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FLOW AND HEAT TRANSFER IN A POROUS MEDIUM DUE TO AN OSCILLATING PLATE WITH OSCILLATING TEMPERATURE IN A VISCOUS FLUID NEAR ITS SURFACE

A.C. Srivastava and **Manju Agarwal**
Department of Mathematics and Astronomy, Lucknow University,
Lucknow - 226007

Abstract

The induced flow and the heat transfer in a porous medium have been discussed when a flat plate parallel to the porous surface oscillates in its own plane with its temperature also oscillating. The gap between two surfaces is filled with a viscous fluid which also fully saturates the porous medium. It is found that when the porous medium is unbounded the amplitude of oscillation of the fluid at the interface increases with the increase of the permeability of the porous medium and also with the increase of Reynolds number. There is a boundary layer formation at the interface in the porous region when the thicknesses of the porous material and the clear fluid are equal. The case when thickness of the porous layer is one-tenth of that of the clear fluid, this system produces a cooling, effect on the porous surface.

Mathematics Subject Classification (2000) 76S05.

Key words: Flow, Heat transfer, porous medium, Oscillating Plate and temperature.

1. Introduction

The flow of a viscous fluid and the heat transfer through a porous medium have broad range application in geothermal system, thermal installation, metal processing, catalytic reaction, filteration and transpiration cooling. Vafai and Tien [1], Vafai [2] and Beckerman and Viskanta [3] have studied the effect of

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1. Introduction

The flow of a viscous fluid and the heat transfer through a porous medium have broad range application in geothermal system, thermal installation, metal processing, catalytic reaction, filteration and transpiration cooling. Vafai and Tien [1], Vafai [2] and Beckerman and Viskanta [3] have studied the effect of variable porosity and variation in the boundary layer and temperature in forcec convection boundary layer flow, heat and mass. transfer along a flat plate embedded in a porous medium.

The object of this paper is to study the induced flow and the effect of cooling in a porous medium when an infinite flat plate parallel to the porous surface oscillates in its own plane. The space between the plate and the porous medium is filled with an incompressible viscous fluid with which the porous medium is fully saturated. The temperature of the oscillating plate also oscillates with the same frequency as that of the oscillation of the plate. It is assumed tha Navier-Stokes equation and Brinkman equation [4] respectively govern the flov in the clear fluid region, called region I and in the porous region, called regior II. At the interface of these two regions the conditions on velocity and stresses suggested by Ochao-Tapia and Whitaker [6] are taken and we have proposec that similar conditions on the temperature be taken at the interface. Our resul shows that the induced steady temperature is such that cooling effects ar produced in the porous medium.

Cooling problem has assumed a continuously growing importance in th development of high speed vehicles (like space vehicles, aircrafts, missiles ete.) One of the effective method of cooling is the transpiration cooling in which th surfaces to be protected are manufactured from porous materials and cold flui is ejected from the pores (See Shivakumara and Venkatachalappa [6]). Anothe method is that the surface be protected from hot fluid is lined with porous materia and our results are useful in this case.

2. Statement of the problem :

Consider the flow and the heat transfer of an incompressible viscous flui confined between an infinite impervious flat plate executing linear harmoni oscillation of frequency n parallel to itself and a porous medium fully saturate with the fluid. Temperature of the oscillating plate also oscillates with frequenc n. Let x denote the coordinate parallel to the direction of motion and y th coordinate perpendicular to the plate. Let the oscillating plate be represented by y = d, the interface by y = 0 and the plane bounding the porous medium by y = - λd where λ is a real constant. The schematic of the problem is given in figure 1. In the region I the flow is governed by Navier-Stokes equation and in region II it is governed by Brinkman equation [4]. They only velocity component in the direction of x and the temprature are functions of y and t only and are respectively denoted by u(y,t), T(y,t) in the region I and U(y,t), H(y,t) in the region II. The boundary conditions of the problem are :

