

The porosity formation effect on irradiated UO₂ fuel thermal conductivity in high burnup structure

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Abstract

One of the factors that change the UO₂ fuel thermal conductivity is the generated porosity in the fuel with increasing burnup. At high burnups, the structure known as rim region is created, which is due to the Xe depletion process from the fuel matrix, porosity formation and fuel grain recrystallization, which in turn changes the fuel thermal conductivity. Using the existing low temperature high burnup fission gaseous swelling model with progressive recrystallization for UO₂ fuel, the matrix swelling terms are calculated and the evolution of total volume porosity up to burnup of 120 MWd/KgU is estimated. To study the effect of porosity formation on irradiated UO₂ thermal conductivity, the irradiated UO₂ thermal conductivity model based on the Maxwell-Eucken correlation for porosity factor is selected as a case study and the calculation of porosity evolution with burnup is carried out. It is shown that taking into account the formation of porosity with burnup compared to the case with constant porosity equal to as-fabricated value leads to a decrease in the UO₂ fuel thermal conductivity up to about 15% at high burnup values of 120 MWd/kgU. Results of the calculations are also compared with the available experimental data and good agreement was found. The conducted parametric study clearly demonstrated the impact of the key parameters on the results of the present investigation.

1. Introduction

The thermal conductivity is one of the most important properties of fuel that has great influence on the fuel operating temperature, performance and behavior. In general, ceramic fuels as UO₂ have rather low thermal conductivity that is affected by several factors such as temperature, porosity, dissolved and precipitated solid fission products, changing in fuel microstructure and establishment of high burnup structure, radiation damage and stoichiometry. The porosity effect on thermal conductivity, among other factors, is one of the most difficult properties to characterize. In fact the oxide fuel is generally fabricated by sintering pressed powdered UO₂ at high temperature. By controlling the sintering conditions, material of any desired density, usually around 90% of the maximum possible or theoretical density of the solid, can be produced. As a result, as-fabricated porosity is already present in unirradiated fuel. The fission gas atoms resulted from the fission process, are known to be insoluble in the fuel matrix and to precipitate into intragranular and intergranular bubbles, which contribute to fuel swelling and porosity generation. With increasing burnup under low temperature condition, UO₂ fuel is known to undergo irradiation-induced recrystallization process by which more grain boundaries are formed to accommodate fission gas atoms. Recrystallization initiates from the boundary of the grain and proceeds toward its center until the grain is totally consumed. Large grains turn into small fine grains so as to absorb gas atoms in the grain boundary effectively, thus large intergranular bubble will be produced and make a major contribution to the gas bubble swelling and corresponding porosity generation [1-5].

Various equations, both empirical and analytical have been developed to describe the effect of porosity on the thermal conductivity. Taking a unit cell of porous material represented as a cube of the solid material surrounding a gas pore, Loab [6] and Kampf et al. [7] derived an analytical expression for the porosity effect on thermal conductivity. Studies on thermal conductivity of high burnup structure and experimental observations of increasing porosity in the rim region of UO₂ pellet led to proposing some correlations for porosity evolution with burnup in this region [8]. Lee et al. [9] studied the effect of calculated porosity of rim region of UO₂ pellet on thermal conductivity degradation assuming that all generated fission gas atoms in the rim region are retained in the rim pores. Using the HALDEN thermal conductivity model, they found that the rim porosity yields a thermal conductivity decrease of about 20% at high burnups. Recently, based on the relevant experimental data obtained by Spino et al. [10], Lemes et al. [11] developed an empirical expression for porosity of UO₂ fuel as a function of local burnup ranging from 60 to 300 MWd/kgU, including the possible effects of pellet-cladding mechanical interaction.

In this paper, an attempt is made to quantify the influence of porosity on the thermal conductivity of UO₂ matrix. This is achieved using a model for determining porosity evolution based on the work of Spino et al. [12] as well as the Rest model [2,4,5] for UO₂ swelling with progressive recrystallization. Then as a case study, the Lucuta model [13] for UO₂ thermal conductivity is selected to evaluate the effect of calculated porosity evolution on the thermal conductivity up to the local burnup of 120MWd/kgU.

