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THE 1ST YOUNG SCIENTIST INTERNATIONAL CONFERENCE OF WATER RESOURCES DEVELOPMENT AND ENVIRONMENTAL PROTECTION

MALANG - INDONESIA

5 - 7 June 2015

PROCEEDING

Environmental Engineering & Water Technology
Integrated Water Systems & Governance
Water Science & Engineering

WATER RESOURCES ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

FOREWORD

The 1st Young Scientist International Conference of Water Resources Development and Environmental Protection 2015 (ICWRDEP 2015) Water Resources Engineering Department, Faculty of Engineering, University of Brawijaya was conducted on 5 - 7 June 2015. The Conference was organized by Faculty of Engineering and collaborated with International University of Malaya (UM), Universiti Sains Malaysia (USM) and Universiti Tun Hussein Onn Malaysia (UTHM).

The participants of the Conference are about 60 participants come from more than 20 higher institutions, such as; Sepuluh Nopember Institute Of Technology, Surabaya (ITS), Bandung Institute of Technology (ITB), Bogor Agricultural University (IPB), The University of Lampung, Sriwijaya University, University of Muhammadiyah Malang (UMM), University of Brawijaya (UB), Padjajaran University, State University of Malang (UM), National Institute of Technology (ITENAS), Tidar university, State Polytechnic of Malang (Politeknik Negeri Malang), Mulawarman University, State Polytechnic of Padang (Politeknik Negeri Padang), Malang National Technology Institute (Institut Teknologi Nasional Malang), BBWS Mesuji Sekampung, Bengkulu University, Diponegoro University (UNDIP), Nusa Cendana University, Khairun University, Bantara University, University of Jember, State Polytechnic of Samarinda (Politeknik Negeri Samarinda), UM (University of Malaya), Universiti Sains Malaysia (USM) and Universiti Tun Hussein Onn Malaysia (UTHM), and others, which reflect the importance water resources engineering development and environmental protection.

The topics of conference are Environmental Engineering & Water Technology, Integrated Water System & Governance and Water Science & Engineering. The conference provide platform for researchers, engineers and academician to meet and share ideas, achievement as well as experiences through the presentation of papers and discussion. These events are important to promote and encourage the application of new concept of water resources development and techniques to practitioners as well as enhancing the knowledge of environmental protection with the current requirements of analysis, design and construction of any engineering concept.

As Head of Water Resources Engineering Department, we would like to express our deepest gratitude to the Rector University of Brawijaya, Keynote Speakers (Prof Satoru Oishi & Prof Tsuyoshi Imai from Japan, Assoc. Prof Faridah Othman and Prof Amir Hamzah from Malaysia), International Advisory Board members, organizing committee and also to all participants.

We would like to express our deepest gratitude to the Faculty of Engineering conducted such conference. This is the first International conference for the Department and we expect that this is will become 2nd annual activity for our Department.

Malang, 5 June 2015

Ir. Mohammad Sholichin, MT., Ph.D
Head of Water Resources Engineering Department
Faculty of Engineering University of Brawijaya

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Heat Effect On Fluid Free Convection Flow Past A Porosity Sphere

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ABSTRACT

Issues raised are free convection flow of viscous-elastic through a porous sphere with the completion of numerically using central finite difference method. The free convection flow can described continuity equation, momentum, and energy. Further, governing equations dimensionless form will be transformed into a non-dimensional equation and transformed again into a non-similar equations. The results of this research about the impact of viscoelastic parameter (K), Prandtl number (Pr), and porosity (P) on the flow velocity profile (f ') is inversely proportional , However effect of heat generation parameter (γ) on the flow velocity profile (f ') is inversely proportional. And the effect of the viscoelastic parameters (K) and heat generation (γ) to the flow temperature profile (θ) is proportional, However the effect of Prandtl number (Pr) parameter and porosity (P) on the flow temperature profile (θ) is inversely proportional.

KEYWORDS

Free Convection, Viscos-Elastic, Prandtl Number, Porosity, Heat Generation, Porosity Sphere.

INTRODUCTION

Convection heat transfer is the transfer of heat from one place to another caused by the movement of the fluid. There are two kind of convection heat transfer, i.e free convection and forced convection. Free convection caused by buoyancy forces due to temperature differences in the fluid. Meanwhile, forced convection happens when fluid is forced to flow over the surface by external or internal sources (Kasim, 2014). The free convection flow which through a porosity sphere can be ilustrated by Figure 1.