$$u = U_O \mathrm{Cos}(nt) \text{ at } y = d, \tag{1}$$

$$T = T_w + T_O \mathrm{Cos}(nt) \text{ at } y = d, \tag{2}$$

$$U = 0 \text{ at } \quad y = -\lambda d, \tag{3}$$

$$H = T_w \quad \text{at} \quad y = -\lambda d. \tag{4}$$

At the interface of the porous medium and clear fluid y = 0, we assume that the velocity component is continuous and the jump in the shearing stress T_{yx} is given by the equation suggested by Ochao-Tapia and Whitaker [5]. These assumptions in our notation can be written as :

$$u = U \quad \text{at} \quad y = 0, \tag{5}$$

$$\mu\frac{\partial U}{\partial y} - \mu\frac{\partial u}{\partial y} = \frac{\beta\mu}{\sqrt{k}}U \quad \text{at } y = 0 \tag{6}$$

where μ is is the viscosity of the fluid, k is the permeability of the porous medium and β is a constant which takes positive as well as negative values and depends on the nature of the porous surface (See Ochao-Tapia and Whitaker [7]). Using these conditions at the interface Srivastava [8] has discussed the torsional oscillation of an infinite disk in a viscous liquid bounded by a porous medium. On the similar basis we propose that temperature is continuous at the interface and there is a jump in the heat flux at the interface which is proportional to the temperature at the interface. This can be written as :

$$T = H \quad \text{at} \quad y = 0, \tag{7}$$

$$K\frac{\partial H}{\partial y} - K\frac{\partial T}{\partial y} = \frac{\alpha K}{\sqrt{k}} \quad T \quad \text{at} \quad y = 0, \tag{8}$$

where K is the thermal conductivity and α is a constant depending on t
surface of the porous medium and its value is similar to that of β.

The equations governing the velocity and temperature in regional I a
respectively given by

$$\frac{\partial u}{\partial t} = \nu\frac{\partial^2 u}{\partial y^2}, \tag{9}$$

$$\rho g C_p \frac{\partial T}{\partial t} = K\frac{\partial^2 T}{\partial y^2} + \mu\left(\frac{\partial u}{\partial y}\right)^2, \tag{1}$$

where ν is the kinematic coefficient of viscosity, p is the density, g is
acceleration due to gravity and C_p is the specific heat at constant pressure. T
equations governing the velocity and temperature in region II, ae respectiv
given by

$$\frac{\partial U}{\partial t} = \nu\frac{\partial^2 U}{\partial y^2} - \frac{\nu}{k}U, \tag{1}$$

$$\rho g C_p \frac{\partial H}{\partial t} = K\frac{\partial^2 K}{\partial y^2} + \mu\left(\frac{\partial U}{\partial y}\right)^2 + \frac{\mu}{k}U^2 \tag{1}$$

The equation (12) is written by taking dissipation due to viscosity as w
as due to permeability. Srivastava and Sharma [9] have studied the heat tran
in a porous medium due to rotation of a disk near its surface by taking equa
(12) for temperature distribution.

3. The Velocity Field :

We adopt here the complex notation with the convention that only
parts of the complex quantities represent the physical quantities. Under
notation boundary condition (1) is written as :

$$u = U_0 e^{it} \qquad \text{at } y = d, \tag{}$$

where τ = nt. We assume the following expressions for the velocity in region I and II respectively

$$u = U_0\, g(\eta) e^{i\tau}, \qquad (14)$$

$$u = U_0\, G(\eta) e^{i\tau}, \qquad (15)$$

where $\eta = (y/d)$. The equations (9) and (11) give the following equations for $g(\eta)$ and $G(\eta)$ respectively :

$$i\,\mathrm{Re}\, g = g'', \qquad (16)$$

$$(i\,\mathrm{Re} + \sigma^2) G = G'', \qquad (17)$$

where $\sigma = (d/\sqrt{k})$, Reynold's number $\mathrm{Re} = (nd^2/\nu)$ and a prime denotes differentiation with respect to η.
The boundary conditions (1) and (3) give

