Article Citation Format
Oyefusi A.S, Amusa S.A, Ibikunle O, Abioye A.R, Abraham M. & Jatto A.O (2020): Thermal Conductivity Through Hollow Sphere Using One Dimensional Steady State. Journal of Advances in Mathematical & Computational Sc. Vol. 8, No. 1. Pp 15-30

Article Progression Time Stamps

Article Type: Research Article
Manuscript Received 18th November, 2019
Final Acceptance: 11th January, 2020
Article DOI: dx.doi.org/10.22624/AIMS/MATHS/V8N1P2

Thermal Conductivity Through Hollow Sphere Using One Dimensional Steady State

Oyefusi A.S, Amusa S.A, Ibikunle O, Abioye A.R, Abraham M. & Jatto A.O
Department of Computer Science and Statistics
D.S Adegbenro ICT Polytechnic
Itori Ewekoro, Ogun State, Nigeria
E-mails: adebayooyefusi@gmail.com; wale4joy2003@yahoo.com; Jide242@gmail.com; abioyeak@yahoo.com; abrahammicheal2299@gmail.com; ozijato@gmail.com;
Phone: +2348034975119; +2348026800769; +2348052008129; +2348032369164; +2347033411487; +2348130678403

ABSTRACT

Thermal conductivity through hollow sphere was considered in this project work. The conduction of heat transfer rate was determined by transforming the partial derivatives of the spherical coordinate in one-dimensional steady state case to an ordinary differential equation. Numerical values for the conduction of heat transfer rate for a spherical shaped vessel under different scenarios were considered. It was found that the rate of heat leakage increases as the thermal conductivity of the material, circumference of material, temperature of the material increases but decreases as thickness of the material increases.

Keywords: Thermal conductivity, steady state, sphere, heat, temperature, differential equation

1. BACKGROUND OF STUDY

The effect of thermal conductivity happens day by day in life among we human being and animals. Thermal conductivity refers to the intrinsic ability of a material to transfer heat. It is one of the three methods of heat transfer, the other two being convection and radiation, take place in all phases of the matter including solid, liquid and gases. Thermal conductivity also called diffusion in the direct microscopic exchange of kinetic energy of particles through two systems. When an object is at different temperature from another body of its surroundings, thermal flows so that the body and surroundings reach the same temperature at which point they are in thermal equilibrium.

1.1 Classification of Low and High Thermal Conductivity

Heat transfer can occur at a lower rate in materials of low thermal conductivity than in materials of high thermal applications and material of low thermal conductivity are used in thermal insulation. The thermal conductivity of a material may depend on the temperature. The reciprocal of thermal conductivity is called thermal resistivity. Mental with high conductivity, e.g. copper, exhibit electricity conductivity.

The heat generated in high thermal conductivity materials is rapidly conducted away from the region of the weld. For metallic materials, the electrical and thermal conductivity correlate positivity i.e. material with high electrical conductivity exhibit high conductivity.

1.2 Examples of Thermal Conductivity

There on the are several examples which we have not noticed around us

1. An ice cube will soon melt if you hold it in your hand. The heat is being conducted from your hand into ice.
2. After a car is turn on the engine become hot. The hood will become warm as heat is conducted from the engine to the hood.
3. A sauce pan of boiling water being heated by an electric stove is receiving heat energy from the stove by conduction
4. Heat flow in opaque solids as in the brick wall of a furnace or the material wall of a tube.

1.3 Aims and Objectives

The main objectives are:

1. To determine the thermal conductivity through hollow sphere in one dimensional steady state.
2. To present second order homogeneous equation to solve a general equation of spherical coordinate
3. To generate the heat leakage against thermal conductivity of the material

1.4 Definition of Operational Terms

Thermal Radiation

This is the heat transfer from the fluid thermal effect. In the emission of electromagnetic wave from all matter that has a temperature greater than absolute zero. It represents a conversion of thermal energy into electromagnetic energy

Thermal Convection

This is the heat transferred from one place to another by the movement of fluids. Convection is usually the dominant form of heat transfer in liquid and gases.

1.5. Thermal Conduction In Spherical Coordinate

The general heat conduction equation in spherical coordinate can be obtained from an energy balance on a volume element in a spherical coordinates (show in Figure 1.1), by the following steps below. It can also be obtained directly by coordinate transformation using the following relations between the coordinates o9f a point in rectangular and spherical coordinate systems;

$$x = r\cos\emptyset\sin\theta,\ y = r\sin\emptyset\cos\theta \text{ and } z = \cos\theta$$

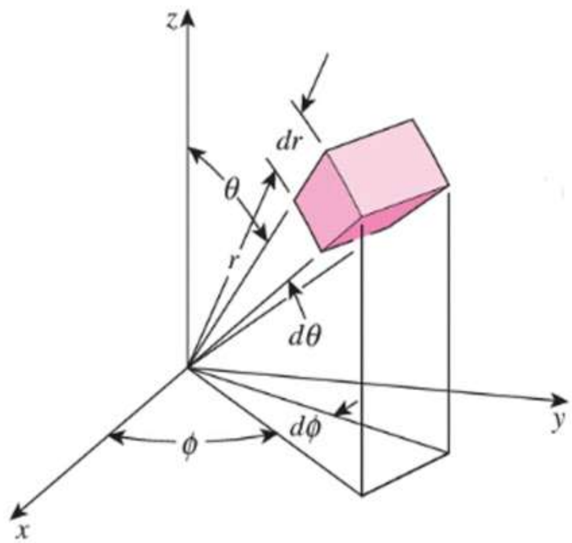

Fig. 1: Thermal Conduction In Spherical Coordinate

1.6 Steady State Conduction

Steady state conduction is the form of conduction that happens when the temperature difference during the conduction is constant so that the spatial distribution of temperature in the conducting object does not change any further, thus all partial derivatives of temperature with respect to space may either zero or having non-zero values, but all derivatives of temperature at any point with respect to time are uniformly zero.