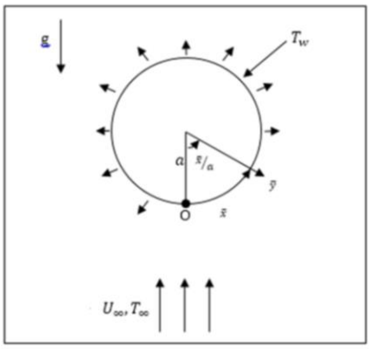

Figure 1. The free convection flow which past a porosity sphere.

The bounded layer that be created from such flow will be analyzed the rub force between fluid and sphere, temperature of sphere, and profile velocity of fluid. Temperature is main factor that influence the thickness of bounded layer. The higher the temperature, the smaller the bounded layer. Therefore,

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such condition can make the fluid velocity is faster and the rub force small. Conversely, if the lower the temperature around the surface will be able to influence the boundary layer, so that the conditions resulting in slow moving fluid velocity profile and greater friction (Anwar, et al, 2008). Governing equations containing the mass conservation equation, momentum, and energy are formulated from Navier-Stokes equations. Those equations steady state and incompressible. After that, those equations are transformed again in non-dimensional form using ψ stream function.

RESEARCH METHOD

To construct a mathematical model of free convection flow of a viscoelastic fluid which passes through the surface of a porous sphere needed conservation equations of mass, momentum, and energy (Widodo, 2011). In addition, it is also influenced by the dimensional parameters and the coefficient associated with the case. To answer the problem of this research, the following steps are needed.

1. Construct a mathematical model beginning from continuity, momentum, and energy equations.
2. Fix the boundary conditions which on the flow that through the porosity sphere.
3. Change the governing equation that be obtained in step 1 and 2 to be non-dimensional equations.
4. Change the non-dimensional governing equations that be obtained in step 2 to be non-similar governing equations.
5. Discrete non-similar governing equations using central finite difference method.
6. Linearizing the result of discretion using Gauss-Seidel method.
7. Visualizing the flow using Matlab software.

RESULT AND DISCUSSION

3.1 Governing Equations

Continuity equation from fluid flow which through a porosity sphere is written below (Kasim, 2014):

$$\frac{\partial}{\partial \bar{x}}(\bar{r}\bar{u}) + \frac{\partial}{\partial \bar{y}}(\bar{r}\bar{v}) = 0 \qquad (3.1)$$

Then, the dimensional momentum equation is obtained as follow:

$$\bar{u}\frac{\partial \bar{u}}{\partial \bar{x}} + \bar{v}\frac{\partial \bar{u}}{\partial \bar{y}} = \bar{v}\left[\frac{\partial^2 \bar{u}}{\partial \bar{x}^2}\right] - \frac{k_0}{\rho}\left[\bar{u}\left(\frac{\partial^3 \bar{u}}{\partial \bar{x}^3 \bar{y}^2}\right) + \bar{v}\frac{\partial^3 \bar{u}}{\partial \bar{y}^3} - \frac{\partial \bar{u}}{\partial \bar{y}}\left(\frac{\partial^2 \bar{u}}{\partial \bar{y}\partial \bar{x}}\right) + \frac{\partial \bar{u}}{\partial \bar{x}}\left(\frac{\partial^2 \bar{u}}{\partial \bar{y}^2}\right)\right]$$
$$+ g\beta(\bar{T} - \bar{T}_\infty)\sin\left(\frac{\bar{x}}{\bar{a}}\right) - \frac{\nu}{K^*}\bar{u} \qquad (3.2)$$

Finally, dimensional energy equation is obtained as follow (Ching, 2008):

$$\bar{u}\frac{\partial \bar{T}}{\partial \bar{x}} + \bar{v}\frac{\partial \bar{T}}{\partial \bar{y}} = \alpha\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} + Q_0(\bar{T} - \bar{T}_\infty) \qquad (3.3)$$

using the following bounded conditional:

$$\left.\begin{aligned} \bar{u} = \bar{v} = 0, \frac{\partial \bar{T}}{\partial \bar{y}} = -\frac{q_w}{k}, for\ \bar{y} = 0 \\ \bar{u} = 0, \frac{\partial \bar{u}}{\partial \bar{y}} = 0, \quad \bar{T} = \bar{T}_\infty\ , \quad for\ \bar{y} \to \infty \end{aligned}\right\} \qquad (3.4)$$

The Equations (3.1) until (3.4) are transformed into non-dimensional equations using non-dimensional variable below:

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$$\left.\begin{aligned}\bar{v} &= vva^{-1}Gr^{\frac{1}{4}}\\ \bar{u} &= uva^{-1}Gr^{\frac{1}{2}}\\ \bar{x} &= ax\\ \bar{y} &= ayGr^{-\frac{1}{4}}\\ (\bar{T}-\bar{T}_\infty) &= \frac{\theta T_w a}{k}\\ \bar{r} &= ar\end{aligned}\right\} \quad (3.5)$$

Substituting Equation (3.5) to Equations (3.1) until (3.4), will be obtained continuity equation:

$$\frac{\partial(ru)}{\partial x} + \frac{\partial(rv)}{\partial y} = 0, \quad (3.6)$$

And non-dimensional momentum equation:

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + \theta \sin x - K\left[u\frac{\partial^3 u}{\partial x \partial y^2} + v\frac{\partial^3 u}{\partial y^3} - \frac{\partial u}{\partial y}\frac{\partial^2 u}{\partial x \partial y} + \frac{\partial u}{\partial x}\frac{\partial^2 u}{\partial y^2}\right] - Pu \quad (3.7)$$

with $P = \left(\frac{k}{g\beta T_w}\right)^{1/2}\frac{v}{K^*}$ is *porosity* parameter. Then we get non-dimensional energy equation:

$$u\frac{\partial \theta}{\partial x} + v\frac{\partial \theta}{\partial y} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} + \gamma\theta \quad (3.8)$$

with $Pr = \frac{v}{\alpha}$ and $\gamma = \frac{a^2 Q_0}{v\rho C_p Gr^{\frac{1}{2}}}$, respectively Prandtl number and heat generation.

The process to obtain non-similar equation using the stream function is define below (Kasim, 2014), we get:

$$f'^2 - 2ff'' = f''' + \theta - K\left[2f'f''' - 2ff'''' - f''^2\right] - Pf' \quad (3.9)$$

and

$$-2f\theta' = \frac{1}{Pr}\theta'' + \gamma\theta \quad (3.10)$$

where $\frac{\partial f}{\partial y} = f'$, $\frac{\partial \theta}{\partial y} = \theta'$.

3.2 Discretization step

The Equations (3.9) until (3.10) are discretized using central finite difference method (Potter, et al, 2008) such that we obtain:

$$t_1 f_{i+2} f_{i+1} - 4t_1 f_i f_{i+2} - t_1 f_{i+2} f_{i-1} + t_2 f_{i+1}^2 + t_3 f_i f_{i+1} - \left(\frac{B}{2}\right) f_{i-1} f_{i+1} - t_1 f_{i-2} f_{i+1} + t_4 f_i^2 + t_3 f_i f_{i-1} - 4t_1 f_i f_{i-2} + t_2 f_{i-1}^2 + t_1 f_{i-2} f_{i-1} + t_5 f_{i+1} - t_5 f_{i-1} + \left(\frac{C}{2}\right) f_{i-2} - \theta_i = 0 \quad (3.11)$$

and

$$(Af_i - B1)\theta_{i-1} - (Af_i + B1)\theta_{i+1} + (2B1 - \gamma)\theta_i = 0 \quad (3.12)$$

Where $A = \frac{1}{\Delta y}$, $B = \frac{1}{\Delta y^2}$, $C = \frac{1}{\Delta y^3}$, $D = \frac{1}{\Delta y^4}$, $t_1 = \frac{DK}{2}$, $t_2 = \frac{B-8DK}{4}$, $t_3 = 12DK - 2B$, $t_4 = 4B - 16DK$, and $t_5 = \frac{2C+AP}{2}$.

With bounded conditional :

$f_i = 0$, $f_{i+1} = f_{i-1}$, $\theta_{i+1} = -2\Delta y + \theta_{i-1}$ for $i = 0$

$$f_{i+1} = f_{i-1}, f_{i+1} = 2f_i - f_{i-1}, \theta_i = \theta_{i-1} - \Delta y, \theta_i = 0 \quad \text{for } i = M \quad (3.13)$$

3.3 Linearizing

Before the equations from discretization are simulated, since differential equation that obtained is non-linear differential equation, it will be linearized using Gauss-Seidel method. The principal of Gauss method is to find variable which the biggest absolute value of coefficient. Then, such coefficient is

