Conductivity of series mechanism for Cylindrical Pellets (Kser)in Fixed Bed Reactor at High Pressure

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الملخص

المفاعل الحفاز ذو القاعدة المعبأة عبارة عن مجموعة من الكريات ذات الحجم الموحد (المحفز) التي يتم ترتيبها عشوائيًا وتثبيتها بثبات في مكانها داخل وعاء أو أنبوب. يتم إمداد المواد المتفاعلة إلى المفاعل مع تدفق الجزء الأكبر من السائل عبر الطبقة المعبأة. عند التلامس مع الجسيم النشط تحفيزيًا ، يخضع المتفاعل لتحولات كيميائية ، والتي عادة ما تكون مصحوبة بتقليل الحرارة أو استهلاك الحرارة. إذا لزم الأمر ، تتم إزالة الحرارة أو إمدادها من خلال جدار الأنبوب .

تم تطوير نماذج رياضية جديدة للتحقيق في المعاملات التي تؤثر على موصلية آلية السلسلة في مفاعل طبقة ثابتة بما في ذلك التوصيل الحراري لمرحلة المائع (kf) والطور الصلب المشتت (ks) مسامية الطبقة (ε) ، الشكل وتوجه الأطراف وكذلك كثافتها. هناك معاملات إضافية بجانب هذه المعاملات التي تساهم بشكل كبير في الخلط الشعاعي في طبقة معبأة ومهمة في المفاعلات الكيميائية وكذلك في عمليات فصل kc المخصصة للمعدات .

غالبًا ما يكون الخلط الشعاعي مرغوبًا لأنه يقلل من التدرج غير المرغوب فيه لدرجة الحرارة الشعاعية في المفاعلات. يعتمد مدى الخلط على عدد رينولدز ، والانتشار الجزيئي لحساسية السوائل للمكونات الفردية وعلى هندسة التعبئة .

الكلمات المفتاحية: سرير معبأ ، مفاعل ، محفز ، جسيم ، مسامية الطبقة

Abstract

Packed bed catalytic reactor is an assembly of usually uniformly sized pellets (catalyst) which are randomly arranged and firmly held in position within

a vessel or tube. The reactants are supplied to the reactor with the bulk of the fluid flowing through the packed bed. Contacting with catalytically active particle, reactant undergo chemical transformations, which are usually accompanied with heat reduce or heat consumption. If necessary, the heat is removed or supplied through the tube wall.

A new mathematical models is developed to investigate the parameters that influence the Conductivity of Series Mechanism in a fixed bed reactor including the thermal conductivity of the fluid phase (k_f) and solid dispersed phase (k_s) the porosity of bed (ε), the shape and orientation of the partied and as well as its density. There are additional parameters beside these parameters that contribute significantly radial mixing in packed bed and important in chemical reactors as well as well as in equipment devoted kc separation processes are considered.

Radial mixing is often desirable since it reduce undesirable radial temperature gradient in reactors. The extent of mixing depends on Reynolds number, molecular diffusion of fluid sensitivity of individual constituents and upon the geometry of the packing.

Keywords: Packed bed, reactor, catalyst, particle bed porosity.

1. Introduction

In packed-bed reactor design, the study of radial heat transfer-mechanism of flowing fluid through packing materials in a single wall tube forms an important aspect of the design of fixed bed reactors. The rational design of packed-bed reactors must satisfy optimum conditions for the reaction through the determination of temperature distribution within the reactor and the operational parameters such as the diameter of the reactor-tube and size of the packing-pellets.

The parameters include the thermal conductivity of continues fluid phase (k_f), the conductivity solid dispelled phase (k_s) and the porosity of the bed (ε) (usually the porosity depends upon the pellet particle-size, particle-shape, particle orientation and its density).Besides these parameters, additional parameters that affected the radial thermal conductivity in packed beds reactors with gaseous fluid flow. The parameters are classified as:

- Fluid Phase Redial Peclet Group
- Turbulent Diffusion

- Effect of Radiation
- Effect of the Pellet Size
- Effect Of high pressure

Argo and smith [1953] method had been modified (Al-meshragi, 1989) to evaluate the series mechanism (k_{ser}) in an uniform packed bed reactor for cylindrical and spherical and hollow cylindrical pellets for radial heat transfer through the pellet solution.

The following assumptions have been made:

i. Heat transfer through the particle occurs only in the radial direction.
ii. A constant temperature gradient exist in the solid particle.
iii. Heat transfer occurs by conduction and convection.
iv. The mean temperature of the particle is equal to the temperature of the surrounding fluid at the center line of the particle.
v. An average heat transfer coefficient may be considered applicable to the cylindrical particles is assumed to occur over elements normal to the direction of flow.

