Seminar of I. Vekua Institute
of Applied Mathematics
REPORTS, Vol. 30, 2004

STEADY STATE RESPONSE TO MOVING LOAD AT FLUID MICROPOLAR SOLID INTERFACE

Rajneesh Kumar and Praveen Ailawalia

Department of Mathematics, Kurukshetra University
Kurukshetra, Haryana, INDIA
*Department of Applied Sciences, I.E.E.T, Makhnumajra, Baddi
Distt. Solan, H.P(INDIA)

Received: 18.06.2003 revised: 7.12.2004

Abstract

The steady state response of a micropolar elastic solid with an overlying infinite non-viscous fluid subjected at the plane interface to a moving point load has been studied. The displacement and stress components for subsonic, supersonic and transonic velocities are obtained by the use of Fourier transform technique. Numerical inversion technique has been applied to obtain the results in the physical domain and the numerical results are illustrated graphically for a particular model.

Key words and phrases: Steady state, micropolar, non-viscous, Fourier transform.

Introduction

The classical theory of elasticity does not explain certain discrepancies that occur in the case of problems involving elastic vibrations of high frequency and short wave length, that is, vibrations due to the generation of ultrasonic waves. The reason lies in the microstructure of the material which exerts a special influence at high frequencies and short wave lengths.

An attempt was made to eliminate these discrepancies by suggesting that the transmission of interaction between two particles of a body through an elementary area lying within the material was affected not solely by the action of a force vector but also by a moment (couple) vector. This led to the existence of couple stress in elasticity. Polycrystalline materials, materials with fibrous or coarse grain structure come in this category. The analysis of such materials requires incorporating the theories of oriented media. For this reason, micropolar theories were developed by Eringen (1966a,b) for elastic solids and fluids and are now universally accepted .

The dynamical response to moving loads is of considerable interest in a variety of technological and geophysical circumstances and several recent investigations are concerned with this problem. For instance, it is of great interest in solid dynamics where ground motions and stresses can be produced by blast waves (surface pressure waves due to explosions), or by supersonic aircraft. This type of investigation occur in many branches of engineering, for e.g in bridges and railways, beams subjected to pressure waves and piping systems subjected to two phase flow. Other applications are encountered within the context of contact mechanics like, the problem of high velocity rocket sleds sliding over steel guide rails. This type of investigation is found also in the foundation problems of soil mechanics. Payton (1964), Eason (1965), Gakenheimer and Miklowitz (1969), Kennedy and Hermann (1973), Halpern and Christiano (1986), Nath and Sengupta (1999), Katz (2001), and Verruijt and Cordova (2001) have investigated the problems of moving load in classical theory of elasticity. Kumar et al. (1992, 2000, 2002, 2003) studied the steady state response to moving loads in micropolar theory of elasticity.

In the present paper we study the moving load problem at fluid/micropolar elastic solid interface. The solution is obtained in the transformed domain by using Fourier transform and the numerical inversion technique is applied to get the results in the physical domain.

Formulation and solution of the problem

We consider a normal point load moving along the interface of non-viscous fluid (Medium II)/micropolar elastic solid (Medium I). We consider a rectangular coordinate system (x, y, z) having origin on the surface $z = 0$ and z - axis pointing vertically into the medium as shown in figure 1. Let us consider a pressure pulse $P(x + Ut)$ which is moving with a constant velocity in the negative x direction. After the load has been moving for some time and the transient effects have died away, the displacements will appear stationary in a coordinate system moving with the load.

