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Heat transfer analysis through semi-spherical fin with Nano-fluid flow

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ABSTRACT :

The objective of the investigation is to analyze the thermal performance of nanofluid flow in different base fluids (water and kerosene) over a fully wet, semi-spherical porous fin, taking into account the impacts of an internal heat source and radiation. Optimal thermal distribution performance was investigated in two distinct base fluids. A Darcy law model is used to create the heat equation. The non-dimensional governing equation solved using the Maple programmer and the Runge Kutta Fehlberg technique's 4thand5th orders. The computational results obtained under various constraints using two base fluids are graphed and thoroughly examined. It should be observed that convection, radiation and wet parameters reduce thermal performance, whilst internal ambient parameters and heat generation increase it. Water performs better in terms of thermal distribution than kerosene base fluid when titanium alloy is present

Keywords: Heat transfer, semi spherical fin, Nano fluid

1. Introduction :

Due to the numerous applications of nano-fluids in heat exchangers, electrical cooling systems, solar collector, and biomedicine, to minimize the size of the body, an extended surface known as a fin is attached; this improves heat transfer rate (q). Applications like aircraft demand lighter fins with excellent heat transfer capabilities, but high thermal conductivity metals can be costly. Consequently, enhancing (q) can be obtained by utilizing compact, cost-effective fins with high (q). In general, increasing the temperature difference, improving heat transfer coefficient (h_c), and expanding the heat transfer area will enhance the (q) transmission. Technological constraints limit the ability to improve the temperature difference, and managing (h_c) is more challenging. Therefore, increasing the surface heat transfer area is the most significant way to enhance the heat exchange rate. Employing fins is a highly effective method for greatly expanding the surface heat transfer area of a system Nabati et al.., have studied the heat transport characteristics of a moving wet fin using numerical methods[1]. Hatami and Ganji (2014) have studied the interaction of heat and mass transfer in a porous circular fin when fully saturated with liquid [2]. Ghasemi et al. (2014) conducted a thermal analysis of a convective fin, examining the effects of temperature-dependent thermal conductivity (K) and heat generation on fin heat transfer [3]. Sobamowo (2017) have studied effect thermal conductivity on fin efficiency by using finite difference method [4]. Gireesha et al. (2020) have studied effect of thermal boundary condition on the effectiveness of fin [5]. Torabi et al. (2012) have studied moving fin with constant velocity by using Differential Transform Method (DTM)[7].

Darvishi et al. (2016) have conducted a numerical study the hyperbolic annular fin with temperature-dependent thermal conductivity[8]. Sowmya et al..,(2020) have studied longitudinal porous fin analyzing the impacts of radiation and convection under wet conditions, [9]. Xu et al. (2014) [9] and Xu (2017) [10] have studied the heat transfer dynamics of thermal non-equilibrium in a solar collector filled in metal foam and in micro heat exchangers containing porous media, respectively. Some of the recent studies by Dogonchi and Ganji (2016), Ma et al.,(2018) Ray et al.(2018) and Turkyilmazoglu.et.al (2018).

2. Problem Description :

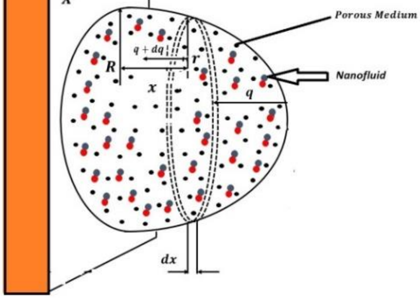

Figure 1:Semi-spherical porous fin[15]

Titanium alloy nanoparticle is immersed in water and kerosene forming base fluids as shown above Figure. 1and thermo physical properties are shown in Table 1. Fin having a radius R . There is a dependence of temperature and fin surface heat transfer is through radiative-convective heat transfer and fin generates internal heat. Atmospheric (Ambient) air temperature (Ta) serves as a thermal radiation absorber, considering that the exposed surfaces possess emissivity. Surface emissivity (ε) is dependent on temperature, but h is kept be constant.

The preceding energy balance equation can be written as.

$$q-(q+dq)+q^{*}A-mC_p(T-T_a)-2\pi rh(1-\psi)(T-T_a)dx \\ -2\pi rh_D i_{fg}(1-\psi)(\omega-\omega_a)dx-2\pi r\varepsilon\sigma f(T^4-T_a^4)dx \tag{2.1}$$

Where q^{*} internal heat generation, A is cross sectional area of the fin, m fluid flow of mass, C_p is specific heat, ψ is porous term, $(1-\psi)$ represents the fraction of the solid area of the fin decreased compared to the pore area needed for convection surface., f is the shape factor, ε is emissivity radiation discharge inside the ambient fluid, T fin temperature, T_a is the ambient (air) temperature of the fin.