2. Models and methods

2.1. Lucuta model of thermal conductivity

The model of irradiated UO₂ thermal conductivity developed by Lucuta et al. [13] can be expressed as:

$$k = k_0 \kappa_B \kappa_S \kappa_{RD} \kappa_P, \quad (1)$$

where k_0 is unirradiated UO₂ thermal conductivity and for a fully dense UO₂ (100% of theoretical density) as a function of temperature is given by the expression [13]

$$k_0 = \frac{1}{0.0375 + 2.165 \times 10^{-4} T} + \frac{4.715 \times 10^9}{T^2} \exp\left(-\frac{16361}{T}\right), \quad (2)$$

where T is the temperature in Kelvin.

κ_B is the burnup dependence factor that consists of the following two contributions:

$$\kappa_B = \kappa_{DS} \kappa_{PS}$$

$$\kappa_{DS} = \left(\frac{1.09}{\text{Bu}^{3.265}} + \frac{.0643}{\sqrt{\text{Bu}(\%)}} \sqrt{T(\text{K})} \right) \arctan \left(\frac{1}{\frac{1.09}{\text{Bu}(\%)^{3.265}} + \frac{.0643}{\sqrt{\text{Bu}(\%)}} \sqrt{T(\text{K})}} \right) \quad (3)$$

$$\kappa_{PS} = 1 + \frac{0.019 \text{Bu}(\%)}{(3 - 0.019 \text{Bu}(\%))} \frac{1}{1 + \exp\left(-\frac{T(\text{K}) - 1200}{100}\right)}, \quad (4)$$

where κ_{DS} and κ_{PS} denote the effect of the dissolved and precipitated solid fission products, respectively and Bu is the fuel burnup in percent .

κ_S is associated to the effect of deviation from the stoichiometry on the thermal conductivity that is important for accident conditions and fuel defects. In both cases, the fuel becomes hyper stoichiometric and thermal conductivity would decrease accordingly [13], but no deviation from the stoichiometry under normal operating conditions is observed, so that under these conditions $\kappa_S = 1$.

κ_{RD} refers to the effect of the radiation damage from the neutrons, α -decay which increases lattice defects and consequently reduces the fuel thermal conductivity. κ_{RD} can be expressed as [13]:

$$\kappa_{RD} = 1 - \frac{0.2}{1 + \exp\left(\frac{T(K)-900}{80}\right)} \quad (5)$$

κ_P indicates the porosity effect on the fuel thermal conductivity. The expression for κ_P , according to Maxwell-Eucken formula [13] consists of a pore shape factor, σ , that equals to 1.5 for the spherical pores and hence the total porosity P given by:

$$\kappa_P = \frac{1-P}{1+(\sigma-1)P} \quad (6)$$

In the present study, we examine the effect of porosity evolution with burnup on the thermal conductivity as expressed by the factor κ_P in the Lucuta formula for irradiated UO_2 fuel thermal conductivity.

2.2. Porosity

Porosity is defined as the ratio of voided volume over the total volume. Total porosity P is composed of two contributions: One comes from pores P_v including as-fabricated voids as initial porosity with no contribution to the matrix swelling and the other named swelling porosity P_s stems from the irradiation induced fission gas bubbles contributing to the matrix swelling. If $\Delta V^{gas\ bubble}/V_0^{matrix}$ represents the fractional fuel matrix swelling due to fission gas bubbles, where V_0^{matrix} denotes the initial matrix volume, and $\Delta V^{gas\ bubble}$ is the increase of matrix volume due to bubble formation, then by definition the swelling porosity P_s is given by:

$$P_s = (\Delta V^{gas\ bubble}/V_0^{matrix}) / (1 + \Delta V^{gas\ bubble}/V_0^{matrix}) \quad (7)$$

Taking the unirradiated fuel volume as the reference state in the fuel swelling calculation, the pore P_v may be obtained by the following expression given in [12]

$$P_v = 1 - (1 + \Delta V^{matrix}/V_0^{matrix})(\rho/\rho_{th}), \quad (8)$$

where ρ is the bulk fuel density and ρ_{th} is the theoretical density of UO_2 , and $\Delta V^{matrix}/V_0^{matrix}$ represents the total fractional fuel matrix swelling caused by both solid ($\Delta V^{solid}/V_0^{matrix}$) and gaseous ($\Delta V^{gaseous}/V_0^{matrix}$) fission products as follows:

$$\Delta V^{matrix}/V_0^{matrix} = \Delta V^{solid}/V_0^{matrix} + \Delta V^{gaseous}/V_0^{matrix} \quad (9)$$