1-1. Mechanisms of radial heat transfer

In the development of a method of predicting effective thermal conductivities two possibilities are available. One is to attempt an empirical or semi-empirical correlation in terms of all the properties of the gas and bed that are involved. Since heat is transferred by several mechanisms, this approach would not only be difficult but also would lead to results which could not be safely extrapolated beyond the range of existing data. A more fundamental approach is to correlate the contribution of each mechanism in terms of the relatively few properties that affect it and then combine these various contributions.

This second proposal was applied first by Schumann and Voss [1934] and Dam Koehler [1937] and later modified by Wilhelm et. al. [1948], particularly to static systems (no gas flow in the bed). Verschoor and Schuit [1950] divided the total heat transfer into two parts by expressing the effective thermal conductivity as the sum of a static contribution and a contribution due to the flowing gas. Singer and Wilhelm [1950] carried the development considerably further by postulating separate mechanisms by which heat is transferred radially in the bed. These mechanisms were:

1) a conductive process in the fluid phase,
2) a convective process in the fluid phase,
3) a conductive process from particle to particle through point-to-point contact and stagnant fluid in the zone of solid-to-solid contact, and
4) Heat flow between fluid and solid particles.

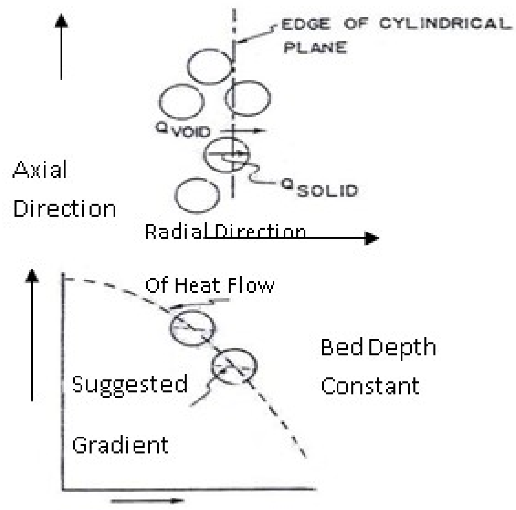
Leva and Grummer [1947] in attempting to explain the improved heat-transfer characteristics of beds packed with high-conductivity metals suggested that some heat was transferred from the gas stream to an individual particle, transmitted through the particle by conduction, and subsequently removed from the same particle on the other side by transfer back to the gas stream. Analysis of this possibility indicates that this series-type of mechanism is an important contribution, even in the case of packing materials considered to be poor conductors. In other words, the path of lowest resistance for transfer of thermal energy already in a solid particle is not necessarily by conduction to the adjacent particle through point contact or stagnant gas fillets, but may be by conduction to the surface of the solid and out into the gas phase by an effective film resistance.

2. Methodology

2-1- Theoretical Development

At steady state conditions, the heat transferred through a cylindrical plane parallel to the center line of a packed cylindrical bed will be the sum of the part passing through the void space and the part passing through the solid material. If q is the total rate of heat flow per unit area of the plane and the effective thermal conductivity k_{er}, then the total rate can be expressed as:

$$q = -k_{er}\frac{\partial t}{\partial r} = q_{void} + q_{solid} \qquad (1)$$



This concept is illustrated in the upper half of Figure (1) the temperature gradient in Equation (1) applies to the bed as a whole and deserves some explanation because of the possibility of temperature differences between solid and fluid phases in a packed bed. Bunnel et. al. [1949] measured temperatures at the same radial position in both the gas and in the center of the solid particle and found no significant difference. The solid particles were activated alumina (relatively low conductivity). On the basis of these data it will be assumed that the average temperature of the particle is the same as that of the gas at the same radial position. This does not require that the temperature gradient within a single solid particle coincide with that of the fluid phase.

As shown in Figure (1), there may existed a considerable temperature difference between gas and particle for the transfer of heat to the particle side and from the particle back to the gas stream. The temperature gradient within the particle would be sufficient to transfer heat from one side to another.

The heat passing across the plane in the void space is the sum of that due to molecular conduction, turbulent diffusion, and radiation. Since these paths are in parallel.

$$q_{void} = -\varepsilon\left(k'_{rf}(p) + k'_m(cp_f(p), \mu_f(p), \rho_f(p)) + k'_{td}(cp_f(p), \mu_f(p), \rho_f(p)) + k'_{rd}\right)\frac{\partial T}{\partial r} \quad (2)$$

Where ε is the void fraction and the prime superscript indicates that the conductivity is based upon the total void and non-void area; i.e., $k_{rf} = \varepsilon k'_{rf}$, etc.