1.7 One Dimensional Heat Flow

The term "one dimensional" is to applied heat conduction problem when

- Only one space coordinate is required to describe the temperature distribution within a heat conducting body.
- Edge effects are neglected
- The flow of heat energy take place along the coordinate measured normal to the surface

1.8 Differential Equation (DE)

In mathematics, we call the changing entities as variables and the speed of alter of one variable with respect to another as a derivative. Equations expressing a relationship among these variables and their derivatives are known as differentials. In other words, a differential equation originates whenever a universal law is expressed by means of variables and their derivatives.

Any equation containing differential coefficients is called a differential equation. (H.Lee., 2002).

- **Order:** This means the order of the highest derivative appearing in the equation.
- **Degree:** This means that exponent where the maximum derivative is being raised either ODE or PDE.

1.9 Ordinary Differential Equation (ODE)

This is a situation where the unknown function depends on one independent variable only.

1.10 Partial Differential Equation (PDE)

This is an equation that has more than two independent variables in an unknown function. The power of PDE is the power of the maximum derivative involved. Partial differential equations are used mathematically to formulate problems in engineering, physical and life sciences. For instance, fluid flow, elasticity, transmission of heat, electrostatics, electrodynamics,etc. (Unsworth, 1979).

2. LITERATURE REVIEW

Makinde (2007) studied the oscillatory flow and heat transfer in a rigid tube of varying cross-section with permeable wall. The flux across any representative section of the tube is viewed as composed of a pulsate part superimposed on a steady part and the effect of fluid absorption through the permeable wall is accounted by prescribing flux as arbitrary function of axial distance and time. The flow downstream of this section is investigated by expanding stream-function, vortices and fluid temperature in asymptotic series about a small parameter, *e*, characterizing the tube aspect ratio. Numerical results computed for wavy wall tube and a tampering tube as presented graphically and discussed quantitatively.

Jha and Ajibade (2012), investigated the natural convection flow of viscous incompressible fluid in a channel formed by two infinite vertical parallel plates. Fully developed laminar flow is considered in a vertical channel with steady-periodic temperature regime on the boundaries. The effect of internal heating by viscous dissipation is taken into consideration. Separating the velocity and temperature fields into steady and periodic parts, the resulting second order ordinary differential equations are solved to obtain the expressions for velocity and temperature. The amplitudes and phases of temperature and velocity are also obtained as well as the rate of heat transfer and the skin-friction on the plates. In presence of viscous dissipation, fluids of relatively small Prandtl number have higher temperature than the channel plates and as such, heat is being transferred from the fluid to the plate.

Jha and Ajibade (2010), presented suction/injection control of free Convective motion of a viscous incompressible fluid between two periodically heated infinite vertical parallel plates. The temperature and velocity fields are separated into steady and periodic parts and the resulting second order differential equations solved to obtain the solution to the problem. The influence of each governing parameter is discussed with maps. The significant result from this study is that temperature is higher near the plate with injection while velocity is more enhanced near the plate with suction. It is also interesting to note that for large values of suction, the nature of the flow is that of constant heating of the plates while for large values of Strouhal number, the flow behaves as if there was no suction/injection at the place (Wang). Adesanya (2012), This paper investigates the combined effect of heat source/sink and radiation of heat transfer to steady flow of a conducting optically thick visco-elastic fluid through a channel filled with saturated porous medium induced by non-uniform wall temperature. Analytical solutions of nonlinear ordinary differential equations governing the flow are obtained using Adomian decomposition method. The effects of different parameters in the model on the temperature and velocity profiles are presented and discussed.

Adesanya and Gbadeyan (2010), studied the combined effect of a magnetic field and radiating heat transfer on steady flow of a conducting, viscous, non-Newtonian and incompressible fluid through a channel filled with saturated porous medium. The Eyring-Powell visco-elastic fluid model is considered. It is also assumed that the boundary condition for the fluid at the wall is one slip. Then the dimensionless governing equation is then solved numerically using Adomian decomposition method (ADM). The ADM confirmed some of the earlier work on the Eyring-Powell model. The effect of various flow parameters as presented and discussed as they influenced the flow. Adesanya and Makinde (2012), investigated the effect of radiation of heat transfer to oscillatory hydro magnetic non-Newtonian couple stress fluid flow through a porous channel with non-uniform wall temperature due to periodic heat input at the heated wall. Based on some simplifying assumptions, the dimensionless partial differential equations are transformed into set ordinary differential equations and then solved using Adomian decomposition method. The effect of the flow parameters on temperature and velocity profiles are shown graphically and discussed.