$$g(1) = 1, \qquad (18)$$

$$G(-\lambda) = 0, \qquad (19)$$

The matching conditions at the interface (5) and (6) become

$$g(0) = G(0), \qquad (20)$$

$$G'(0) - g'(0) = \beta\sigma G(0) \qquad (21)$$

The solutions of the equations (16) and (17) satisfying (18) - (21) are

$$g(\eta) = (1/\mathrm{sh}\, p)\, [C_1\, \mathrm{sh}\, \lambda q\, \mathrm{sh}\, p(1-\eta) + \mathrm{sh}\, p\eta], \qquad (22)$$

$$G(\eta) = C_1\, \mathrm{sh}\, q(\lambda+\eta), \qquad (23)$$

where $(1/C_1) = (1/p)\, [p\, \mathrm{sh}\, \lambda q\, \mathrm{ch}\, p + q\, \mathrm{sh}\, p\, \mathrm{ch}\, \lambda q - \beta\sigma\, \mathrm{sh}\, \lambda q\, \mathrm{sh}\, p] = A_1 e^{i\phi_1}$ (24)

$$p = (1+i)\sqrt{(\mathrm{Re}/2)}, \quad q = a_1 + i a_2 = a\left[Cos\left(\frac{\theta}{2}\right) + i\ Sin\left(\frac{\theta}{2}\right)\right]$$

$$a = \left(\mathrm{Re}^2 + \sigma^4\right)^{\frac{1}{4}}, \qquad \tan\theta = \left(\mathrm{Re}/\sigma^2\right),$$

In writing the above solution cosh χ and sinh χ are written as ch χ and and sh χ respectively.

The case when the porous region is unbounded can be deduced from the above solution by taking limits of the expressions as $\lambda \to \infty$.
The expression for g(η) is unchanged except that the value of C_1 is modified as

$$\lim_{\lambda \to \infty} C_1 = (i/p)\left[p \ ch \ p + (q - \beta\sigma) sh \ p\right] = A_2 e^{i\phi_2} \quad (25)$$

The expression for G(η) is given by

$$G(\eta) = (1/A_2) e^{q\eta - i\phi_2} \quad (26)$$

The case when λ = 1, the amplitude of oscillation of the induced velocity in the porous region is given by

$$|U| = (U_0/A_3)\left[ch \ 2a_1(1+\eta) - Cos \ 2a_2(1+\eta)\right]^{\frac{1}{2}} \quad (27)$$

where

$$(1/p)(p \text{ sh } q \text{ ch } p + q \text{ sh } p \text{ ch } q - \beta\sigma \text{ sh } p \text{ sh } q) = A_3 e^{i\phi_3} \quad (28)$$

4. Temperature Field :

The viscous dissipation function in equation (10) can be written as :

$$\left(\frac{\partial u}{\partial y}\right)^2 = U_0^2\left[\text{Re}al\left(\frac{\partial g}{\partial y} e^{i\tau}\right)\right]^2$$

$$= \frac{U_0^2}{2}\frac{\partial g}{\partial y}.\frac{\partial \bar{g}}{\partial y} + U_0^2 Re \ al\left[\frac{1}{2}\left(\frac{\partial g}{\partial y}\right)^2 e^{2i\tau}\right] \quad (29)$$

where $\bar{g}$ is the conjugate complex of g. Similar expressions can be written for U

and $\left(\frac{\delta U}{\delta y}\right)^2$ in the equation (12). Hence, the temperature field consists of three parts the first part and the second part oscillate with frequencies n and 2n respectively and the third part is steady one independent of time. We assume the following form of the temperature in the region I and region II respectively

$$T - Tw = T_0[h_1(\eta)\, e^{i\tau} + h_2(\eta)\, e^{2i\tau} + h_3(\eta)], \tag{30}$$

$$H - Tw = T_0[H_1(\eta)\, e^{i\tau} + M_2(\eta)\, e^{2i\tau} + M_3(\eta)], \tag{31}$$

