2 was performed.

As a result, the whole Wigner energy in the graphite was the cause that the surface of the graphite is apt to uneasy to deform its original form at one hour external fire. On the other hand, the elimination of 80~90% of the Wigner energy from the irradiated graphite shows a stable temperature profiles.

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