Mehmood and Ali (2007), examined oscillatory motion of a magneto hydrodynamic fluid with heat transfer analysis through a porous planar channel filled with a saturated porous medium. It is assumed that the no-slip condition between the wall and the fluid remains no longer valid. The effect of the wall slip on velocity fluid is studied. Also, the results are discussed through graphs. Makinde and Mhine (2006), investigated the combined effect of transverse magnetic field and radiation of heat transfer to unsteady flow of a conducting optically thin fluid through a channel filled with saturated porous medium and non-uniform walls temperature. On the basis of certain simplifying assumptions, the fluid equations of continuity, momentum and energy are obtained. Closed-form analytical solutions are therefore constructed for the problem and important properties of the overall structure of the flow are discussed.

Abel and Mahesha (2008) carried out to study the magneto hydrodynamic boundary layer flow and heat transfer characteristics of a non-Newtonian visco- elastic fluid over a flat sheet with a linear velocity in the presence of thermal radiation and non-uniform heat source. The thermal conductivity is assumed to vary as a linear function of temperature. The basic equations governing the same have been reduced to a set of nonlinear ordinary differential equations applying suitable similarity transformation. The transformed equations are solved analytically by regular perturbation method. Numerical solution of the problem is also obtained by the efficient shooting method, which agrees well with the analytical solution. The effects of various physical properties such as visco-elastic parameter, Chandrasekhar number, Prandtl number, variable thermal conductivity parameter, Eckert number, thermal radiation parameter and non-uniform heat source/sink parameters which determine the temperature profiles are shown in several plots and the heat transfer coefficient is tabulated for a range of values in several plots and the heat transfer coefficient is tabulated for a range of values of said parameters. Some important findings reported in this work reveals that combined effect of variable thermal conductivity, radiation and non-uniform heat source have significant impact in controlling the rate of heat transfer in the boundary layer region.

Bisash Saboo (2010), considered the entrained flow and heat transfer of a non-Newtonian third grade fluid due to a linearly stretching surface with partial slip. The partial slip is controlled by a dimensionless slip factor, which varies between zero (total adhesion) and infinity (full slip). Suitable similarity transformations are used to reduce the resulting higher nonlinear partial differential equations into ordinary differential equations. The issue of paucity of boundary conditions is addressed and an effective second order numerical scheme has been adopted to solve the obtained differential equation even without augmenting any extra boundary conditions. The important finding in this communication is the combined effects of the partial slip and the third grade fluid parameter on the velocity, skin friction coefficient and the temperature field. It is interesting to find that the slip and the third grade fluid parameter have opposite effects on the velocity and the thermal boundary layers.

3. MATERIAL AND METHODS

Consider a hollow sphere made of spherical material having a constant thermal conductivity. According to the steady one-dimensional heat conduction problem, this is used by obtaining the applicable differential equation and specifying the boundary condition

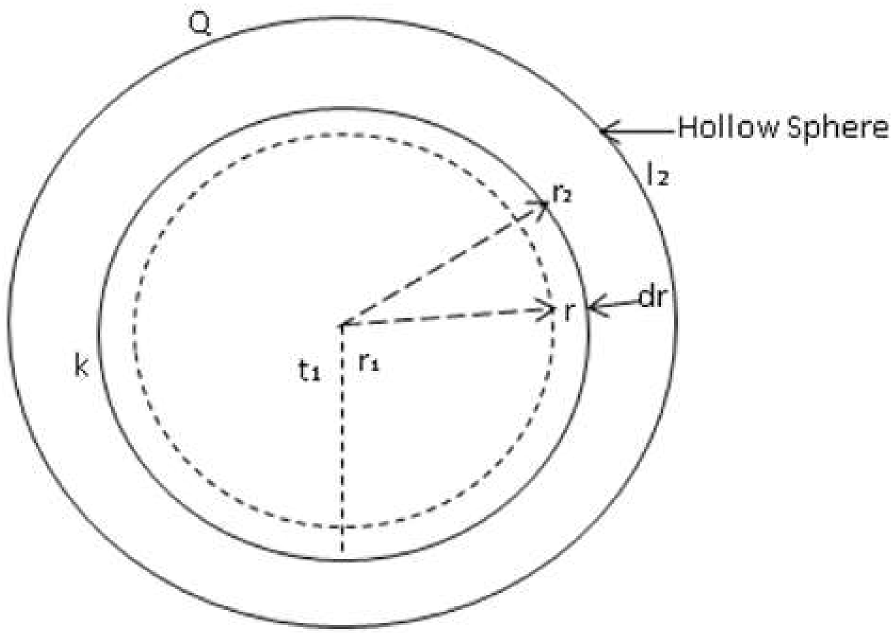

Fig 2: Hollow Sphere Made Of Spherical Material Having A Constant Thermal Conductivity

The governing equation

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)+\frac{1}{r^2 sin^2\emptyset}.\frac{\partial T}{\partial \emptyset}\left(k\frac{\partial T}{\partial \emptyset}\right)+\frac{1}{r^2 sin\theta}\frac{\partial}{\partial \theta}\left(sin\theta\frac{\partial T}{\partial \theta}\right)+q_v=PC_p\frac{\partial T}{\partial_T} \qquad (3.1)$$

Where parameter description

K is the material conductivity (W $m^{-1}k^{-1}$)

q_v Is the rate at which energy is generated per unit volume of the medium (Wm^{-8})

P is density (kHzm^3)