The boundary conditions (2) and (4) give respectively the following conditions:

$$h_i(1) = 1, \quad h_i(1) = 0, \quad i = 2, 3 \tag{32}$$

$$H_i(-\lambda) = 0, \; i = 1,2,3, \tag{33}$$

Matching conditions (7) and (8) at the interface in terms of h_i and H_i can be written as :

$$h_i(0) = H_i(0), \; i = 1,2,3 \tag{34}$$

$$\frac{dH_i}{d\eta} - \frac{\partial h_i}{\partial \eta} = a \;\sigma\; H_i, \qquad i = 1,2,3 \tag{35}$$

Substituting (30) and (31) in (10) and (12) respectively and equating coefficient of $e^{i\tau}$, $e^{2i\tau}$ and terms independent of time on both sides of the equations we get the following differential equations for $h_1(\eta)$, $H_1(\eta)$, $h_2(\eta)$, $H_2(\eta)$, $h_3(\eta)$, $H_3(\eta)$:

$$i \;\mathrm{Re}\; P_r \; h_1 = \frac{d^2 h_1}{d\eta^2}, \tag{36}$$

$$i \;\mathrm{Re}\; P_r \; H_1 = \frac{d^2 H_1}{d\eta^2} \tag{37}$$

$$2\; i \;\mathrm{Re}\; P_r \; h_2 = \frac{d^2 h_2}{d\eta^2} + \left(\frac{EP_r}{2}\right)\left(\frac{dg}{d\eta}\right)^2, \tag{38}$$

$$2\; i \;\mathrm{Re}\; P_r \; H_2 = \frac{d^2 H_2}{d\eta^2} + \left(\frac{EP_r}{2}\right)\left[\left(\frac{dG}{d\eta}\right)^2 + \sigma^2 G^2\right], \tag{39}$$

$$\frac{d^2 h_3}{d\eta^2} = -\left(\frac{EP_r}{2}\right)\left|\frac{dg}{d\eta}\right|^2, \tag{40}$$

$$\frac{d^2 H_3}{d\eta^2} = -\left(\frac{EP_r}{2}\right)\left[\left|\frac{dG}{d\eta}\right|^2 + \sigma^2 |G|^2\right], \quad (4$$

where Pr= (μg C_p/K) is the Prandtl number and $E = \left[U_0^2 / \left(gC_p T_0\right)\right]$ is

Eckert number.

The solutions of (36) and (37) satisfying (32) - (35) are :

$$h_1(\eta) = (1/\text{sh } m)\,[C_4 \text{ sh } \lambda \text{ m sh } (1-\eta)m + \text{sh } m\eta] \quad (4$$

$$H_1(\eta) = C_4 \text{ sh m } (\lambda + \eta), \quad (4$$

$$(1/C_4) = (1/m)\,[\text{m sh } \lambda \text{ m ch m} + \text{m sh m ch } \lambda \text{ m} - \alpha\, \sigma \text{ sh } \lambda \text{ m sh m}]$$

where $m = (1+i)\sqrt{(\text{Re } P_r/2)}$. This is the case of pure conduction as there i term involving convection in the differential equations. Substituting expressions of g(η) and G(η) from (22) and (23) in the equations (38) and respectively, we get the follwoing solutions for $h_2(\eta)$ and $H_2(\eta)$:

$$h_2(\eta) = \frac{EP_r p^2}{8sh^2 p}\Bigg[-B_1 chm\eta\sqrt{2} + B_2 shm\eta\sqrt{2}$$

$$-\frac{ch\ \ 2p\eta + C_1^2 sh^2 \lambda q ch 2p(1-\eta) - 2C_1 sh\lambda q chp(1-2\eta)}{2p^2 - i\,\text{Re}\,P_r}$$

$$+\frac{i\left(1 + C_1^2 sh^2 \lambda q - 2C_1 sh\lambda q chp\right)}{\text{Re}\,P_r}\Bigg], \quad ($$

$$H_2(\eta) = \frac{EP_r C_1^2}{8}\Bigg[\ D_1 chm\eta\sqrt{2} + D_2 shm\eta\sqrt{2}$$

$$-\frac{\left(q^2 + \sigma^2\right)ch2q(\lambda + \eta)}{2q^2 - i\,\text{Re}\,P_r} + \frac{i\left(q^2 - \sigma^2\right)}{\text{Re}\,P_r}\Bigg],$$

Constants B_1, B_2, D_1, D_2 can be determined by substituting (44) and (45) in (32) - (35). For the present we are interested in steady part only so we have not determined them.