The precise evaluation of the heat transfer through the particle presents a mathematically complex problem. This complexity arises both from the geometry of the bed and the several mechanisms by which heat can enter and leave the pellet. To solve this problem, no simplification will be made concerning the heat-transfer mechanisms, but an ideal model of the packed bed will be employed in order to avoid unsolvable geometrical difficulties. The methods by which heat can enter a particle from its inner side are radiation, convection from the gas stream, and conduction through point contacts and stagnant fillets as indicated in Figure (2) heat is transferred through the particle and leaves the other side by the same three mechanisms. The three processes are in series and hence the whole will be designated as the series mechanism. Hence

$$q_{solid} = -k'_{series}(1-\varepsilon)\frac{\partial T}{\partial R} \quad (3)$$

Combining Equations (1, 2 and 3) gives an expression for the point effective thermal conductivity in terms of contributions for each mechanism responsible for radial heat transfer.

$$k_{er} = \varepsilon\ (k'_{rf}(p)+k'_{m}(cp_f(p),\mu_f(p),\rho_f(p))+k'_{td}(cp_f(p),\ \mu_f(p),\rho_f(p))+k_{rd})+(1-\varepsilon)k'_{series}$$

$$=k_{rf}(p)+k_m((cp_f(p),\mu_f(p),\rho_f(p))+k_{td}(cp_f(p),\ \mu_f(p),\rho_f(p))+\ k_{rd}+k_{series}$$

$$k_{er} = \varepsilon\left(k'_{rf}(p)+k'_m(cp_f(p),\mu_f(p),\rho_f(p))+k'_{td}(cp_f(p),\mu_f(p),\rho_f(p))+k_{rd}\right)+(1-\varepsilon)k'_{series} \quad (4)$$

$$= k_{rf}(p)+k_m(cp_f(p),\mu_f(p),\rho_f(p))+k_{td}(cp_f(p),\mu_f(p),\rho_f(p))+k_{rd}+k_{series} \quad (5)$$

k'_{series} = conductivity of series mechanism based upon non void area.

Where $k_{series} = (1-\varepsilon)\ k'_{series}$ where k_{series} is based upon void and non-void area.

2.2 Molecular Conductivity

The molecular conductivity (K_m) of the fluid makes little contribution. At high Reynolds numbers, it becomes significantly on the radial heat transfer.

The molecular conductivity may be represented by

$$k_m = D_p.C_p.G / R_{ep}.P_r \tag{6}$$

2.3 Fluid-Phase Conduction

The value of $K_{rf}'(P)$ in equation (5) is the molecular conductivity of the fluid, its value will change with radial position because of the temperature and pressure variation in the bed. For gases $k_{rf}(P)$ is so low and not an important contribution to k_{er} while for liquids this is not true.

2.4 Turbulent Diffusion

The contribution of turbulent diffusion k_{td} is a measure of heat transfer as a result of turbulent mixing of portions of the gas stream at different temperatures. Singer and Wilhelm [1950] have pointed out that its value can be advantageously estimated from measurements of mass transfer radially by the same mechanism. The advantage of using mass transfer data is due to the fact that the transfer of mass radially in a packed bed does not involve the series or radiation mechanisms, but is caused only by molecular conduction and turbulent diffusion and the former contribution is small. On this basis:

$$K_{td}' = \frac{\rho c_p D_P}{\varepsilon} \tag{7}$$

$$\left(Pe_m = \frac{d_{P''}}{D_e} \right) \tag{8}$$

Determined from mass-transfer data,

$$K_{td}' = \rho c_p \left(\frac{d_{p''}}{\varepsilon Pe_m} \right) = \frac{d_p c_p G}{Pe_m \varepsilon} \tag{9}$$

2.5 Evaluation of Series Mechanism (k_{ser})

Argo and smith [1953] method had been modified (Al-meshragi, 1989) to evaluate the series mechanism (k_{ser}) in an uniform packed bed reactor for cylindrical and spherical and hollow cylindrical pellets for radial heat transfer through the pellet solution.

The following assumptions have been made:

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iv. The mean temperature of the particle is equal to the temperature of the surrounding fluid at the center line of the particle.
v. An average heat transfer coefficient may be considered applicable to the cylindrical particles is assumed to occur over elements normal to the direction of flow.