The varying internal heat generation rate as a function of temperature, given by.

$$q^{*}=q_0(1+\lambda(T-T_a)) \tag{2.2}$$

Mass flow rate through porous material

$$m=\rho v2\pi rdx \tag{2.3}$$

Darcy's model for Passage velocity given

$$v=\frac{gK\rho\beta(T-T_a)}{\mu_f} \tag{2.4}$$

Substituting equation (2.2)-(2.4) into the equation (2.1) resulted in following equation

$$q-(q+dq)+q_0(1+\lambda(T-T_a))A-\frac{2\pi r(\rho C_p)_{nf}(\rho\beta)_{nf}gK(T-T_a)^2}{\mu_{nf}} \\ -2\pi rh(1-\psi)(T-T_a)dx-2\pi rh_D i_{fg}(1-\psi)(\omega-\omega_a)dx-2\pi r\varepsilon\sigma f(T^4-T_a^4)dx \tag{2.5}$$

In addition, Fourier law of conduction is

$$q=-k_{nf}A\frac{dT}{dx} \tag{2.6}$$

Here, A denotes the cross sectional area of the fin. $A=\pi r^2$. Heat transmission is observed to occur at x and The dependence between two variables r and x can be expressed as follows (figure 1).

$$r^2=R^2-X^2 \tag{2.7}$$

Substitute equations (2.6)-(2.7) to the equation (2.5)

$$-\frac{d}{dx}\left(-k_{nf}\pi(R^2-x^2)\frac{dT}{dx}\right)+q_o(1+\lambda(T-T_a))\pi(R^2-x^2) \\ -\frac{2\pi\sqrt{R^2-x^2}(\rho C_p)_{nf}(\rho\beta)_{nf}gK(T-T_a)^2}{\mu_{nf}}-2\pi\sqrt{R^2-x^2}h(1-\psi)(T-T_a) \\ -2\pi\sqrt{R^2-x^2}h_D i_{fg}(1-\psi)(\omega-\omega_a)-2\pi\sqrt{R^2-x^2}\varepsilon\sigma f(T^4-T_a^4) \tag{2.8}$$

Thermal power is the function (h)

$$h=\left[\frac{T-T_a}{T_b-T_a}\right]^n=h_D C_p Le^{\frac{2}{3}}$$

(2.9)

Here, h_a shown as heat transfer coefficient at T_a and n is the power law index.

Substituting equation (2.9) into the equation (2.8), we have

$$k_{nf}\left(R^2-x^2\right)\frac{d^2T}{dx^2}-2xk_{nf}\frac{dT}{dx}+q_0\left(1+\lambda\left(T-T_a\right)\right)\left(R^2-x^2\right)$$
$$-\frac{2\sqrt{R^2-x^2}\left(\rho C_p\right)_{nf}\left(\rho\beta\right)_{nf}gK\left(T-T_a\right)^2}{\mu_{nf}}-2\sqrt{R^2-x^2}h_a\left(1-\psi\right)\frac{\left(T-T_a\right)^{n+1}}{\left(T_b-T_a\right)^n}$$
$$-2\sqrt{R^2-x^2}\frac{h_a}{C_pLe^{\frac{2}{3}}}\frac{\left(T-T_a\right)^{n+1}}{\left(T_b-T_a\right)^n}i_{fg}\left(1-\psi\right)b_2-2\sqrt{R^2-x^2}\varepsilon\sigma f\left(T^4-T_a^4\right)$$

(2.10)

Boundary conditions at a Temperature=Constant:

$$T(0)=T_b \quad \text{at} \quad x=0; \quad \frac{dT}{dx}=0 \quad \text{at} \quad x=R$$

(2.11)

Non-dimensional of the parameters:

$$X=\frac{x}{R},\ \theta=\frac{T}{T_b},\ \theta_a=\frac{T_a}{T_b},\ Ng=\frac{q_0R^2}{T_bk_f},\ B=\lambda T_b,\ Nc=\frac{2\left(\rho C_p\right)_f\left(\rho\beta\right)_f gKT_b}{k_f\mu_f},$$
$$m_0=\frac{2Rh_a\left(1-\psi\right)}{k_f},\ m_1=\frac{2Rh_a i_{fg}b_2\left(1-\psi\right)}{C_pLe^{\frac{2}{3}}k_f},\ Nr=\frac{2R\varepsilon\sigma fT_b^3}{k_f},$$
$$\left(\omega-\omega_a\right)=b_2\left(T-T_a\right),m_2=m_0+m_1.$$