With $\Delta V^{gaseous}/V_0^{matrix}$ representing the total fractional gas swelling resulting from both gas atoms in the dynamic solution and the fission gas bubbles as follows

$$\Delta V^{gaseous}/V_0^{matrix} = \Delta V^{gas\ atom}/V_0^{matrix} + \Delta V^{gas\ bubble}/V_0^{matrix} \quad (10)$$

The swelling due to solid fission products is given by [14] :

$$\Delta V^{solid}/V_0^{matrix} = 0.0032 * Bu(GWd/tM)/10, \quad (11)$$

where Bu depicts the fuel burnup. To estimate the swelling due to gaseous fission products, an analytical approach to fuel element swelling developed in the low temperature condition ($T < 850$ K) is used [5,15].

Hence the total porosity $P = P_s + P_v$ takes the following form:

$$P = 1 - (1 + \Delta V^{matrix}/V_0^{matrix})(\rho/\rho_{th}) + (\Delta V^{gas\ bubble}/V_0^{matrix}) / (1 + \Delta V^{gas\ bubble}/V_0^{matrix}) \quad (12)$$

To study the evolution of porosity with burnup using Eq. (12), one needs to calculate the terms associated with the matrix swelling.

2.3. Matrix swelling before grain recrystallization

An analytical approach in the low burnup regime to obtain fission gas induced swelling was developed in References [4,5,12]. For completeness, this approach is outlined in this Section.

In this approach, fission gas swelling is a function of the fission gas atoms and bubbles concentration and lattice size in the fuel matrix. The density of the gas in the intragranular bubbles change by irradiation time and can be written as the sum of the two equations, representing the time evolution of the fission gas bubble density c_b and of the gas atoms content in bubbles n_b as follows [4,5,12]:

$$\frac{dc_b(t)}{dt} = \frac{16\pi f_n D_g r_g c_g(t) c_g(t)}{n_b(t)} - \frac{b}{2} c_b(t) \quad (13)$$

$$\frac{dn_b(t)}{dt} = 4\pi r_b(t) D_g c_g(t) - \frac{b}{2} n_b(t), \quad (14)$$

where f_n ($\approx 10^{-4}$) is the bubble nucleation factor, b is related to the effects of fission-induced gas atom resolution and is the rate of gas atoms ejected from the bubble, and c_g , D_g , r_g and r_b are the concentration of the intragranular gas atom, diffusion coefficient and radii, respectively.

In present work, the system of Eqs. (13) and (14), with initial conditions ($c_b=n_b=0$) is solved numerically the by Runge Kutta-4 to obtain c_b and n_b . The first term on the RHS of Eq. (14) represents the creation rate of intragranular bubbles with an average size of r_b . The last terms on the RHS of Eqs. (13) and (14) are a loss due to the whole bubbles destruction and a loss term due to gas atom chipping from bubbles, respectively.

The concentration of gas atoms within grain $c_g(t)$, according to Rest [2] is formulated as

$$c_g(t) = \frac{-(1+f_s) + [(1+f_s)^2 + 64\pi f_n r_g D_g \alpha \dot{f} t / b]^{\frac{1}{2}}}{32\pi f_n r_g D_g / b}, \quad (15)$$

where \dot{f} (fission/ $m^{-3}sec^{-1}$) is the fission density rate, α is the number of gas atoms produced per fission event and f_s is the fraction of the gas that diffuses to the grain boundary of diameter d_g and can be approximated by [4]

$$f_s = \frac{8}{d_g} \left(\frac{D_g t}{\pi} \right)^{\frac{1}{2}} - \frac{6}{d_g^2} D_g t \quad \frac{4\pi^2 D_g t}{d_g^2} \leq 1 \quad (16)$$

$$f_s = 1 - \frac{d_g^2}{60 D_g t} + \frac{d_g^2}{2 D_g t} \exp\left(-\frac{4\pi^2 D_g t}{d_g^2}\right) \quad \frac{4\pi^2 D_g t}{d_g^2} > 1 \quad (17)$$