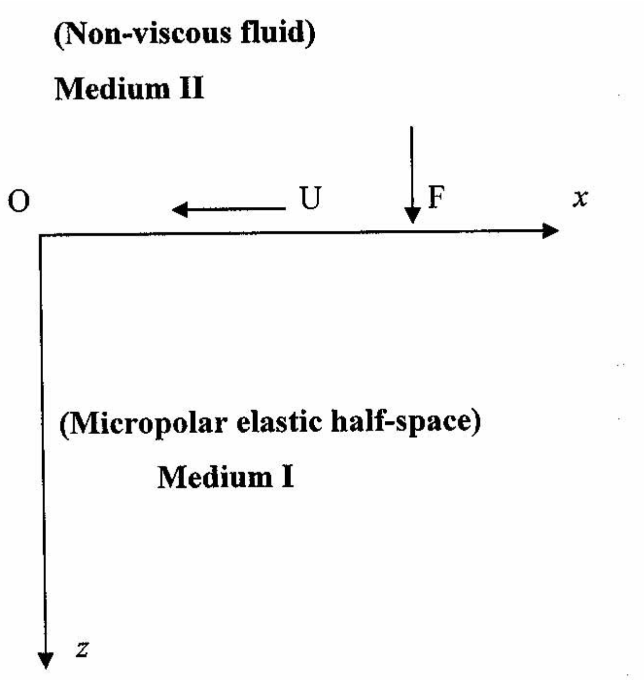


Figure 1: Moving load on interface.

Following Eringen (1966a), the field equations and constitutive relations in micropolar elastic solid without body forces and body couples can be written as,

$$(\lambda+2\mu+K)grad\ div\vec{u}-(\mu+K)rot\ rot\ \vec{u}+Krot\vec{\phi}=\rho\frac{\partial^2\vec{u}}{\partial t^2}, \tag{1}$$

$$(\alpha+\beta+\gamma)grad\ div\vec{\phi}-\gamma rot\ rot\vec{\phi}+Krot\vec{u}-2K\vec{\phi}=\rho j\frac{\partial^2\vec{\phi}}{\partial t^2}, \tag{2}$$

$$t_{kl}=\lambda u_{r,r}\delta_{kl}+\mu(u_{k,l}+u_{l,k})+K(u_{l,k}-\varepsilon_{klr}\phi_r), \tag{3}$$

$$m_{kl}=\alpha\phi_{r,r}\delta_{kl}+\beta\phi_{k,l}+\gamma\phi_{l,k},\quad k=l=1,2,3, \tag{4}$$

where

$\lambda,\mu,K,\alpha,\beta,\gamma$ are material constants, ρ is the density of micropolar elastic solid , j is the microinertia, $\vec{u}$ is the displacement vector and $\vec{\phi}$ is the microrotation vector, t_{kl} and m_{kl} are respectively force stress tensor and couple stress tensor in micropolar elastic medium and ∇ is the gradient operator.

The equation which governs the motion of the fluid is given by Ewing, Jardetzky and Press (1957) as

$$\lambda_f\nabla(\nabla.\vec{V})=\rho_f\frac{\partial^2\vec{V}}{\partial t^2}, \tag{5}$$

where λ_f is Lame's constant and ρ_f is density of fluid.

For two dimensional problem, all quantities depend only on space coordinates x,z and time t and we take the displacement vector and microrotation vector in medium I and displacement vector in medium II respectively as,

$$\vec{u}=(u_1,0,u_3),\quad \vec{\phi}=(0,\phi_2,0),\quad \vec{V}(V_1,0,V_3). \tag{6}$$

The displacement components in both the medium are related by potential functions q,ψ and ϕ_f as

$$u_1=\frac{\partial q}{\partial x}+\frac{\partial\psi}{\partial z},\ u_3=\frac{\partial q}{\partial z}-\frac{\partial\psi}{\partial x}, \tag{7}$$

where ψ is the y^{th} component of displacement vector $(-\vec{u})$ and

$$V_1=\frac{\partial\phi_f}{\partial x},\ V_3=\frac{\partial\phi_f}{\partial z}, \tag{8}$$

Using (6), (7) and (8) in equations (1), (2) and (5) we obtain,

$$\left[\nabla^2-\frac{\rho}{(\lambda+2\mu+K)}\frac{\partial^2}{\partial t^2}\right]q=0 \tag{9}$$

$$\left[\nabla^2-\frac{\rho}{(\mu+K)}\frac{\partial^2}{\partial t^2}\right]\psi-\frac{K}{(\mu+K)}\phi_2=0 \tag{10}$$

$$\left[\nabla^2-\frac{2K}{\gamma}-\frac{\rho j}{\gamma}\frac{\partial^2}{\partial t^2}\right]\phi_2+\frac{K}{\gamma}\nabla^2\psi=0 \tag{11}$$

$$\nabla^2\phi_f=\frac{{\rho_f}^2}{{\lambda_f}^2}\frac{\partial^2\phi_f}{\partial t^2}. \tag{12}$$