(2.12)

Substituting equation (2.12) into the equation (2.10), we get

$$\frac{d^2\theta}{dX^2}-\frac{2X}{1-X^2}\frac{d\theta}{dX}+Ng\left(1+B\left(\theta-\theta_a\right)\right)\frac{k_f}{k_{nf}}-\frac{Nc}{\sqrt{1-X^2}}\left(\theta-\theta_a\right)^2$$
$$\frac{\left(\rho C_p\right)_{nf}}{\left(\rho C_p\right)_f}\frac{\left(\rho\beta\right)_{nf}}{\left(\rho\beta\right)_f}\frac{\mu_f}{\mu_{nf}}\frac{k_f}{k_{nf}}-\frac{m_2}{\sqrt{1-X^2}}\frac{\left(\theta-\theta_a\right)^{n+1}}{\left(1-\theta_a\right)^n}\frac{k_f}{k_{nf}}-\frac{Nr}{\sqrt{1-X^2}}\left(\theta^4-\theta_a^4\right)\frac{k_f}{k_{nf}}$$

(2.13)

and the following (2.11) will becomes

$$\theta\left(X\right)=1 \quad \text{at} \quad X=0; \quad \frac{d\theta}{dX}=0 \quad \text{at} \quad X=1$$

(2.14)

Where, Ng is the generation parameter, B non-dimensional internal heat generation parameter, Nc is convective parameter, m_2 is wet porous parameter, n is power law index, Nr is radiative parameter, θ_a is the ambient non-dimensional temperature and θ is the non-dimensional temperature. The non-dimensional governing equation solved using the Maple programmer and the Runge Kutta Fehlberg technique's 4thand5th orders.

The thermo physical expression of nanofluid is expressed mathematically as $\rho_{nf} = \left(\varphi\rho_s + (1-\varphi)\rho_f\right)$

$$\left(\rho C_p\right)_{nf} = \left(\varphi\left(\rho C_p\right)_s + (1-\varphi)\left(\rho C_p\right)_f\right)$$

$$(\rho\beta)_{nf} = \left[\left((1-\phi)(\rho\beta)_f\right) + \phi\,(\rho\beta)_s\right]$$

$$\mu_{nf} = \frac{\mu_f}{(1-\phi)^{2.5}}$$

$$k_{bf} = \frac{(k_s + 2k_f) - 2\phi(k_f - k_s)}{(k_s + 2k_f) + \phi(k_f - k_s)} k_f$$

Here ϕ represents solid volume fractions and s, nf, indicates solid nanoparticles of TI6AL4V viscous fluid, nanofluid respectively. The themo physical properties represent in below table 1

Tabe.1: Thermo-physical Properties of the fluid and Nano-fluid

Material	Kerosene	Water	Ti6Al4V
P (kg-m^3)	780	997.1	4420
C_p (J-kg^{-1}K^{-1}	2090	4179	0.56
K(W-m^{-1},K^{-1}	0.149	0.613	7.2
β (×10^{-5}) K^{-1}	99	21	0.86