C_p Is the specific heat capacity (J$Kg^{-1}k^{-1}$)

r_1 Inner radii of the Sphere

r_2 Outer radii of the Sphere

T_1 Temperature of the inner surface

T_2 Temperature of the Outer surface

Q Heat flow radically outward

The equation reduces to

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)+\frac{1}{r^2 sin^2\emptyset}.\frac{\partial^2 T}{\partial\emptyset}\left(k\frac{\partial T}{\partial\emptyset}\right)+\frac{1}{r^2 sin\theta}\frac{\partial}{\partial\theta}\left(sin\theta\frac{\partial T}{\partial\theta}\right)+\frac{q_v}{k}=\frac{1}{\alpha}.\frac{\partial T}{\partial_T}$$

Where the property $\alpha = \frac{k}{PC}$ is again the thermal diffusivity of the material. For steady state $\frac{\partial T}{\partial_T}$ = 0, unidirectional heat flow in the radical direction $\{T \neq \mathcal{F}(\theta,\emptyset)\}$ and with no heat generator $q_g = 0$.

Equation (3.1) becomes

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)+\frac{1}{r^2 sin^2\emptyset}.\frac{\partial^2 T}{\partial\emptyset}\left(k\frac{\partial T}{\partial\emptyset}\right)+\frac{1}{r^2 sin\theta}\frac{\partial}{\partial\theta}\left(sin\theta\frac{\partial T}{\partial\theta}\right)=0 \quad (3.2)$$

We replaced the partial derivatives by ordinary, the one-dimensional steady heat conduction case since partial and ordinary derivatives of a function are identical with the function depend on a single variable only.

The above equation reduces to

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{dT}{dr}\right)=0 \quad (3.3)$$

$$\frac{d}{dr}\left(r^2\frac{dT}{dr}\right)=0\ or\ \frac{1}{r^2}\neq 0 \quad (3.4)$$

$$r^2\frac{d^2T}{dr^2}+\ 2r\frac{dT}{dr}=0 \quad (3.5)$$

Divide through by r

$$r\frac{d^2T}{dr^2}+\ 2\frac{dT}{dr}=0 \quad (3.6)$$

3.1 Methods of solution

First Method
Using second order homogeneous Equation

Auxiliary equation,

r$t^2 + 2t$ = 0

$$t=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

a = r, b = 2, c = 0

$$t = \frac{-2 \pm \sqrt{(2)^2 - 4(r)(0)}}{2r}$$

$$t = \frac{-2 \pm \sqrt{4 - 0}}{2r}$$

$$t = \frac{-2 \pm \sqrt{4}}{2r}$$

$$t = \frac{-2 \pm 2}{2r}$$

$$t = \frac{-2 + 2}{2r}, t = \frac{-2 - 2}{2r}$$

$$t = \frac{0}{2r} \; or \; t = \frac{-4}{2r}$$

$$t = 0 \; or \; t = \frac{-2}{r}$$

$$T_{(r)} = A\mathrm{e}^{0} + B\mathrm{e}^{-2/r}$$

$$T_r = A + B\mathrm{e}^{-2/r} \qquad (3.8)$$

Where A and B are constant

For boundary at

$r = r_1, T = T_1;\ at\ r = r_2, T = T_2$

$$T_{1_{(r)}} = A\mathrm{e}^{0} + B\mathrm{e}^{-2/r_1} \qquad (3.9)$$

$$T_{2_{(r)}} = A\mathrm{e}^{0} + B\mathrm{e}^{-2/r_2} \qquad (3.10)$$

Subtract equation (3.10) from (3.9)

$$T_1 - T_2 = A - A + B\mathrm{e}^{-2x/r_1} - B\mathrm{e}^{-2x/r_2}$$

$$T_1 - T_2 = B\mathrm{e}^{-2x/r_1} - B\mathrm{e}^{-2x/r_2}$$

$$B = \frac{T_1 - T_2}{\mathrm{e}^{-2x/r_1} - \mathrm{e}^{-2x/r_2}} \qquad (3.11)$$

Substitute B from equation (3.9)

$$T_1 = A + \frac{T_1 - T_2}{(e^{-2x/r_2} - e^{-2x/r_2})} \cdot e^{-2x/r_1}$$

$$\therefore \quad A = T_1 - \frac{T_1 - T_2}{e^{-2x/r_1} - e^{-2x/r_2}} \cdot e^{-2x/r_1} \tag{3.12}$$

Substituting the values of these constants A and B in equation (3.8)

$$T_{(r)} = A + Be^{-2x/r_1}$$

$$T_{(r)} = T_1 - \frac{T_1 - T_2}{(e^{-2x/r_1} - e^{-2x/r_2})} \cdot e^{-2r/r_1} + \frac{T_1 - T_2}{(e^{-2x/r_1} - e^{-2x/r_2})} \cdot e^{-2x/r} \tag{3.13}$$

$$T = T_1 + \frac{T_1 - T_2}{(e^{-2x/r_1} - e^{-2x/r_2})} \cdot (e^{-2x/r} - e^{-2x/r_2}) \tag{3.14}$$

$$T - T_1 = \frac{t_1 - t_2}{(e^{-2x/r_1} - e^{-2x/r_2})} \cdot (e^{-2x/r} - e^{-2x/r_2}) \tag{3.15}$$

$$\frac{T - T_1}{T_{2-T_1}} \frac{e^{-2r/r_1} - e^{-2r/r}}{e^{-2r/r_1} - e^{-2r/r_2}} \tag{3.16}$$

$$\frac{T - T_1}{T_{2-T_1}} = \frac{e^{-2x\left[\frac{1}{r_1} - \frac{1}{r}\right]}}{e^{-2x\left[\frac{1}{r_1} - \frac{1}{r_2}\right]}} \tag{3.17}$$

$$e^{-2x\left[\frac{1}{r_1} - \frac{1}{r_2}\right]} \cdot \frac{T - T_1}{T_{2-T_1}} = e^{-2x\left[\frac{1}{r_1} - \frac{1}{r}\right]} \tag{3.18}$$