Following Fung (1968), a Galilean transformation

$$x^* = x + Ut, \quad z^* = z, \quad t^* = t. \tag{13}$$

is introduced. The boundary conditions would be independent of t^* and assuming the dimensionless variables defined by

$$x' = \frac{x^*}{h}, \quad z' = \frac{z^*}{h} \quad, \phi_2' = \frac{j}{h^2}\phi_2, \quad q' = \frac{q}{h^2}, \quad \psi' = \frac{\psi}{h^2}, \quad t_{ij} = \frac{t_{ij}}{\lambda}, \quad m_{ij}' = \frac{m_{ij}}{\lambda h},$$
$$\phi_f' = \frac{\phi_f}{h^2}, \quad p' = \frac{p}{\lambda}. \tag{14}$$

where h is characteristic length and p is fluid pressure given by $p = -\rho_f \dfrac{\partial^2 \phi_f}{\partial t^2}$, in equations (9)-(12) and applying the Fourier transform defined by

$$\tilde{f}(\xi, z) = \int\limits_{-\infty}^{\infty} f(x, z) e^{i\xi x} dx \tag{15}$$

we get (after suppressing the primes),

$$\left[\frac{d^2}{dz^2} - \xi^2\left(1 - \frac{U^2}{c_1^2}\right)\right]\tilde{q} = 0, \tag{16}$$
$$\left[\frac{d^2}{dz^2} - \xi^2\left(1 - \frac{U^2}{c_3^2}\right)\right]\tilde{\psi} - \frac{Kh^2}{j(\mu + K)}\tilde{\phi}_2 = 0, \tag{17}$$
$$\left[\frac{d^2}{dz^2} - \frac{2K}{\gamma} - \xi^2\left(1 - \frac{U^2}{c_4^2}\right)\right]\tilde{\phi}_2 + \frac{Kj}{\gamma}\left(\frac{d^2}{dz^2} - \xi^2\right)\tilde{\psi} = 0, \tag{18}$$
$$\left[\frac{d^2}{dz^2} - \xi^2\left(1 - \frac{U^2}{c_5^2}\right)\right]\tilde{\phi}_f = 0, \tag{19}$$

where

$$c_1^2 = \frac{\lambda + 2\mu + K}{\rho}, \quad c_3^2 = \frac{\mu + K}{\rho}, \quad c_4^2 = \frac{\gamma}{\rho j} \quad c_5^2 = \frac{\lambda_f}{\rho_f}. \tag{20}$$

Eliminating $\tilde{\phi}_2$ from (17) and (18) we obtain

$$\left[\frac{d^4}{dz^4} + A^*\frac{d^2}{dz^2} + B^*\right]\tilde{\psi} = 0, \tag{21}$$

where

$$A^* = -\frac{2K}{\gamma} - \xi^2\left(2 - \frac{U^2}{c_3^2} + \frac{U^2}{c_4^2}\right) + \frac{K^2h^2}{\gamma(\mu + K)},$$
$$B^* = \frac{2K\xi^2}{\gamma}\left(1 - \frac{U^2}{c_3^2}\right) + \xi^4\left(1 - \frac{U^2}{c_3^2}\right)\left(1 - \frac{U^2}{c_4^2}\right) - -\xi^2\frac{K^2h^2}{\gamma(\mu + K)}. \tag{22}$$

Introducing mach numbers $M_n (n = 1, 3, 4, 5)$ and the parameters α_n and α_n' as

$$M_n = \frac{U}{c_n}, \;\; n = 1, 3, 4, 5$$

$$\alpha_n^2 = 1 - \frac{U^2}{c_n^2} = 1 - M_n^2, \;\; if \;\; M_n < 1$$

$$\alpha_n'^2 = \frac{U^2}{c_n^2} - 1 = M_n^2 - 1, \;\; if \;\; M_n > 1. \tag{23}$$

Boundary conditions

For a concentrated point force, we take $P(x + Ut) = F\delta(x^*)$, where $\delta(x^*)$ is Dirac-delta function and F is the magnitude of force applied, therefore in moving coordinates the boundary conditions at the interface $z = 0$ are ,

(i) $\;t_{33} = -p - F\delta(x^*),$
(ii) $\;m_{32} = 0,$
(iii) $\;t_{31} = 0,$
(iv) $\;Normal\ component\ of\ velocity\ of solid = Normal\ velocity\ of\ fluid,$

$$i.e \quad \frac{\partial^2 \phi_f}{\partial z \partial t} = \frac{\partial u_3}{\partial t}. \tag{24}$$