2.5.1. Conductivity of Series Mechanism for Cylindrical Pellets (kser):

It is desired to analysis the transport of heat by radial transport in a cylindrical tube packed with catalyst pellets. The tube is heated using a steam jacket and is operated under steady- state conditions. This type of heat transfer may be described by:

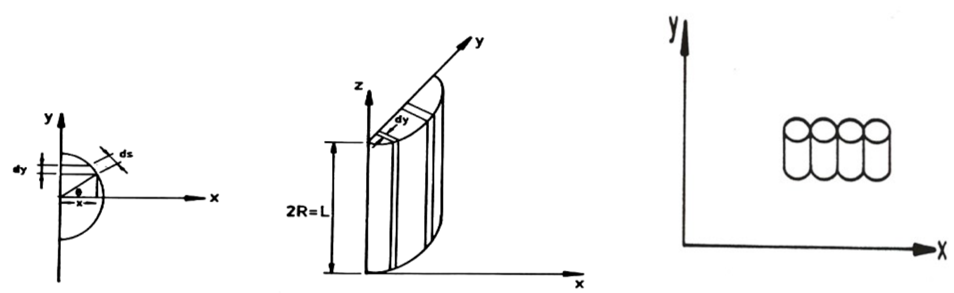

Figure2: Radial direction of Heat flow and axial direction of fluid flow.

$$Q = -k_{er}\frac{\partial T}{\partial r} \quad (10)$$

An energy balance on the element (dsdyL) leads to:

$$dq = k_{s,r}.l.dy(T_c - T_s)/x \quad (11)$$

and at steady state this must be equal to the heat removed at the surface.

$$dq = h'.l.ds(T_s - T_b) \qquad (12)$$

where:

$k_{s,r}$ = thermal conductivity of solid particle in the radial direction.

h' = total (Series) heat transfer coefficient from particle to fluid or two other particle.

1 = length of the particle.

T_c = temperature at center plane of particle.

T_s = temperature of surface of particle at distance x

T_b = temperature of bulk fluid at a distance x.

From geometrical considerations.

$$ds = dy / \cos\theta = dy * r / x = dy * D_p / 2x$$

= element of surface through which heat is transferred to the gas stream or to another particle.

r,D_p are the radius and diameter of the particle respectively.

By elimination of T_s from equations (11) and (12)

$$T_s = T_c - \frac{dq * x}{k_{s,r} * l * dy} \qquad (13)$$

$$T_s = T_b + \frac{dq * x}{h' * l * dy * r} \qquad (14)$$

$$T_C = \frac{dq * x}{k_{s,r} * l * dy} = T_b + \frac{dq * x}{h' * l * dy * r} \qquad (15)$$

$$T_b - T_c = -\frac{dq * x}{dy * l}\left\{1 / h' * r + 1 / k_{s,r}\right\} \qquad (16)$$

At any distance x the total heat flow in the particle leads to:

$$q = -\left\{\frac{h' * k_{s,r} * r}{h' * R + k_{s,r}}\right\} * A.dT / dx \qquad (17)$$

where q is the heat transferred through the solid based upon the temperature gradient of the bed.

Since heat is transferred through the particle and leaves the other side by two mechanisms (conduction and convection), the processes are in series, and can be lumped together in series mechanism (k_{ser}).

$$q_{solid} = -k_{ser}(1.0-\varepsilon)\,dT/dx \tag{18}$$

Since q_{solid} is based on a unit area of the normal plane, including both void and non-void surface.

$$q_{solid} = \frac{q'}{A}(1-\varepsilon) = -k'_{ser}(1-\varepsilon)\frac{\partial T}{\partial x} \tag{19}$$

$$= -\frac{h' * k_{s,r} * r}{h' * r + k_{s,r}}(1.0-\varepsilon)\,dT/dx \tag{20}$$

Comparing equation (19) and equation (20), series mechanism (k_{ser}) can be written as:

$$k'_{ser} = \frac{h' * k_{s,r} * r}{h' * r + k_{s,r}} \tag{21}$$

Or in terms of the particle diameter (D_p)

$$k'_{ser} = \frac{h' * k_{s,r} * D_p}{2k_{s,r} + h' * D_p} \tag{22}$$

The above equation can be rearranged in the following from

$$k'_{ser} = k_{s,r}\left\{\frac{N\ u'}{2k_{s,r}/k_f + Nu'}\right\} \tag{23}$$

where :

$$N'u = (h' * D_p)/k_f \tag{24}$$

Dixon and Cresswell [1979] and Sixon [1988] suggested new formula for B_{if} in a fixed bed reactor packed with both cylindrical and spherical particles, which can be written as:

$$B_{if} = N_{uwf}\,(dt/2d_p)(P_{erf}/R_{ep}\,P_r) \tag{25}$$

Where:

$Nu_{wf} = 0.523 * (1- d_p / dt) P_r^{0.33} R_e^{0.738}$ (26)

$$\frac{1}{P_{erf}} = \frac{1}{P_{erf}(\infty)} + \frac{0.74\varepsilon}{\operatorname{Re} P_r} \quad (27)$$

$$P_{erf}(\infty) = \begin{cases} 12 & \text{spheres} \\ 7 & \text{cylinders} \\ 6 & \text{hollow cylinders} \end{cases}$$

$$Bif = r / D_P \frac{N'u}{\ker} * \frac{C_P * G * D_P}{R_{ep} * P_r} \quad (28)$$

or $N'u = Bif\ (D_P / r)\ (R_{ep} * P_r) / P_{er}$ ----- (29)

Where:

P_{er} : is the effective radial Peclet number.

Wellauer et al [1982] proposed an equation for P_{er} which can be written as:

$$1/P_{er} = 1/P_{erf} + (k_{s,r} / k_f)/(R_{ep} * P_r) * \left\{\frac{1+4/Bif}{8/N_s + 1}\right\} \text{------} \quad (30)$$

Equation (29) can be expressed as:

$$N'u = 2\, Bif (D_p / D_t).\gamma.\left\{\frac{1+4/Bif}{8/N_s + 1}\right\} \text{------} \quad (31)$$

where $\gamma = (k_{s,r} * R_{ep} + R_{ep} * P_r) / P_{erf}$

N_s = inter phaseheat transfer group

$= a\, r^2\, h/k_{s,r}$

a = specific interfacial surface area

$= 4 / D_p (1-\varepsilon)$ (for cylindrical packing)

h = fluid to packing heat transfer coefficient

The fluid to packing heat transfer coefficient has been regarded by Stuke [1948] as a lumped parameter which includes the true fluid-solid film heat transfer coefficient (h_{fs}) and the particle conductivity (k_P). The appropriate lumping was show to be

$$1/h = 1/h_{fs} + D_P / \beta\, k_P \qquad (32)$$

Where β = 10 , 8 and 6 for spheres , cylinders and slabs respectively.

Substituting for h from equation (32) and eliminating h in terms of ($Nu_{fs} = hf_s D_P/k_f$)we obtained.

The inter phase heat transfer group (N_S) is correlated by the relation made by Dixon and Cresswell (1979) and Dixon (1988):

$$N_S = \frac{0.25(1-\varepsilon)(\frac{AP}{VP})(\frac{d^2 t}{dp})}{\frac{k_{rs}}{k_f}\left[\frac{1}{Nu_{fs}} + \left(\frac{1}{\beta}\right)\left(\frac{kf}{ks}\right)\right]} \qquad (33)$$

Where :

$$\frac{k_{rs}}{k_f} = \sqrt{1-\varepsilon} * \frac{2}{M}\left[\frac{B(k_S - 1)}{M^2 k} Ln\left(\frac{k}{B}\right) - \left(\frac{B+1}{2}\right) - \left(\frac{B-1}{M}\right)\right] \qquad (34)$$

Where :

$$M = \frac{K-B}{K} \quad , \quad K = \frac{K_s}{K_f} = \frac{K_P}{K_f}$$

$$B = C\left(\frac{1-\varepsilon}{\varepsilon}\right)^{10/9}$$

$$\beta = \begin{cases} 10 & \text{spherical particle} \\ 8 & \text{spherical particle} \end{cases}$$

$$N_{Uf_s} = 2.0 + 1.1 P_r^{1/3} . \mathrm{Re}\, p^{0.6}$$

$$C = \begin{cases} 1.25 & \text{for spherical particle} \\ 2.5 & \text{for cylindrical particle} \end{cases}$$

The viscosity of a gas is a strong function of pressure as proposed by Reichenberg method [1971, 1975 and 1979] and the viscosity ratio μ/μ^{o} can be written as the following equation:

$$\frac{\mu_f}{\mu^{o}} = 1 + Q\frac{A.P_r^{3/2}}{\beta P_r + \left(1 + C\, P_r^{\,D}\right)^{-1}} \tag{35}$$

The constants A,B,C and D are functions of the reduced temperature (Tr) and can be evaluated from the following equations.