Multiply both side by In

$$In. e^{-2x\left[\frac{1}{r_1} - \frac{1}{r_2}\right]} \cdot \frac{T - T_1}{T_{2-T_1}} = In. e^{-2x\left[\frac{1}{r_1} - \frac{1}{r}\right]} \tag{3.19}$$

$$-2x\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \cdot \frac{T - T_1}{T_{2-T_1}} = -2x\left[\frac{1}{r_1} - \frac{1}{r}\right] \tag{3.20}$$

$$\frac{T - T_1}{T_{2-T_1}} = \frac{-2x\left[\frac{1}{r_1} - \frac{1}{r}\right]}{-2x\left[\frac{1}{r_1} - \frac{1}{r_2}\right]} \tag{3.21}$$

$$\frac{T-T_1}{T_2-T_1} = \frac{\frac{1}{r_1}-\frac{1}{r}}{\frac{1}{r_1}-\frac{1}{r_2}}$$

$$\frac{T-T_1}{T_2-T_1} = \frac{r_2}{r}\left[\frac{r-r_1}{r_2-r_1}\right] \longrightarrow \text{Dimensionless form} \qquad (3.22)$$

It is evident that the temperature distribution associated with conductivity through a sphere is represented by a hyperbola.

3.2 Determination of conduction of heat

The conduction heat transfer rate is determined by using the temperature distribution expression in conjunction with Fourier's equation as follows:

$$Q = -kA\frac{dT}{dr} \qquad (3.23)$$

Differentiate in respect of r,

$$Q = -k\,.4\pi r^2 \frac{d}{dr}\left[T_1 - \frac{T_1 - T_2}{(e^{-2x/r_1} - e^{-2x/r_2})}.(e^{-2x/r} - e^{-2x/r_1})\right]$$

$$Q = -k\,.4\pi r^2 \left[\frac{T_1 - T_2}{\left(e^{-\frac{2x}{r_1}} - e^{-\frac{2x}{r_2}}\right)}.\frac{2x}{r^2}.e^{-2x/r_1}\right]$$

$$Q = -k\,.4\pi r^2 \frac{T_1 - T_2}{\left(e^{-\frac{2x}{r_1}} - e^{-\frac{2x}{r_2}}\right)}.\frac{2xe^{-\frac{2x}{r}}}{r^2} \qquad (3.24)$$

$$Q\,(e^{-2x\left[\frac{1}{r_1}-\frac{1}{r_2}\right]}) = -k4\pi(T_1 - T_2).2xe^{-\frac{2x}{r}} \qquad (3.25)$$

The above equation reduce

$$Q = k\,.4\pi\,.\frac{T_1 - T_2}{\frac{1}{r_1}-\frac{1}{r_2}} \qquad (3.26)$$

$$Q = \frac{T_1 - T_2}{\frac{r_2 - r_1}{4k\pi r_1 r_2}} \qquad (3.27)$$

$$Q = \frac{\Delta T}{R_{th}} \qquad (3.28)$$

Where $\frac{r_2-r_1}{4k\pi r_1 r_2}$ is the thermal resistance (R_{th}) for heat through hollow sphere.

4. RESULT AND DISCUSSION

To show the approximate numerical values for a spherical shaped vessel under different scenarios, we consider the following case studies:

Case I:
Consider a spherical shaped\ vessel of 1.4*m* diameter which is 90*mm* thick. If the temperature difference between the inner and outer surfaces is 220°C. The graph below displays the rate of heat the transfer/leakage considering the thermal conductivity of the material of the sphere.