Case (i):*Subsonic.* $M_i < 1 (i = 1, 3, 4, 5)$.
In this caseA^* and B^* in equation (22) take the form

$$A^* = -\frac{2K}{\gamma} - \xi^2(a_3^2 + a_4^2) + \frac{K^2 h^2}{\gamma(\mu + K)},$$

$$B^* = \frac{2K\xi^2}{\gamma}\alpha_3^2 + \xi^4 \alpha_3^2 \alpha_4^2 - \xi^2 \frac{K^2 h^2}{\gamma(\mu + K)}. \tag{25}$$

The solutions of equations (16) and (21) with A^* and B^* defined by (25), satisfying the radiation conditions that $\tilde{q}, \tilde{\phi}_2, \tilde{\psi} \rightarrow 0$ as $z \rightarrow \infty$ and the solution of equation (19) satisfying the conditions that $\tilde{\phi}_f \rightarrow 0$ as $z \rightarrow -\infty$ are,

$$\tilde{q} = A_1 \exp(-\xi_1 z), \tag{26}$$

$$\tilde{\psi} = A_3 \exp(-\xi_3 z) + A_4 \exp(-\xi_4 z), \tag{27}$$

$$\tilde{\phi}_2 = a_3 A_3 \exp(-\xi_3 z) + a_4 A_4 \exp(-\xi_4 z), \tag{28}$$

$$\tilde{\phi}_f = A_5 \exp(\xi_5 z), \tag{29}$$

where $\xi_{3,4}^2$ the roots of the equation (21) given by

$$\xi_{3,4}^2 = \frac{[-A^* \pm \sqrt{A^{*2} - 4B}^*]}{2}, \;\; \xi_{1,5} = \xi\alpha_{1,5}, \;\; \text{and} \;\; a_{3,4} = \frac{j(\mu + K)}{Kh^2}(\xi^2\alpha_3^2 - \xi_{3,4}^2). \tag{30}$$

Using equations (3), (4), (6)-(7) and (13)-(14) in the boundary conditions (24) (after suppressing the primes), applying the transform defined by (15) and using (26)-(29) in the resulting expressions, we obtain the transformed expressions for normal displacement, normal force stress, tangential couple stress and fluid pressure at fluid/ micropolar elastic solid interface as,

$$\tilde{u}_3 = \frac{F}{\Delta}|\xi_1\Delta_1' e^{-\xi_1 z} + i\xi\Delta_2' e^{-\xi_3 z} - i\xi\Delta_3' e^{-\xi_4 z}|, \tag{31}$$

$$\tilde{t}_{33} = -\frac{F}{\Delta}|f_1\Delta_1' e^{-\xi_1 z} - f_2\Delta_2' e^{-\xi_3 z} + f_3\Delta_3' e^{-\xi_4 z}|, \tag{32}$$

$$\tilde{m}_{32} = -\frac{F\gamma}{j\lambda\Delta}|a_3\xi_3\Delta_2' e^{-\xi_3 z} - a_4\xi_4\Delta_3' e^{-\xi_4 z}|, \tag{33}$$

$$\tilde{p} = -\frac{F}{\Delta}E\xi^2\Delta_4' e^{\xi_5 z} \tag{34}$$

where

$$\Delta = \frac{\Delta_1'}{\xi_5}(f_1\xi_5 - E\xi^2\xi_1) - \frac{\Delta_2'}{a_4\xi_4}(f_2 a_4\xi_4 - f_3 a_3\xi_3) - \frac{iE\xi^3\Delta_3'}{a_3\xi_3\xi_5}(a_4\xi_4 - a_3\xi_3),$$

$$\Delta_1' = \xi_5(a_4\xi_4 r_2 - a_3\xi_3 r_3), \quad \Delta_2' = \xi_5 r_1 a_4\xi_4, \quad \Delta_3' = \xi_5 r_1 a_3\xi_3,$$

$$\Delta_4' = i\xi r_1(a_4\xi_4 - a_3\xi_3) + \xi_1(r_2 a_4\xi_4 - r_3 a_3\xi_3), \quad r_1 = (2\mu + K)i\xi\xi_1,$$

$$r_{2,3} = \mu\xi^2 + (\mu + K)\xi_{3,4}^2 - \frac{Kh^2}{j}a_{3,4}, \quad f_1 = \left(\frac{\lambda + 2\mu + K}{\lambda}\right)\xi_1^2 - \xi^2,$$

$$f_{2,3} = -i\xi\xi_{3,4}\left(\frac{2\mu + K}{\lambda}\right), \quad E = \frac{\rho_f c_5^2}{\lambda}M_5^2. \tag{35}$$