To obtain the bubble concentration on the grain boundary, $C_b(t)$, one can use an approximate relation as [4,5,12]:

$$C_b(t) = \left(\frac{8zaK}{12^{1/3}\pi^2\xi D_g \delta} \right)^{\frac{1}{2}}, \quad (18)$$

where $\frac{a^3}{12}$ is the average atomic volume in UO_2 [12], a is the lattice constant, z is the number of sites explored per gas-atom jump, δ is the width of the boundary, ξ is a grain-boundary diffusion enhancement factor, and K is the diffusion flux of gas-atoms from grain interior to the grain boundary given by [12]:

$$K = \frac{d_g}{3} \frac{dc_g}{dt} \frac{d(f_s t)}{dt}, \quad (19)$$

with

$$\frac{dc_g}{dt} = \frac{\alpha \dot{f} - c_g df_s/dt}{1 + f_s + 32\pi f_n r_g D_g c_g/b} \quad (20)$$

The gas concentration on the grain boundaries, C_g , is given by:

$$C_g(t) = \frac{d_g}{3} f_s(t) c_g(t) \quad (21)$$

And the average number of gas atoms in a grain boundary bubble is

$$N_b = \frac{C_g(t)}{C_b(t)} \quad (22)$$

The radius of the intragranular bubble r_b can be calculated using the modified Van der Waals gas law as:

$$\frac{2\gamma}{r_b} \left(\frac{4\pi r_b^3}{3} - h_s B n_b \right) = n_b k T \quad (23)$$

where B is the Van der Waals constant for Xe, k is Boltzmann's constant, T is the absolute temperature, γ is the surface tension and h_s is a fitting parameter that for a given T makes Eq. (23) equivalent to the hard sphere equation of state [12].

An approximate solution to Eq. (23) for intragranular bubbles in the nanometer size range is given by

$$r_b(t) = \left(\frac{3h_s B n_b(t)}{4\pi} \right)^{1/3}, \quad (24)$$

where B is the Van der Waals constant for Xe, k is Boltzmann's constant, T is the absolute temperature, γ is the surface tension and h_s is a fitting parameter that for a given T makes Eq. (23) equivalent to the hard sphere equation of state [12].

The radius of the intergranular bubble R_b can be obtained by numerically solving Eq. (23) written on the grain boundary while substituting n_b and r_b with N_b and R_b , respectively.

Finally, the total fractional gaseous swelling defined by Eq. (4) is given as [12]

$$\left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_g = \frac{c_g a^3}{4} + \frac{4\pi}{3} \left(r_b^3 C_b + \frac{3R_b^3 C_b}{d_g} \right) \quad (25)$$

The first term on the RHS of Eq. (25), represents the swelling due to gas atoms in the dynamic solution and does not contribute to the swelling porosity P_s , and the second term represents the contribution of intragranular and intergranular bubbles to the matrix swelling leading to swelling porosity formation, respectively.

2.4. Matrix swelling with grain recrystallization

In low temperature, high burnup conditions, irradiation induced recrystallization process wherein the as-fabricated micron-size grains are transformed to submicron-sized grains accelerates the fission gas swelling. This is due to a combination of short diffusion distances which further facilitates gas depletion, increased grain-boundary area per unit volume, and greater intergranular bubble growth rates as compared to that in the grain interior. The initiation of the recrystallization has been observed to occur predominantly along the preexisting grain boundaries at a fission density of F_{dx} estimated as [2,5]

$$F_{dx} = 4 \times 10^{24} \dot{f}^{2/15}. \quad (26)$$

Subsequently, the recrystallization front moves toward the grain center eventually consuming the entire grain. Thus, the volume fraction of recrystallized material is a function of the irradiation time as well as the initial grain size given by [2,5]

$$V_r = 1 - \left[1 - \frac{96\nu B_2(F_d - F_{dx})}{d_g C_A C_\rho} \sqrt{\frac{f(v)}{2\pi}} \right]^3, \quad (27)$$

where F_d and $F_{dx} = \dot{t}_x$ are the fission density related to the irradiation time, t , and onset of the recrystallization time, t_x respectively, $f(v) = (1 - \nu/2)/(1 - \nu)$, where ν is poisson's ratio, C_A is 3 for the cubic cells, C_ρ is within a factor of unity [2,5], B_2 is a parameter in the expression for the fission induced microscopic creep, $\dot{\epsilon} = B_2 \dot{f} \sigma$, and stress, σ , is a function of the lattice displacement, $\sigma = E \Delta a / a_0$, where E is the bulk modulus of fuel material [3]. After the onset of the recrystallization, the original grain is divided into two regions of the recrystallized and unrecrystallized grain. The total fractional gas swelling can be expressed as