$$A = \frac{\alpha_1}{T_r}\exp \alpha_2 T_r^{\,a} \qquad \& \qquad B = A(\beta_1 T_r - \beta_2)$$

$$C = \frac{\gamma_1}{T_r}\exp \gamma_2 T_r^{\,C} \qquad \& \qquad D = \frac{\delta_1}{T_r}\exp \delta T_r^{\,d}$$

$$Q = \left(1 - 5.665\mu_r\right)$$

Where:

$$\mu_r = 52.46\,\frac{\mu^2 P_c}{T_c}$$

$\alpha_1 = 1.9824\times10^{-3}$ $\qquad \alpha_2 = 5.2683$ $\qquad a = -0.5767$ $\qquad \beta_1 = 1.6552$

$\beta_2 = 1.2760$ $\qquad \gamma_1 = 0.1319$ $\qquad \gamma_2 = 3.7035$ $\qquad C = -79.8678$

$\delta_1 = 2.9496$ $\qquad \delta_2 = 2.9190$ $\qquad d = -16.16169$

$$\mu_f = \mu^{o}\left[1 + Q\frac{A.P_r^{3/2}}{BP_r + (1 + CP_r^{\,D})^{-1}}\right] \tag{36}$$

The relation thermal conductivities of all gases with pressure can be evaluated by the following equations:

$$k_f = \frac{1.22\times10^{-2}\left[\exp(0.535\rho_r - 1)\right]}{\Gamma Z_c^{\,5}} - K_f^{\,0} \qquad \rho_r > 0.5 \tag{37}$$

$$k_f = \frac{1.14\times10^{-2}\left[\exp(0.67\rho_r) - 1.069\right]}{\Gamma Z_c^{\,5}} - k_f^{\,o} \qquad 2.0 > \rho_r > 0.5 \tag{38}$$

$$k_f = \frac{2.60\times10^{-3}\left[\exp(1.55\rho_r)+2016\right]}{r Z_c^{5}} - k_f^{\,o} \qquad 2.8 > \rho_r > 2.0 \qquad (39)$$

and

$$\Gamma = 210\left(\frac{T_c M^3}{P_c^4}\right)^{1/6} \qquad (40)$$

The effect of pressure on the density of gases can be calculated by the following equation:

$$\rho_f = \frac{P.M_{wt}}{Z.R.T} \qquad (41)$$

Where: $Z = 1 + (B^0 + wB^1)\dfrac{P_r}{T_r}$ (42)

Where: $B^0 = 0.083 - \dfrac{0.422}{T_r^{1.6}}$, $B' = 0.139 - \dfrac{0.172}{T_r^{4.2}}$

The departure function for C_p is obtained by the following equation

$$C_{P_f} = \frac{k_f}{\mu_f * 1000} - \frac{10.4}{M^{W.t}} \qquad (43)$$

Substituting in equation (31) using equation (23) the series mechanism (k_{ser}) for cylindrical pellets can be written as in the following form:

$$\boldsymbol{K_{ser(c,s)} = k_{s,r}\left[\frac{Bif\,(D_p/D_t).\gamma.\left[\dfrac{1+4/Bif}{8/N_s+1}\right]}{k_{s,r}/k_f + Bif\,(D_p/D_t).\gamma\left[\dfrac{1+4/Bif}{8/N_s+1}\right]}\right]} \qquad (44)$$

3. Results and Discussion

In this work three different mathematical models were conducted to investigate the parameters that affected the radial thermal conductivity in packed bed heat exchanger under high pressure up to 25 bars. These models provide a comprehensive relation in predicting the radial Peclet number for a heat transfer through a packed bed with random packing of solid particles.

Three different catalyst-shapes of pellets were considered in the mathematical models (cylindrical, hollow cylindrical and sphere) for evaluation of radial thermal conductivity in the packed bed reactor. The predicted values were compared with the experimental data obtained for the nickel- alumina cylindrical pellets, packed in a 50.8 mm inside diameter tube reactor through which air at high pressure up to 20 bars flowed through the beds.

Attention is focused on the theoretical model describing the behavior of high pressure on a radial thermal conductivity in fixed bed reactor packed with catalyst pellets, where the reactants fluid flows through the packed bed specially at high pressure a varies of physical and chemical phenomena occur in the reactors. Moreover, many elementary processes taking place in the reactor, which more parameters are involve due the complexity of these phenomena. These required where details to be include in the mathematical model, which need more parameters it will be contain. The best model is selected on the basis of the properties of the particular system under consideration and assumption. The availability of the model equation includes the description behavior of the packed bed reactors packed with different size of the pellets using the gas flowing through the bed catalysts.