Particular case. Neglecting micropolarity effect i.e ($\alpha = \beta = \gamma = K = j = 0$) in equations (31)-(34), the expressions for normal displacement, normal force stress and fluid pressure at fluid/elastic solid interface are given by,

$$\tilde{u}_3 = \frac{F}{\Delta_0}|\xi_1\Delta_{10}' e^{-\xi_1 z} - i\xi\Delta_{20}' e^{-\xi_3' z}|, \tag{36}$$

$$\tilde{t}_{33} = -\frac{F}{\Delta_0}|f_1'\Delta_{10}' e^{-\xi_1 z} - f_2'\Delta_{20}' e^{-\xi_3' z}|, \tag{37}$$

$$\tilde{p} = -\frac{F}{\Delta}E\xi^2\Delta_{30}' e^{\xi_5 z}, \tag{38}$$

where

$$\Delta_0 = \xi_5(f_1' r_2' - f_2' r_1') - E\xi^2(i\xi r_1' + \xi_1 r_2'), \quad \Delta_{10}' = r_2'\xi_5, \quad \Delta_{20}' = r_1'\xi_5,$$

$$\Delta_{30}' = -(i\xi r_1' + \xi_1 r_2'), \quad r_1' = 2\mu i\xi\xi_1, \quad r_2' = \mu(\xi^2 + \xi_3'^2),$$

$$f_1' = \left(\frac{\lambda + 2\mu}{\lambda}\right)\xi_1^2 - \xi^2, \quad f_2' = -i\xi\xi_1\frac{2\mu}{\lambda}, \quad \xi_3'^2 = \alpha_3^{0^2}\xi^2, \quad \alpha_3^{0^2} = 1 - M_3^{0^2},$$

and $\alpha_{1,3}$ in the expressions of A^*, and B^* takes the form

$$\alpha_{1,3}^0 = \sqrt{1 - M_{1,3}^{0^2}}, \quad M_{1,3}{}^0 = \frac{U}{c_{1,3}^0}, \quad c_1^{0^2} = \frac{\lambda + 2\mu}{\rho}, \quad c_3^{0^2} = \frac{\mu}{\rho}. \tag{39}$$

Case (ii): *Supersonic.* $M_i > 1$ $(i = 1, 3, 4, 5)$.

In this case, the solutions of equations (16), (19) and (21) satisfying the regularity conditions are given by

$$\tilde{q} = A_1 \exp(-i\xi_1 z), \tag{40}$$

$$\tilde{\psi} = A_3 \exp(-i\xi_3 z) + A_4 \exp(-i\xi_4 z), \tag{41}$$

$$\tilde{\phi}_2 = a_3 A_3 \exp(-i\xi_3 z) + a_4 A_4 \exp(-i\xi_4 z), \tag{42}$$

$$\tilde{\phi}_f = A_5 \exp(i\xi_5 z), \tag{43}$$

With the help of (40)-(43) we obtain the corresponding expressions as given by (31)-(34) with A^*, B^* and $a_{3,4}$ taking the form,

$$A^* = -\frac{2K}{\gamma} + \xi^2(\alpha_4'^2 + \alpha_3'^2) + \frac{K^2 h^2}{\gamma(\mu + K)},$$

$$B^* = -\frac{2K\xi^2}{\gamma}\alpha_3^2 + \xi^4 \alpha_3'^2 \alpha_4'^2 - \xi^2 \frac{K^2 h^2}{\gamma(\mu + K)},$$

$$a_{3,4} = -\frac{j(\mu + K)}{Kh^2}(\xi^2 \alpha_3'^2 + \xi_{3,4}'^2) \text{ and } \xi_{1,5}' = \xi \alpha_{1,5}' \tag{44}$$

Particular case. If we neglect micropolarity effect, then the expressions (36)-(38) are obtained in case of fluid/elastic solid interface with A^*, B^* and $a_{3,4}$ defined by equation (44), with $a_1^{0^2}$ and $a_3^{0^2}$ replaced by $a_1^{*^2}$ and $a_3^{*^2}$respectively, where

$$\alpha_1^* = \sqrt{M_1^{0^2} - 1}, \quad \alpha_3^* = \sqrt{M_3^{0^2} - 1}. \tag{45}$$

Case (iii): *Transonic.* $M_{1,3} < 1,\ M_{4,5} > 1$.