$$\left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_{\text{TOT}} = (1 - V_r) \left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_g + V_r \left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_{gx}, \quad (28)$$

where V_r is given by Eq. (27), $\left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_g$ indicates the gaseous swelling within the unrecrystallized zone which is still composed of both the intragranular and intergranular bubbles given by Eq. (25), and $\left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_{gx}$ denotes the gaseous swelling within the recrystallized area which is due to the Xe depletion in the fuel matrix stemming from the intergranular bubbles only, and can be calculated by [2,5]

$$\left(\frac{\Delta V_{\text{gaseous}}}{V_0^{\text{matrix}}} \right)_{gx} = 4\pi R_{bx}^3 \left(\frac{C_b}{d_g} + \frac{C_{bx}}{d_{gx}} + \frac{1}{3d_{gx}^3} \right), \quad (29)$$

where R_{bx} and C_{bx} are the radius and the density of the intergranular fission gas bubble and d_{gx} is the grain size after the recrystallization. For evaluation of C_{bx} , Eq. (18) is used, and Eq. (23) is numerically solved for R_{bx} , with as fabricated grain size d_g replaced with the recrystallized grain size d_{gx} and N_b with N_{bx} which is obtained by the modified expression given by Yi Cui et al. [16] as follows:

$$N_{bx} = \frac{\alpha \dot{t}}{3 \left(\frac{C_b}{d_g} + \frac{C_{bx}}{d_{gx}} + \frac{1}{3d_{gx}^3} \right)}. \quad (30)$$

In Eq. (30), it was assumed that in the recrystallized region of the fuel, the majority of the generated gas is on the grain boundaries. This assumption is consistent with the fractional gas release calculated using Eq. (17) for $\frac{4\pi^2 D_g t}{d_g^2} > 1$ [4].

3. Results and discussion

3.1. Matrix swelling

The values of the parameters used in the present calculations are listed in Table 1. Fig. 1 depicts the total matrix swelling of UO_2 fuel as a function of the local burnup calculated at a representative temperature of 800K for various recrystallized grain sizes. It is seen that after initiation of recrystallization, the fuel matrix swelling rate increases showing a ‘‘Knee’’ in the corresponding curve as would be expected. Moreover, the increase of recrystallized grain

Table 1. Values of various parameters used in the calculations.

Parameter	Value	Unit	Reference
α	0.26	-	[14]
b_0^{*1}	10^{-23}	m^3	[12]
D_0^{*2}	1.2×10^{-39}	m^5	[12]
r_g	2.16×10^{-10}	m	[14]
ξ	1.65×10^3	-	[12]
δ	2×10^{-9}	m	[2]
γ	1	Jm^{-2}	[14]
B	8.5×10^{-29}	$m^3 atom^{-1}$	[14]
f_n	10^{-2}	-	[12]
h_s	0.6	-	[12]
d_g	5×10^{-6}	m	[5]
\dot{f}	2×10^{19}	$m^{-3}s^{-1}$	This work
B_2	1×10^{-34}	$m^5 N^{-1}$	[2]
ν	0.31	-	[17]
d_{gx}	0.15×10^{-6}	m	[18]

*1 $b = b_0 \dot{f}$,

*2 $D_g = D_0 \dot{f}$

size leads to increasing the fuel swelling rate. Also shown in Fig. 1 is the available bulk swelling data [19], which demonstrate an agreement with the calculated bulk swelling values.

Fig. 2 shows the total matrix swelling as a function of temperature for various burnups. In fact high temperature will induce the large intergranular bubble radius leading to high gaseous bubble swelling.

3.2. Porosity evolution

Having determined the gas bubble swelling $\Delta V^{gas\ bubble}/V_0^{matrix}$ as well as the total fractional matrix swelling $\Delta V^{matrix}/V_0^{matrix}$ we can now calculate the swelling porosity P_s , pore contribution P_v , and the total porosity P by virtue of Eqs.(7), (8), and (12), respectively, with the relative immersion density ρ/ρ_{th} for the local burnups in the range 15-100 MWd/kgU estimated by the following expression [12].

$$\rho/\rho_{th} = (0.9383 - 1.71 \times 10^{-4} Bu^{3/2})^{1/2}, \quad (31)$$

where Bu is burnup in MWd/kgU.