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used as numerator (Bruce, et al, 2008), If the Equations (3.11) until (3.13) are linearized by lettering, we obtain:

$$f_i^2 = (-1)(t_1 f_{i+2} f_{i+1} - 4t_1 f_i f_{i+2} - t_1 f_{i+2} f_{i-1} + t_2 f_{i+1}^2 + t_3 f_i f_{i+1} - \left(\frac{B}{2}\right) f_{i-1} f_{i+1} - t_1 f_{i-2} f_{i+1} + t_4 f_i^2 + t_3 f_i f_{i-1} - 4t_1 f_i f_{i-2} + t_2 f_{i-1}^2 + t_1 f_{i-2} f_{i-1} + t_5 f_{i+1} - t_5 f_{i-1} + \left(\frac{C}{2}\right) f_{i-2} - \theta_i)/t_4 \quad 3.18)$$

And

$$\theta_i = \frac{-Af_i\theta_{i-1} + Af_i\theta_{i+1} + \frac{B}{Pr}\theta_{i+1} - \frac{B}{Pr}\theta_{i-1}}{\left(\frac{2B}{Pr} - \gamma\right)} \quad (3.14)$$

3.4 Simulating Result and Discussion

The result of this research is graphic that represent the solution of problem. The analyzed graphics are given below :

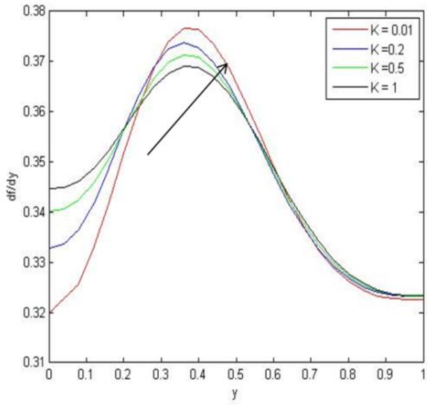

Figure 2: The fluid velocity profile of with effect of parameters value $\gamma = 0.5, Pr = 1, P = 10$ and viscosity (K) variated.

Figure 2 describe about the fluid velocity profile with effect of parameters value $\gamma = 0.5, Pr = 1, P = 10$ and viscosity (K) variated. From the simulation results shown that the smaller the value viskoselastic (K = 0.01), then the flow velocity is increase (red color chart). But, when the greater viscosity (K = 1), then the value of the rate of flow of the fluid is decrease (black color chart). This is caused by the friction between the walls of the sphere with the fluid. Clear that, if a fluid flow has a high viscosity, then when there is friction with the media past which would cause friction stronger, thus slowing the velocity of flow. So, it can be concluded that the value of the viscosity of a fluid is inversely proportional to the velocity of flow that flows through the porous surface of a sphere.

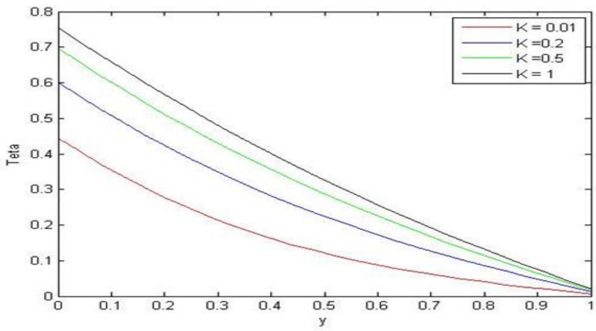

Figure 3: The profile of fluid temperature with effect of parameters value $\gamma = 0.5, Pr = 1, P = 10$ and viscosity (K) variated.

Figure 3 describe about the fluid temperature profile with effect of parameters value $\gamma = 0.5, Pr = 1, P = 10$ and viscosity (K) variated. From the simulation results shown that the

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smaller the viscosity values (K = 0.01), the temperature of the fluid is decrease (red color chart). This happens because the friction between the walls of sphere with the fluid. Therefore, when the smaller the viscosity of the fluid resulting friction is also small. As a result, the lower the flow temperature when the viscosity of the fluid is getting smaller. Likewise, when the greater viscosity (K = 1), then the value of the temperature of the fluid flow is increase (black color chart). So it can be concluded that the value of the viscosity of a fluid is proportional to the temperature of the flow through a porous surface of a sphere.

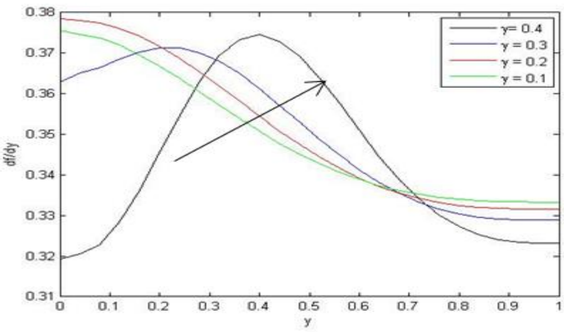

Figure 4: The profile of fluid velocity with effect of parameters value $K = 0.01,\ Pr = 10,\ P = 1,$ and parameters of heat generation (γ) variated.