Substituting the expressions of $g(\eta)$ and $G(\eta)$ from (22) and (23) in the equation (40) and (41) we get the following solutions for $h_3(\eta)$ and $H_3(\eta)$

$$h_3(\eta)=\frac{EP_r}{8\left(ch2\sqrt{\mathrm{Re}}-Cos2\sqrt{\mathrm{Re}}\right)}\left[\left(\frac{b}{A_1}\right)^2\left\{Cos2(1-\eta)\sqrt{\mathrm{Re}}\right.\right.$$

$$\left.-ch2(1-\eta)\sqrt{\mathrm{Re}}\right\}+\left(\frac{2b}{A_1}\right)\left\{Cos(1-2\eta)\sqrt{\mathrm{Re}}ch\sqrt{\mathrm{Re}}-ch(1-2\eta)\sqrt{\mathrm{Re}}Cos\sqrt{\mathrm{Re}}\right\}$$

$$\left.Cos(\psi-\phi_1)+\left(Cos2\eta\sqrt{\mathrm{Re}}-Cos2\sqrt{\mathrm{Re}}\right)-\left(ch2\eta\sqrt{\mathrm{Re}}-ch2\sqrt{\mathrm{Re}}\right)\right]$$

$$+\left(\frac{EP_r}{16}\right)(1-\eta)M_1, \tag{46}$$

$$H_3(\eta)=\frac{EP_r}{(4A_1\lambda a_1 a_2)^2}\left[a_1^2\left\{\sqrt{(\mathrm{Re}^2+\sigma^4)}-\sigma^2\right\}\left\{Cos2\lambda(1+\eta)a_2-1\right\}\right.$$

$$\left.-a_2^2\left\{\sqrt{(\mathrm{Re}^2+\sigma^4)}+\sigma^2\right\}\left\{ch2\lambda(1+\eta)a_1-1\right\}\right]$$

$$+\left(\frac{EP_r}{16}\right)(\lambda+\eta)M_2 \tag{47}$$

where sh $\lambda q = be^{i\psi}$. These experessions for $h_3(\eta)$ and $H_3(\eta)$ satisfy the boundary conditions (32) and (33). Two constants M_1 and M_2 are determined by the conditions (34) and (35) which can be written as :

$$M_1-\lambda M_2=\frac{1}{(\lambda a_1 a_2 A_1)^2}\left[a_1^2\left\{\sqrt{(\mathrm{Re}^2+\sigma^4)}-\sigma^2\right\}(Cos2\lambda a_2-1)-a_2^2\right.$$

$$\left\{\sqrt{\left(\mathrm{Re}^2+\sigma^4\right)}+\sigma^2\right\}\ (ch2\lambda a_1-1)\Bigg]+2\left[\left(\frac{b}{A_1}\right)^2+1\right] \tag{48}$$

$$(1+\alpha\sigma)M_1+M_2=2\alpha\sigma\left\{\left(\frac{b}{A_1}\right)^2+1\right\}+\frac{4\sqrt{\mathrm{Re}}}{ch2\sqrt{\mathrm{Re}}-Cos2\sqrt{\mathrm{Re}}}$$

$$\left[\left(\frac{b}{A_1}\right)^2\left(Sin2\sqrt{\mathrm{Re}}+sh2\sqrt{\mathrm{Re}}\right)+\left(\frac{2b}{A_1}\right)\left(Sin\sqrt{\mathrm{Re}}\ \ ch\sqrt{\mathrm{Re}}\right.\right.$$

$$\left.\left.+Cos\sqrt{\mathrm{Re}}\ \ sh\sqrt{\mathrm{Re}}\right)Cos(\psi-\phi_1)\right]-\frac{2}{\lambda a_1 a_2 A_1^2}\Big[\ a_1\left\{\sqrt{\left(\mathrm{Re}^2+\sigma^4\right)}-\sigma^2\right\}$$

$$Sin2\lambda a_2+a_2\left\{\sqrt{\left(\mathrm{Re}^2+\sigma^4\right)}-\sigma^2\right\}sh2\lambda a_1)\ \Big] \tag{49}$$