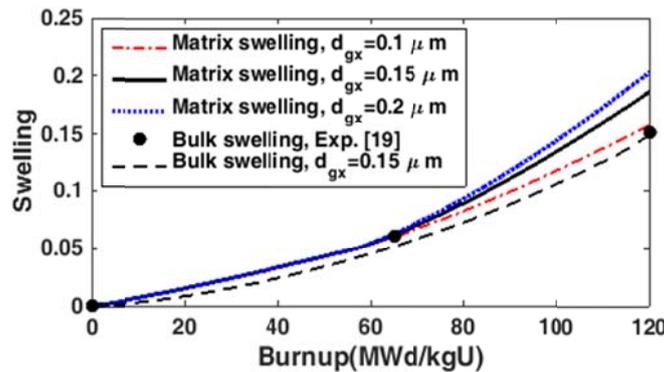


Fig. 1. Total matrix swelling of UO_2 fuel calculated for different recrystallized grain sizes at $T=800K$

$$\left(\frac{\Delta V^{matrix}}{V_0^{matrix}}\right)_{TOT} = \left(\frac{\Delta V^{gaseous}}{V_0^{matrix}}\right)_{TOT} + \left(\frac{\Delta V^{solid}}{V_0^{matrix}}\right)$$

in addition UO_2 bulk swelling) calculated and data.

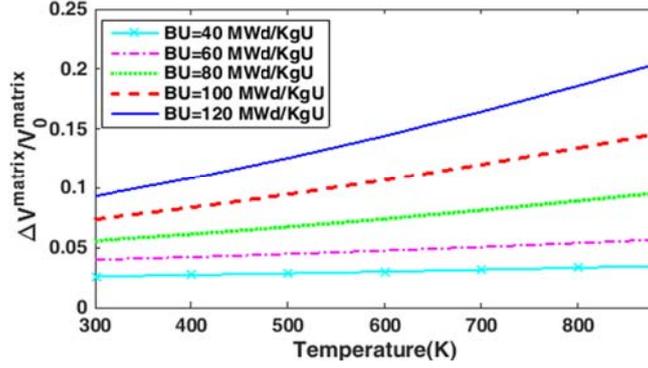


Fig. 2. Total matrix swelling of UO_2 fuel as a function of temperature for different burnups with $dgx = 0.15 \mu m$.

Fig. 3 displays the calculated swelling porosity P_s , pore P_v , and the total porosity P as a function of burnup compared with the experimental data [10]. It is seen that at the high burnups owing to the increase of gas bubble swelling contributed by the intergranular bubbles gathered in the recrystallized grain boundary, the swelling porosity increases, resulting in an increase in the total porosity. As shown in Fig. 3, the calculated total porosity values follow the trend of the porosity data as a function of burnup.

3.3. Thermal conductivity

The thermal conductivity of this work was obtained with calculation of total porosity (by using Eq. (12)) that is indicated in Fig. 3 and by placing in the Maxwell-Eucken formula, Eq. (6). Fig. 4a and b compare the evolution of UO_2 thermal conductivity based on the Lucuta model Eq. (1) as a function of the local burnup for two cases: a constant volume porosity of 5% and a varying porosity computed by the present methodology for $T=490K$ and $T=800K$. It can be seen that taking into account the evolution of porosity with burn up leads to a decrease in the thermal conductivity of about 15% at a local burnup of 120MWd/kgU for $T=490K$ and 800K. In addition, it has better agreement with the trend of Experimental data of thermal conductivity by Walker et al. [18] and Ronchi et al. [20] rather than original Lucuta model.