Figure 4 describe about the profile of fluid velocity with effect of parameters value $K = 0.01,\ Pr = 10,\ P = 1,$ and parameters of heat generation (γ) variated. From the simulation results shown that the smaller the heat generation value (γ = 0.1), then the flow velocity of the faster (black color chart). Likewise, when the greater heat generation (γ = 1), then the value the lower fluid flow velocity (green color chart). This is due to the presence of additional heat generation is given to the flow. So it can be concluded that the value of heat generation parameter (γ) is inversely proportional to the rate of flow that flows past the porous surface of a sphere.

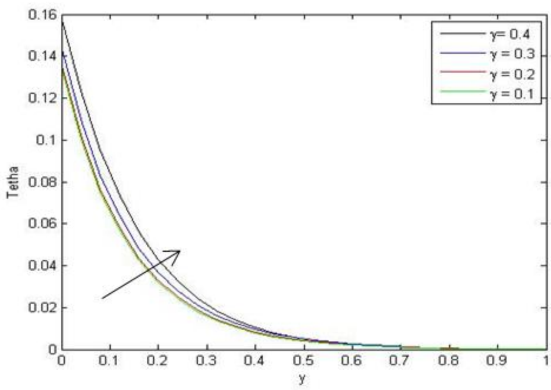

Figure 5: The profile of fluid velocity with effect of parameters value $K = 0.01,\ Pr = 10,\ P = 1,$ and parameters of heat generation (γ) variated.

Figure 5 describe about the profile fluid velocity with effect of parameters value $K = 0.01,\ Pr = 10,\ P = 1,$ and parameters of heat generation (γ) variated. From the simulation results shown that the smaller the heat generation (γ = 0.1), then the temperature of the fluid is decrease (black color chart). Likewise, if the greater heat generation (γ = 0.4), then the temperature of the flow is increase (green color chart). This is due to the presence of additional heat generation is given to the flow. So it can be concluded that the heat generation parameter (γ) is proportional to the temperature of the flow past the porous surface of sphere.

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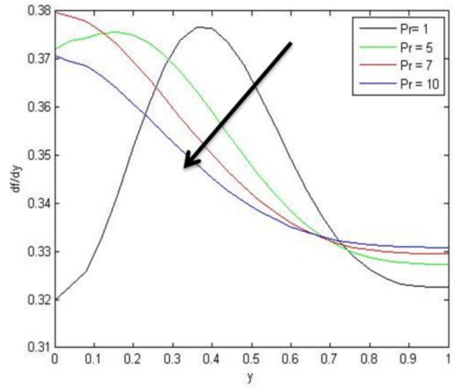

Figure 6: The profile of fluid velocity with effect of parameters value $K = 0.01,\ \gamma = 0.2,\ P = 10$ and parameters of Prandtl number (Pr) variated.

Figure 6 describe about the profile graphic of fluid velocity with effect of parameters value $K = 0.01,\ \gamma = 0.2,\ P = 10$ and parameters of Prandtl number (Pr) variated. From the simulation results shown that the smaller value a given Prandtl number (Pr = 1), resulting in the flow velocity is increase (black color chart). However, on the contrary if the Prandtl number given greater (Pr = 10), then the velocity of fluid flow is decrease (blue color graph). This is due to the influence of the Prandtl number given value. So it can be concluded that the parameters Prandtl number (Pr) is inversely proportional to the flow velocity past the porous surface of sphere.

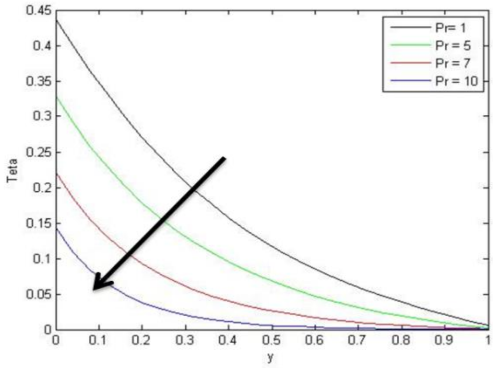

Figure 7: The profile graphic of fluid temperature with effect of parameters value $K = 0.01,\ \gamma = 0.2,\ P = 10$ and parameters of Prandtl number (Pr) variated.