3.1 Effect of Reynolds Number upon the conductivity of Serious Mechanism (K_{ser}):

The values of conductivity of serious mechanism (Kser) were predicted at different Reynolds number and pressure and plotted in figures 3 to 6. As seen in Figures 3 and 4, the values of Kser increase greatly with the increase of Reynolds number at the same pressure. Also, for the same Reynolds number Kser value increase with increase of pressure. However, for low Reynolds number the difference in Kser value with the variation of pressure is smaller than that at higher Reynolds number. This can be explained due to the variation of gas properties and flow pattern with the pressure and Reynolds number.

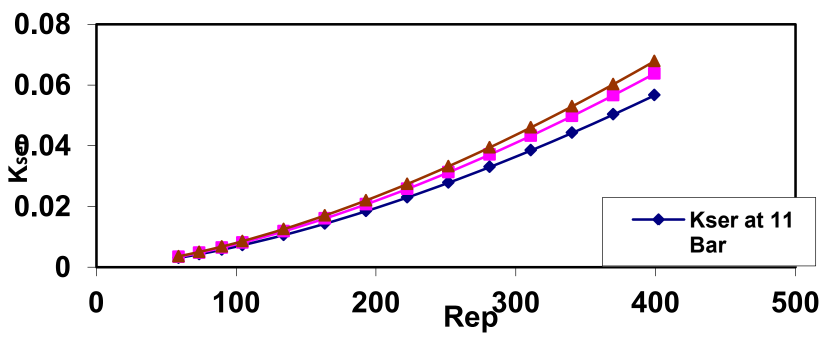

Figure 3: Effect of Column Pressure on K_{ser} for Cylindrical Pellets (with 3.175*3.175mm)

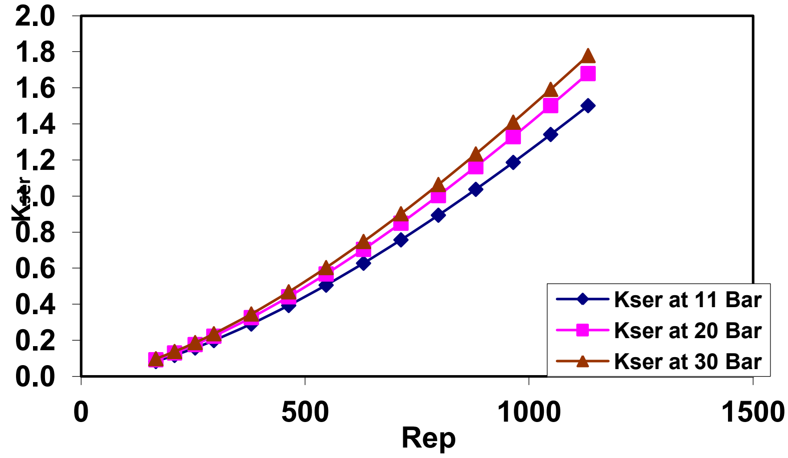

Figure 4: Effect of Column Pressure on K_{ser} for Cylindrical Pellets (with 9.00*5.00 mm)

The same trend was seen in Figures 3 and 4. But the variation in K_{ser}-value with pressure at the same Reynolds number was smaller and the can be found in the following manner:

K_{ser} at 11bar > K_{ser} at 20bar > K_{ser} at 30bar.

3.2. Effect of Pellet Size on Kser for Cylindrical Pellets.

A comparison between Kser-value for different particle size of cylindrical pellet were shown in figures 5 and 6 at a pressure of 11 and 20 bar. From Figures, the size of pellet affected greatly Kser and it was clearly that the greater the size the greater the value of Kser. However, At low Reynolds numbers the variation is smaller than that at high once.

An explanation for this effect is that the Conductivity of Series Mechanism for cylindrical pellets (k_{ser}) depends on the structure and irregular interconnections between the solid particles in the bed. The void fraction (€) is a major factor affecting at transfer through the fixed bed. Higher voidages would give rise to lower solid-to-solid contact areas and less solid media for heat transfer. Lower void fractions in packed beds are expected to result in higher Conductivities of Series Mechanism for large D_t/D_p ratios. Moreover, for fixed beds of high D_t/D_p ratio the extra resistance to heat transfers at the wall region is caused by the ordering of the packing by the wall.