3. Results and Discussions :

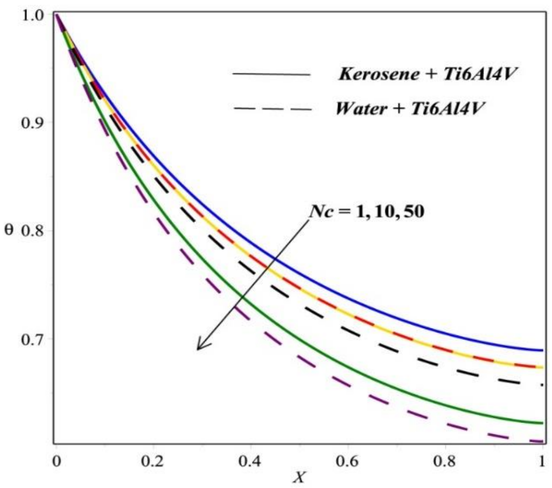

Fig (2) Impact of Convection parameter on temperature filed

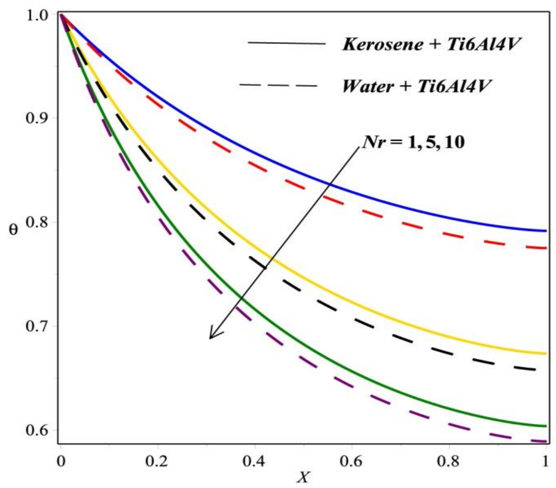

Fig (3) Impact of Radiative parameter on temperature filed

The varying N_c=radiative parameter, N_r=heat generation factor, N_g=internal, ambient temperature θ_a wet porous parameter m_2, were graphically showed and by altering each parameter by keeping others constant. Figure 2 shows the variation in N_c on heat transfer. An increase in the convective parameter (N_c) leads to a significant decrease in the temperature distribution. This is due to variation in Rayleigh (Ra) and Darcy (Da) number and direct impact of buoyance of the system. This is due of higher (Q) from fin surfaces to environment. The variation of radiative factor (N_r) on the (Q) for nanofluid shown in figure 3. Increase in radiative factors reduces the fin (Q). This is because of enhancement of radiation effect.

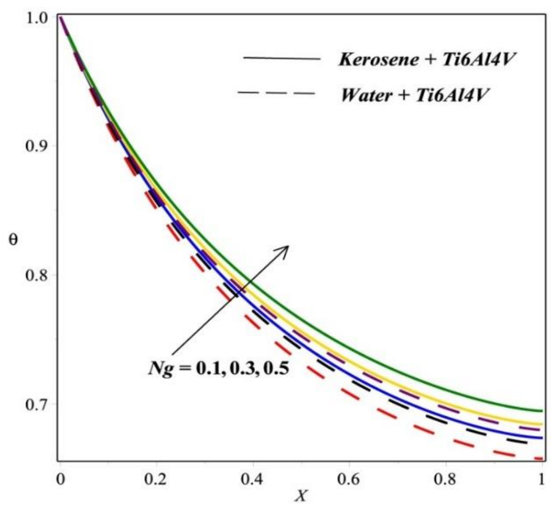

Fig (4) Impact of Internal heat on temperature filed

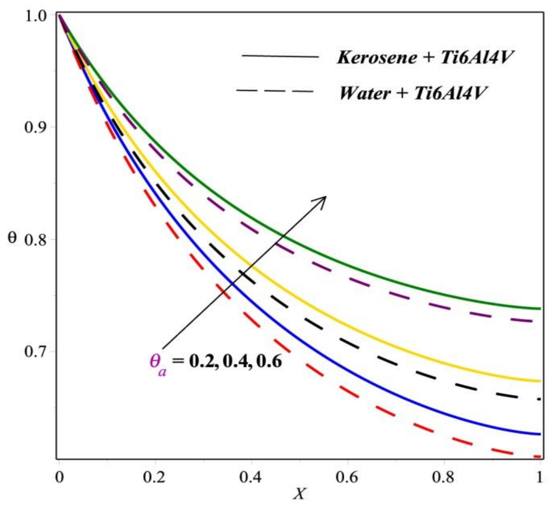

Fig (5) Impact of ambient temperature on temperature filed

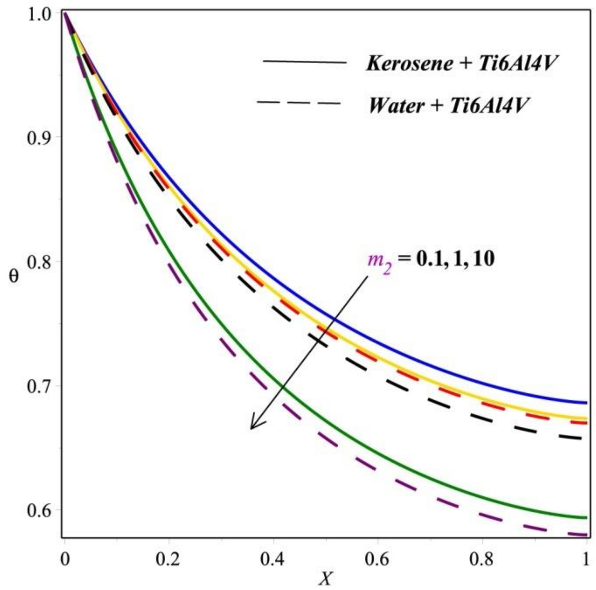

Fig (6) Impact of Wet porous parameter on temperature filed

Figure 4 shows the variation of N_g on thermal characteristics. Thermal profile increases as heat generation parameter increases. This is because of to development of internal heat inside the fin, improves the temperature rise of the surface area of fin. This resulting in decrease in thermal distribution. Figure 5 variation of ambient temperature θ_a on the heat transfer of fin. As the value of θ_a improves the fin temperature. This due to heat transfer of fin decrease as surrounding temperature fluid rises. The variation of wet porous factor m_2 on temperature distribution of the fin as shown in Figure 6. The fin's moist characteristics helps remove additional heat from the atmosphere, while its permeability permits fluid to pass through. Therefore, the wet porous nature of the fin aids in temperature distribution and benefits the fin's surface.. As a result, it is clearly established that as this parameter increases, the thermal profile of the fin decreases, leading to an improvement in the fin's cooling effect