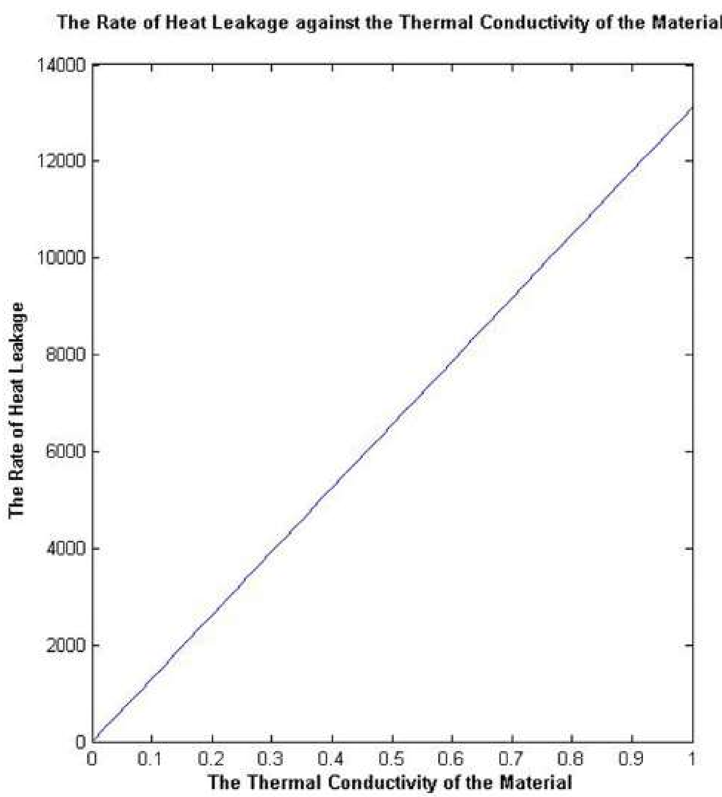

Figure 4.1: The rate of heat transfer/leakage against the thermal conductivity of the material

From Figure 4.1, the rate of heat transfer/leakage increases as the thermal conductivity of the material increases.

Case II:
Suppose the thermal conductivity of the material is 0.083W/m^2c. The graph below shows the rate of heat transfer/leakage when the temperature of the materials is being examined.

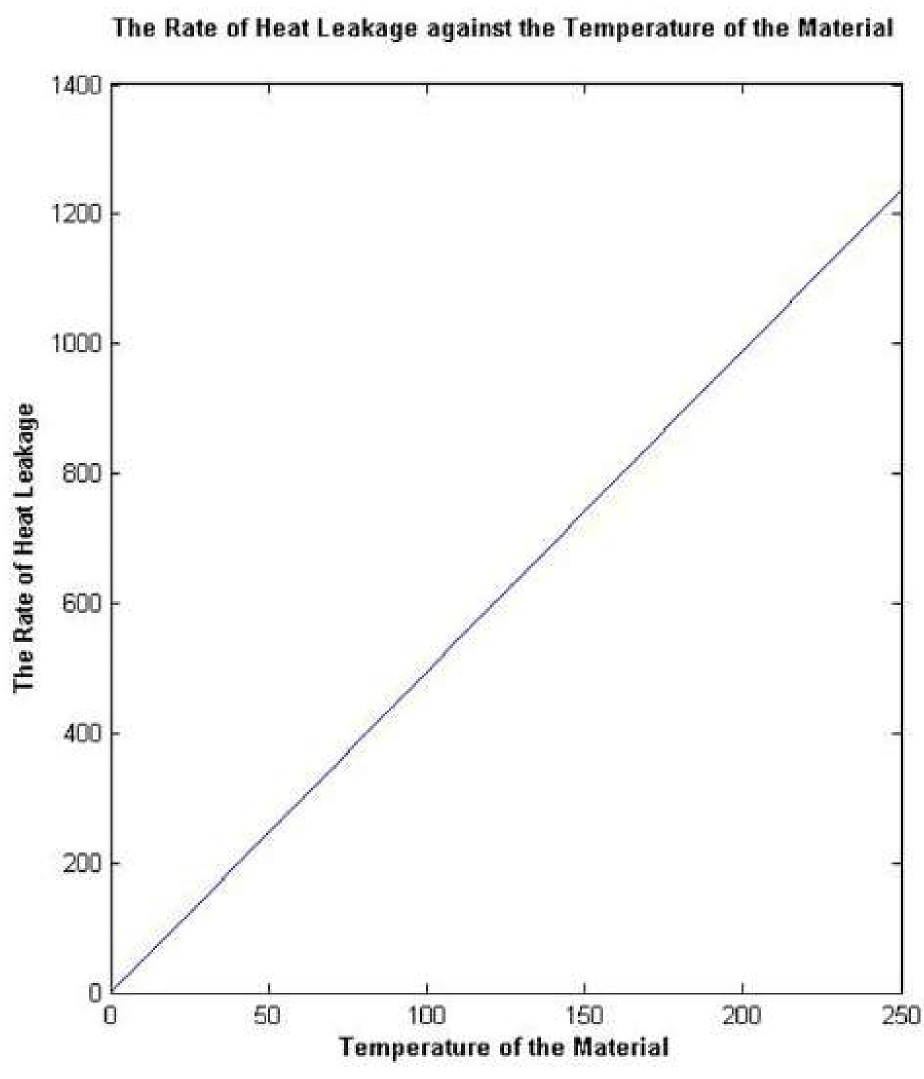

Figure 4.2: The rate of heat transfer/leakage against the thermal conductivity of the material

From Figure 4.2, the rate of heat transfer/leakage increases as the temperature of the material increases.

Case III:

Suppose the thermal conductivity of the material is $0.083W/m^2c$ and the temperature difference between the inner and outer surfaces is 220°C. The graph below displays the rate of heat transfer/leakage considering the thickness of the spherical shaped vessel which is 1.4mdiameter.