Figure 7 describe about the profile graphic of fluid temperature with effect of parameters value $K = 0.01,\ \gamma = 0.2,\ P = 10$ and parameters of Prandtl number (Pr) variated. From the simulation results shown that the smaller the number of parameters Prandtl (Pr = 1) were given to the flow, resulting in the temperature of the flow is increase (black color chart). Likewise, if the greater the Prandtl number (Pr = 10) were given to the flow, resulting in the temperature of the flow is decrease (blue color chart). This is due to the influence of the Prandtl number given. So it can be concluded that the parameters Prandtl number is inversely proportional to the temperature of the flow through the porous surface of sphere.

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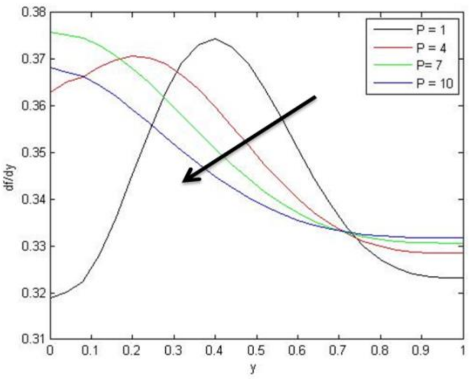

Figure 8: The profile graphic of fluid velocity with effect of parameters value $K = 0.01,\ \gamma = 0.2,$ $Pr = 1$ and parameters of porosity (P) variated.

Figure 8 describe about the profile graphic of fluid velocity with effect of parameters value $K = 0.01,\ \gamma = 0.2,\ Pr = 1$ and parameters of porosity (P) variated. From the simulation results shown that the smaller the sphere porosity values (P = 1), resulting in the flow velocity is increase (black color chart). Conversely, if value the porosity of the larger sphere (P = 10), then the velocity of fluid flow is decrease (blue graph). So it can be concluded that the value the parameter porosity (P) is inversely proportional to the flow rate through the porous surface of sphere.

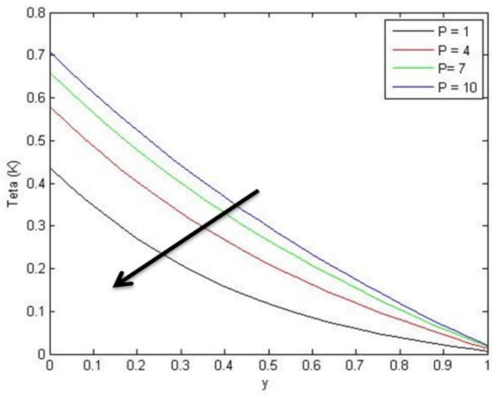

Figure 9: The profile of fluid temperature with effect of parameters value $K = 0.01,\ \gamma = 0.2,$ $Pr = 1$ and parameters of porosity (P) variated.

Figure 9 describe about the profile of fluid temperature with effect of parameters value $K = 0.01,\ \gamma = 0.2,\ Pr = 1$ and parameters of porosity (P) variated. From the simulation results shown that the smaller the sphere porosity values (P = 1), resulting in the temperature of the flow is decrease (black color chart). Conversely, if the value of the porosity of sphere the greater (P = 10), then the temperature of the fluid flow is increase (blue graph). This is due to the influence of the Prandtl number given. So it can be concluded that the parameters Prandtl number is proportional to the temperature of the flow through the porous surface of sphere.

CONCLUSION

The effect of heat generation parameter values (γ = 0.5), Prandtl number (Pr = 1), porosity (P = 10), and viscosity are varied (K = 0.01, 0.2, 0.5, 1) is inversely proportional to the flow velocity, but to the flow temperature is proportional. The effect of the viscosity parameter values (K = 0.01), Prandtl number (Pr = 10), porosity (P = 1), and heat generation are varied (γ = 0.1, 0.2, 0.3, 0.4) is proportional to the flow velocity and the flow temperature. The effect of the viscosity parameter

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values (K = 0.01), heat generation ($\gamma = 0.2$), Prandtl number (Pr = 1), and porosity are varied (P = 1, 4, 7, 10) is inversely proportional to the flow velocity, but to the flow temperature is proportional. The effect of the viscosity parameter values (K = 0.01), porosity (P = 10), heat generation ($\gamma = 0.2$), and the Prandtl number (Pr = 1, 5, 7, 10) that varied inversely proportional to the flow velocity and to the flow temperature.

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