The thermal conductivity of present work is normalized from the 97% theoretical density to 95% by using the following relations that is the general form of the relation in Ref. [21]:

$$k_0 = \frac{1+(\sigma-1)(1-d)}{d} k_d \quad (32)$$

$$k_{d'} = \frac{d'}{1+(\sigma-1)(1-d')} k_0, \quad (33)$$

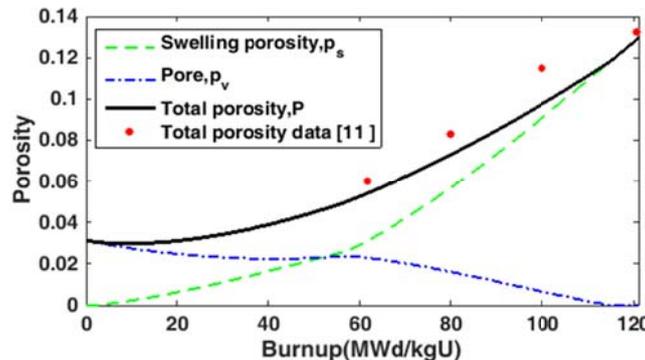


Fig. 3. Formation of pore P_v , swelling porosity P_s , and total porosity P as a function of burnup at 800K in addition total porosity data.

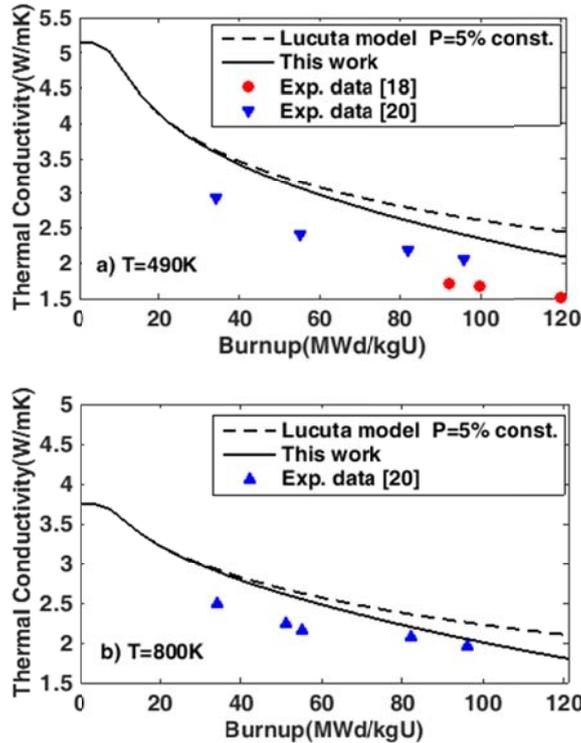


Fig. 4. UO₂ thermal conductivity based on Lucuta model vs. burnup with porosity evolution included in comparison to the case with constant porosity 5% and experimental data at a) 490K, b) 800K.

where k_0 and k_d are the thermal conductivity at 100% and $d\%$ theoretical density, respectively. $k_{d'}$ is the thermal conductivity at the percentage of theoretical density, d' . The term, $\frac{1+(\sigma-1)(1-d)}{d}$, adjusts the thermal conductivity from $d\%$ to 100% theoretical density. So, for this case d is 97% and d' is 95%. The shape factor, σ , is 1.5 for spherical pore shape [13].

4. Conclusions

In this paper the volume porosity formation of irradiated UO₂ fuel with burnup was estimated using the existing gaseous swelling model. It was found that at high burnups, around 120MWd/kgU, total porosity of the order of 15% can be produced as a result of the swelling porosity generated due to speeding up the formation of intergranular bubbles gathered on the boundary of recrystallized grains.

In order to study the influence of the porosity formation on the irradiated UO₂ thermal conductivity, the Lucuta model for UO₂ thermal conductivity consisting of a porosity correction factor was applied. It was found that a decrease in the UO₂ thermal conductivity up to about 15% at local burnup levels of around 120MWd/kgU compared to the case with as fabricated porosity during irradiation time $T=490$ and 800K occurs. The obtained results were consistent with the trends of the available data. A parametric study conducted into the key parameters used in the calculations indicated that although, in general, these parameters have a considerable impact on the calculated matrix swelling after the grain recrystallization, but their impact on the calculated thermal conductivity (due to porosity factor) turned out to be very limited.

It is expected that the degradation of thermal conductivity due to formation of porosity increases for local burnups higher than 120MWd/kgU. The model presented can be incorporated into fuel modeling codes to improve calculations of fuel thermal conductivity and in turn fuel operating temperature under normal and accident conditions at extended burnup.

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