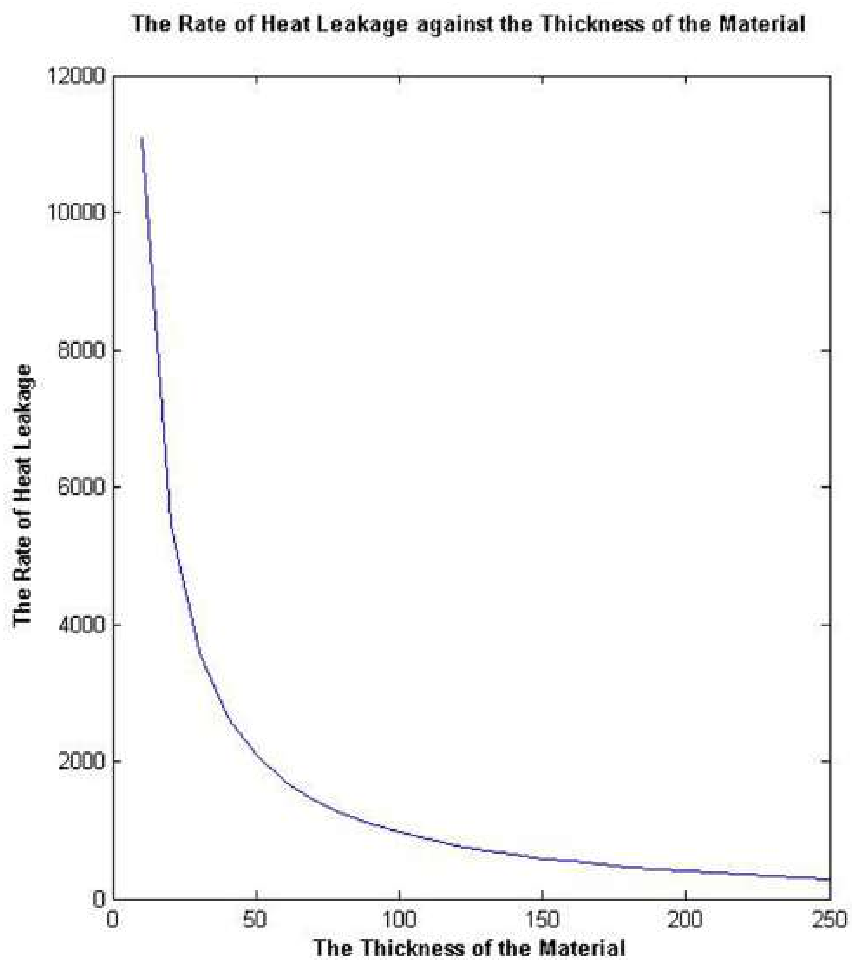

Figure 4.3: The rate of heat transfer/leakage against the thermal conductivity of the material

From Figure 4.3, the rate of heat transfer/leakage decreases with increase in the thickness of the material.

Case IV:
Suppose the thermal conductivity of the material is 0.083W/m^2c and the temperature difference between the inner and outer surfaces is 220℃. The graph below shows the rate of heat transfer/leakage when we examine the circumference of the spherical shaped vessel of thickness *90mm.*

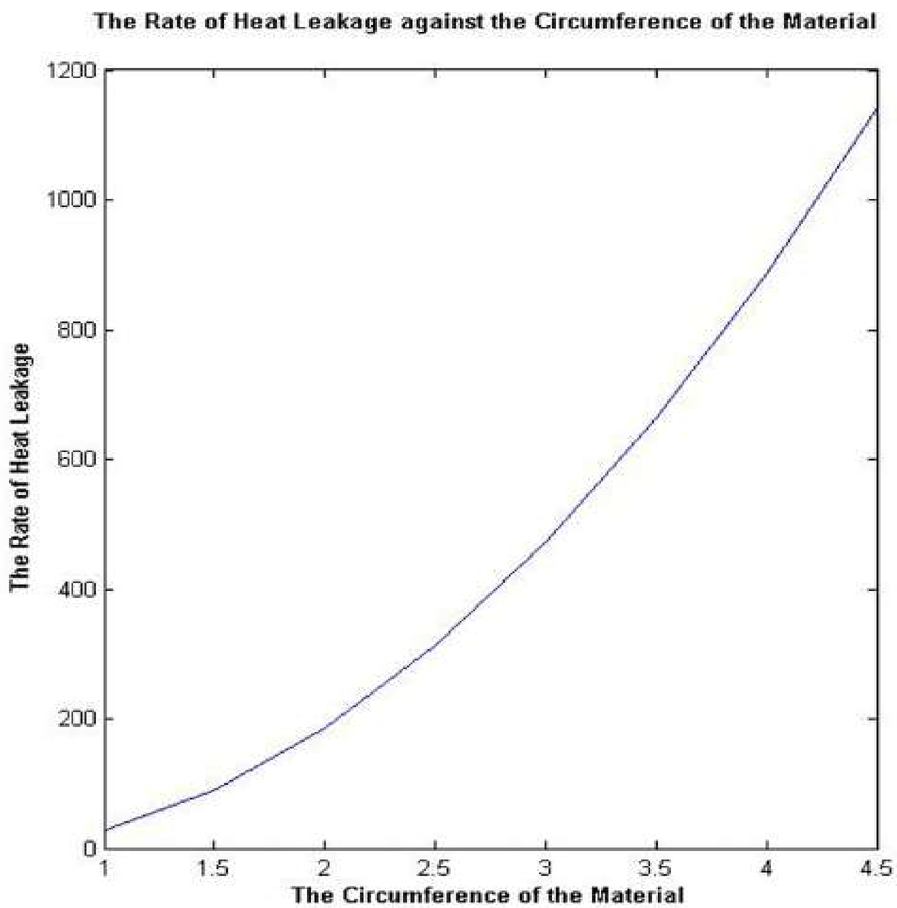

Figure 4.4: The rate of heat transfer/leakage against the thermal conductivity of the material

From Figure 4.4, the rate of heat transfer/leakage increases with increase in the circumference

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

Thermal conductivity through hollow sphere was considered in this project work. The conduction of heat transfer rate was determined by replacing the partial derivatives of the spherical coordinate in one-dimensional steady case (as regarded as our governing equation i.e. (3.1) in this project) by ordinary derivatives since the partial and ordinary derivatives of a function are identical with the function on a single variable only. Numerical values for the conduction of heat transfer rate for a spherical shaped vessel under different scenarios were considered.