4. Conclusion :

Thermal properties of natural convection and radiation effects have been investigated using a semispherical permeable fin which is completely saturated in a nanofluid. The temperature field is greatly affected by natural convection, radiation, and the moist environment around the porous fin, with improvements attributed to the wet porous parameter, internal heat generation, and generation number. Additionally, increases in the power law index, ambient temperature, and solid volume fraction enhance thermal behaviour, especially in nanofluids compared to regular nanofluids.

REFERENCES:

1. M. Fallah Najafabadi, H. Talebi Rostami, K. Hosseinzadeh, D. Domiri Ganji, Thermal analysis of a moving fin using the radial basis function approximation, Heat Tran. 50 (2021) 7553–7567, https://doi.org/10.1002/htj.22242.
2. Hatami, M. and Ganji, D.D. (2014), “Investigation of refrigeration efficiency for fully wet circular porous fins with variable sections by combined heat and mass transfer analysis”, International Journal of Refrigeration, Vol. 40, pp. 140-151.
3. Ghasemi SE, Hatami M and Ganji DD. Thermal analysis of convective fin with temperature-dependent thermalconductivity and heat generation. Case Studies Therm Eng 2014; 4: 1–8.
4. Sobamowo, M.G. “Analysis of convective longitudinal fin with temperature-dependent thermal conductivity and internal heat generation”, Alexandria Engineering Journal, 2017, Vol. 56 No. 1, pp. 1-11.
5. Gireesha, B.J., Sowmya, G., Khan, M.I. and Öztop, H.F. “Flow of hybrid nanofluid across a permeable longitudinal moving fin along with thermal radiation and natural convection”, Computer Methods and Programs in Biomedicine, 2020, Vol. 185, pp. 105166.
6. Torabi, M., Yaghoobi, H., Aziz, A., Analytical Solution for Convective Radiative Continuously Moving Fin with Temperature-Dependent Thermal Conductivity. International Journal of Thermophysics 33, 924–941, 2012
7. Darvishi, M.T., Khani, F., Aziz, A., Numerical investigation for a hyperbolic annular fin with temperature dependent thermal conductivity. Propulsion and Power Research 5(1), 55–62, 2016.
8. G. Sowmya AbeerBaslem, B.J. Gireesha, B.C. Prasannakumara, Mohammad Rahimi-Gorji, Nguyen Minh Hoang, Analysis of thermal behavior of a porous fin fully wetted with nanofluids: convection and radiation, J. Mol. Liq. 307, 2020, 112920.
9. Xu H, Gong L, Huang S, Xu M. Non-equilibrium heat transfer in metal-foam solar collector with no-slip boundary condition. Int J Heat Mass Transf. 2014;76:357–65.
10. Xu H. Performance evaluation of multi-layered porous-medium micro heat exchangers with effects of slip condition and thermal non-equilibrium. Appl Therm Eng. 2017;116:516–27.
11. Dogonchi AS and Ganji DD. Convection-radiation heat transfer study of moving fin with temperature-dependent thermal conductivity, heat transfer coefficient and heat generation. Appl Therm Eng 2016; 103: 705–712. 14.
12. Ma J, Sun Y and Li B. Simulation of combined conductive, convective and radiative heat transfer in moving irregular porous fins by spectral element method. Int J Therm Sci 2017; 118: 475–487. 15.
13. Roy PK, Mallick A, Mondal H, et al. A modified decomposition solution of triangular moving fin with multiple variable thermal properties. Arab J Sci Eng 2018; 43: 1485–1497. 16.
14. Turkyilmazoglu M. Heat transfer from moving exponential fins exposed to heat generation. Int J Heat Mass Tran 2018; 116: 346–351.
15. G. R Maonahar, B.J Gireesha, J.K Madhukesh, G.K Ramesh, Dynamic of hybrid nanofluid through a semi spherical porous fin with internal heat generation, Partial Differential equation in Applied Mathematics, 4 (2021) 100150