5. Discussions and Conclusions :

The induced velocity in the porous medium when it is unbounded below is given by substituting (26) in (15) as :

$$U=(U_0/A_2)e^{a_1\eta}Cos\,(\tau+a_2\eta-\phi_2) \tag{50}$$

This shows that the induced velocity in the porous medium has the form of damped harmonic oscillations the amplitude of which is $(U_0/A_2)e^{a_1\eta}$. The fluid layer at a distance $(2\pi d/a_2)=2\pi[2\nu k/\{\sqrt{(n^2k^2-\nu^2)}-\nu\}]^{1/2}$ apart oscillates with the same phase and this distance is called the depth of penetration of the viscous layer (See Schlichting [10]).

The amplitude of oscillations of the fluid velocity at the interface is given by (U_0/A_2). The value of $(A_2)^{-1}$ has been is table 1 for σ = 5,6,7,8,9,10; Re = 2,3,4 and β = -0, 5, 0.5. The table 1 shows that amplitude of oscillations of the fluid decreases with the increase of σ for all values of Re and β. It increases with the increase of Re for all values of σ and β. It decreases much with the decrease of β and its values for β = -0.5 is less than half of those for β = 0.5. The values of β for the porous surfaces depends on the porous material and can be experimentally determined from other experiments (See Ochao - Tapia and Whitaker [7]).

In the case λ = 1, the amplitude of the fluid oscillations in the porous medium is given by

$$|(U/U_0)| = (1/A_3)\left[Ch\ \ 2a_1(1+\eta) - Cos\ \ 2a_2(1+\eta)\right]^{\frac{1}{2}} \tag{51}$$

where A_3 = |(1/p)(p sh q ch p + q sh p ch - βσ sh p shq)|

Taking Re = 2, β = 0.5 the graph of $|(U/U_0)|$ has been drawn against η from η = 0 to -1.0 for σ = 5,6,7,8. The graph shows that this amplitude reduces with the increase of σ and there is a boundary formation near the interface. Comparing the values of $|(U/U_0)|_{\eta=0}$ in the graph and those given in the table 1 we find that these reduce much when the porous medium is bounded by another plane below.

Now we will discuss the case of steady heat transfer where there is a lining of a surface by a porous material. The rate of the heat transfer at the nominal surface (interface) η = 0 from the porous material to the clear fluid is given by :

$$Q = -K\left(\frac{\partial T}{\partial Y}\right)_{y=0} = \left(\frac{KT_0}{d}\right)N \tag{53}$$

where N is the Nusselt number given by

$$N = -\left(\frac{dH_3}{d\eta}\right)_{\eta=0} \tag{54}$$

Substituting the value of $H_3(\eta)$ from (47) in (54) we get

$$N = \frac{EP_r}{8A_1^2\lambda a_1 a_2}\left[\left\{\sqrt{(\mathrm{Re}^2+\sigma^4)}+\sigma^4\right\}a_2 sh2\lambda a_1\right.$$

$$+\left\{\sqrt{\left(\mathrm{Re}^2+\sigma^4\right)}-\sigma^2\right\}a_1 Sin2\lambda a_2\Big]-\frac{EP_r}{16}M_2 \quad (55$$

The values of N are positive, hence heat transfer takes palce from t porous surface to the clear fluid and there is cooling of the porous meteri Hence when a surface is lined with a porous material surrounded by an oscillati fluid the surface is cooled. The oscillation of temperature is not important as gives only conduction effect. Taking $\lambda = 0.1$, the ratio of N to the product of E is given is table 2 for $\alpha = 0.5$, $\beta = 0.5, -0.5$; Re = 2,3,4; σ =5,6,7,8,9,10. Tab 2 shows that the rate of cooling decreases with increase of σ as well as Re for = 0.5. For $\beta = -0.5$ this cooling rate increases with increase of Re but decreas with increase of σ. It is very much reduced with the decrease of β whose valu are determined experimentally. Hence such porous lining would be done wi material having high values of β.