5.2 Conclusion

It can be concluded from Figure 4.1-4.4 that the rate of heat leakage increases linearly as the thermal conductivity of the material increases, likewise for the temperature of the material but decreases drastically to zero as the thickness of the material increases. Considering the circumference of the material as it increases, the rate of heat leakage also increases.

5.3 Recommendation for Further Study

It was recommended further that research can be carried out using two-dimensional steady state and unsteady state technique to solve the problem under consideration.

REFERENCES

[1] Bala A.J. and KumarS. V. (2011). Unsteady MHD heat and mass transfer flow past a semi-infinite vertical porous moving plate with variable in the presence of heat generation and homogeneous chemical reaction. International Journal of Applied Mathematics and Mechanicsm7 (9):20-44.

[2] D. S. (2009). Effect of suction and injection on MHD 1-dimensional coquette flow and heat transfer through a porous medium. Journal of Naval Arch Marine Engineering, 10(1):41-51

[3] Ibrahim E. N., Essawy A. H., Hedar M. R. and Grad E. O. (2004). Flow of a visco-elastic fluid between Coaxial rotating porous disks with uniform suction and injection, bulletin of Calcutta Mathematical Society, 96(3):241-242.

[4] Jain N. C. and Eupta P. (2007). Unsteady magneto polar free convection flow in slip flow regime with variable permeability and constant heat flux,33 Journal of Energy, Heat and Mass transfer,29:227-240

[5] Knandelwal K., Gupta and Poonan N. C. (2003). Effects of couple stresses on the flow through a porous medium with variable permeability in slip flow regime. Journal Ganita, 54(2): 203-212.

[6] Makinde O. D, Mhone P. Y.(2005). Heat transfer to MHD oscillatory flow in a channel filled with porous medium. Romanian Journal of Physics, 50(9-10):931-938.

[7] Makinde O. D. and Osalusi I. (2006). MHD steady flow in a channel with slip at the permeable boundaries. Romania Journal of Physics, 51(3-4):319-328.

[8] Makinde O. D., Olajuwon B.I. and Gbolagade A. W. (2007). Adomiah decomposition approach to a boundary layer flow with thermal radiation past a moving vertical porous plate. International Journal of Applied Math and Vheeh, 3(3):62-70.

[9] Makukula Z. G., Sibande P. and Motsa S. S. (2010). Con Solutions for great transfer in a visco elastic fluid between parallel plates. International Journal of Mathematical Models and Methods in Applied Sciences 4(4):221-230.

[10] Mansour M. A., Mohamed R. A. and Abel-Elaziz, M. M. Ahmed (2007). 34 Fluctuating thermal and mass diffusion on unsteady MHD convection of a micro polar fluid through a porous medium past, a vertical plate in slip-flow regime. International Journal of Applied Mathematics and Mechanics 3:99-117. [11] Mansutti D. G., Pontrelli and Rajagupalc K. R. (1993). Steady flow of Non-Newtonian fluids past a porous plate with suction or injection. Rut Journal of Numerical Method Fluids 17:929-941.

[12] Mehmood A. and Ali(2007). The effect of slip condition on unsteady MHD oscillatory flow of viscous fluid in a planer channel. Rom Journal of Physics 52(1-2):85-91.

[13] Permutter M,and Siefel R. (1906). Heat transfer to an electrically conducting flowing in a channel with a transverse magnetic field. NASAJN.D 875.

[14] Pop and Ingham (2001). Convection heat transfer. Mathematical and computational modeling of viscous fluids and porous media pergamon, Oxford.

[15] Prasuna I. G., Murthy M. V., Ramachrywhin N. C. P. and Rao G. (2010). Unsteady flow of visco-elastic fluid through a porous media between two impermeable parallel plates. Journal of emerging trends in Engineering 35 and Applied Sciences, 1(2):220-224.

[16] Rajagopal K., Veena P. H. and Pravon V. K. (2006). Oscillating motion of an electrically conducting visco-elastic fluid over a stretching sheet in saturated porous medium with suction/blowing mathematical problem in Engineering, 1-14.

[17] Rajeswari R., Jothiram B. and Nelson V. K. (2009). Chemical reaction, heat and mass transfer on nonlinear MHD boundary layer flow through a vertical porous surface in the presence of suction. Journal of Applied Mathematical Science 3(50):2469-2480.

[18] Sahim A (2010). The effect of viscous dissipative heat on three dimensional oscillatory fluids with periodic suction velocity. Indian Jounal Sci I echol 3(3):276-283.

[19] Umarath C. J., Chamkha A. J., Mathin A. and Al-Mudhai A. (2009). Unsteady oscillatory flow and heat transfer in a horizontal composite porous medium channel. Non-linear Analysis Model Control 14(3):347-415.36