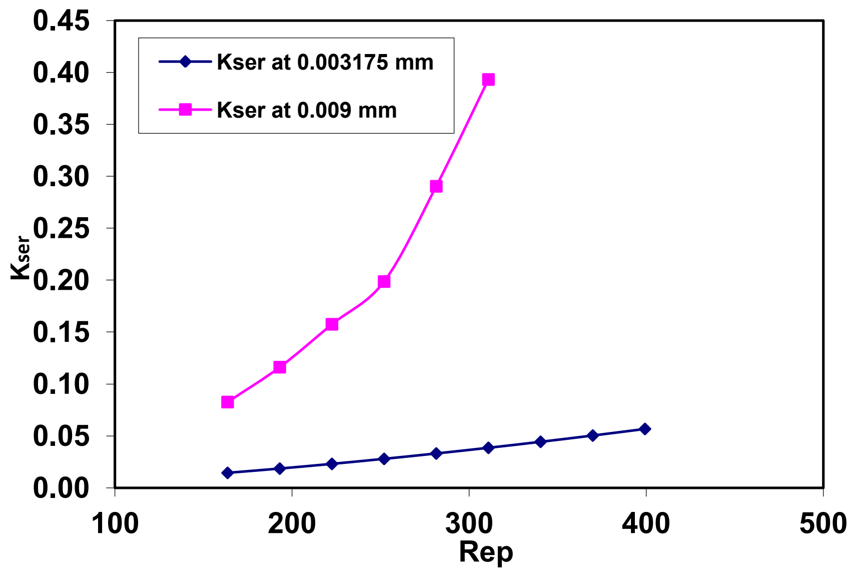

Figure 5: Effect of Pellet Size on K_{ser} for Cylindrical Pellets at 11 Bar.

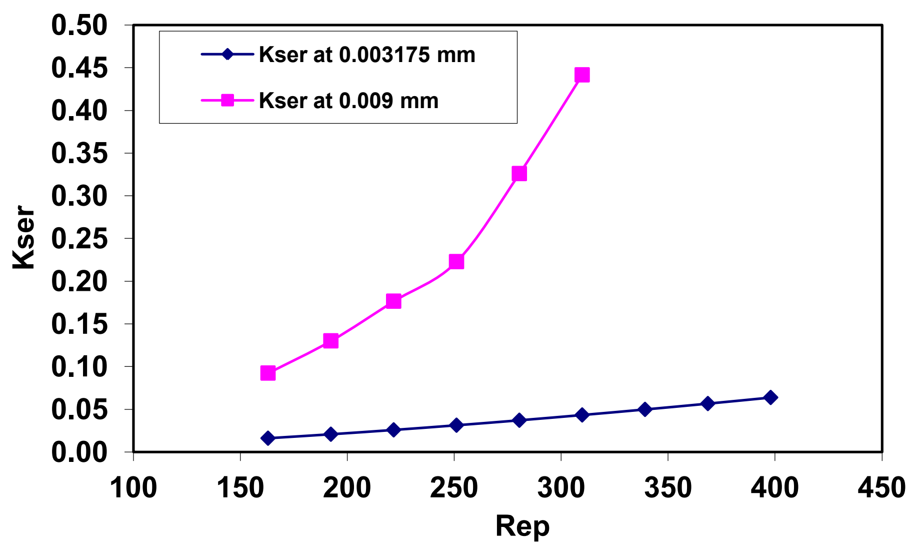

Figure 6: Effect of Pellet Size on Kser for Cylindrical Pellets at 20 Bar

4. Conclusion

The model for the prediction of radial thermal conductivity in packed-bed reactor has been developed. Parameters that affect the radial thermal conductivity under high pressure (up to 30 bars) are considered in the models. Noting that, the catalyst-shape of pellets were considered in the mathematical models (cylindrical) for evaluation of radial thermal conductivity in the packed bed reactor, from the results, man can conclude that:

- At all pressure (11 and 20 bar), it is observed that the radial thermal conductivity was a strong function of pressures at the same Reynolds number and it increased linearly with the increase of pressure.

- The difference between the thermal conductivity at 20 bar and those of 11 bar can be up to 60% .

- The radial thermal conductivity was affected by the pellet size on cylindrical pellets were used.

- For solid pellets Independent of shape and size a small variation in radial thermal conductivity under the same pressure and Reynolds number were observed. However for cylindrical pellets, a large difference between the small and large pellets was very pronounced.

- The values of Kser increase directly proportional with Reynolds number and pressure .

- Low variation in Kser value was found at low Reynolds than higher Reynolds number .

- The size of pellet affected greatly Kser and it was clearly that the greater the size the greater the value of Kser.

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