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	$\beta = 0.5$			$\beta = -0.5$		
σ \ Re	2	3	4	2	3	4
5	0.36901	0.43724	0.47103	0.16122	0.17884	0.20407
6	0.32906	0.38972	0.42805	0.13784	0.15797	0.17253
7	0.29456	0.34888	0.38695	0.11989	0.12906	0.14855
8	0.26868	0.31427	0.35134	0.10794	0.11312	0.13056
9	0.24681	0.28511	0.32093	0.09655	0.10065	0.11602
10	0.22641	0.26027	0.29451	0.08654	0.09062	0.10457

Table 1. : Amplitude of oscillation of the fluid at the interface.

	β = 0.5			β = -0.5		
Re / σ	2	3	4	2	3	4
5	0.86903	0.74755	0.63428	0.21356	0.23123	0.23973
6	0.76408	0.55763	0.52476	0.11360	0.12097	0.12408
7	0.53491	0.45939	0.39197	0.07896	0.08326	0.08515
8	0.47760	0.39439	0.34437	0.06103	0.06384	0.06471
9	0.42089	0.34626	0.29729	0.04996	0.05196	0.05288
10	0.37622	0.30940	0.26377	0.04238	0.04391	0.04452

Table 2. : The value of (N/EP_r) for $\alpha = 0.5$.

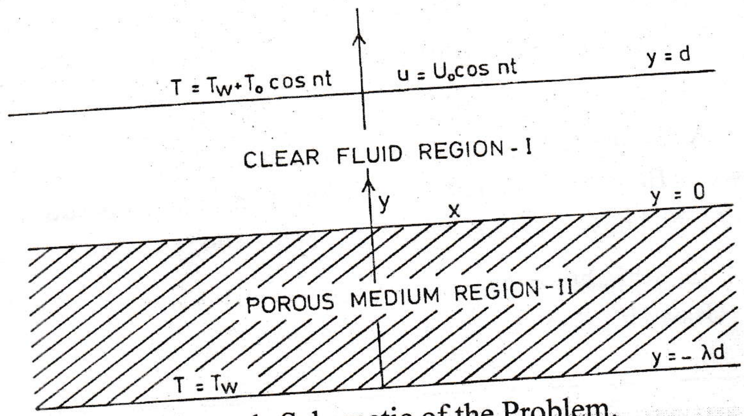

Figure 1. Schematic of the Problem.

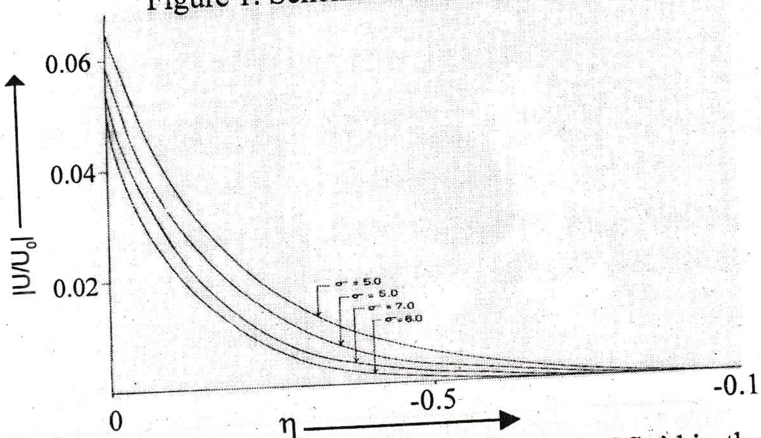

Figure 2. The graph of the amplitude of oscilations of fluid in the porous medium against the distance from interface.