For transonic load velocity the solutions of equations (16), (21) and (19) satisfying the radiation conditions are given by (26), (43) and

$$\tilde{\psi} = A_3 \exp(-\xi_3 z) + A_4 \exp(-i\xi_4 z), \tag{46}$$

$$\tilde{\phi}_2 = a_3 A_3 \exp(-\xi_3 z) + a_4 A_4 \exp(-i\xi_4 z), \tag{47}$$

respectively

The expressions for normal displacement, normal force stress and tangential couple stress are given by (31)-(34) with the following changed values of A^*, B^* and $a_{3,4}$

$$A^* = -\frac{2K}{\gamma} - \xi^2(\alpha_3^2 - \alpha_4'^2) + \frac{K^2 h^2}{\gamma(\mu + K)},$$

$$B^* = \frac{2K\xi^2}{\gamma}\alpha_3^2 - \xi^4 \alpha_3^2 \alpha_4'^2 - \xi^2 \frac{k^2 h^2}{\gamma(\mu + K)},$$

$$a_3 = \frac{j(\mu + K)}{Kh^2}(\xi^2 \alpha_3^2 - \xi_{3,4}'^2), \quad a_4 = -\frac{j(\mu + K)}{Kh^2}(\xi^2 \alpha_3'^2 + \xi_4'^2). \tag{48}$$

where ξ_1 and ξ_5' are defined by equations (30) and (44) respectively.

Particular case. Neglecting micropolarity effect, the transformed expressions for normal displacement and normal force stress are again given by equations (36)-(38) with α_1^2 and α_3^2 replaced by $\alpha_1^{0^2}$ and $\alpha_3^{0^2}$ defined by (39).

Inversion of the transform

To obtain the solution of the problem in the physical domain, we must invert the transform in (31)-(34) and (36)-(38). These expressions are functions of z and the parameter of Fourier transform ξ, hence are of the form $\tilde{f}(\xi, z)$. To get the function $f(x, z)$ in the physical domain we invert the Fourier transform using,

$$\begin{aligned} f(x,z) &= \frac{1}{2\pi}\int_{-\infty}^{\infty} \tilde{f}(\xi,z)\, e^{-i\xi x} d\xi \\ &= \frac{1}{2\pi}\int_{-\infty}^{\infty} [\mathrm{Cos}(\xi x) f_e - i\mathrm{Sin}(\xi x) f_0] d\xi. \end{aligned} \tag{49}$$

where f_e and f_0 are respectively even and odd parts of the function $\tilde{f}(\xi, z)$. The method for evaluating this integral is described by Press et al.(1986) which involves the use of Rhomberg's integration with adaptive step size. This also uses the results from successive refinements of the extended trapezoidal rule followed by extrapolation of the results to the limit when the step size tends to zero.

Numerical results and disscussion

For micropolar elastic solid (Medium I) we take the values of parameters for magnesium crystal like material given by Eringen (1984) as,

$\lambda = 9.4 \times 10^{11}\ \ dyne/cm^2,\ \ \mu = 4.0 \times 10^{11}\ \ dyne/cm^2,\ \ K = 1.0 \times 10^{1}\ \ dyne/cm^2,$
$\gamma = 0.779 \times 10^{-4}\ \ dyne,\ \ j = 0.2 \times 10^{-15}\ \ cm^2,\ \ \rho = 1.74\ g/cm^3,$

For medium II we water as non-viscous fluid, for which the values of density and Lames constant are given by Ewing et al.(1957),

$$\rho_f = 1.0\ g/cm^3,\ \ \lambda_f = 0.214 \times 10^{11}\ dyne/cm^2.$$

The variations of normal displacement, normal force stress, tangential couple stress and fluid pressure with distance x at the plane $z = 1.0$ and $h^2 = 1.0 \times 10^{-15} cm^2$, for
(i) Micropolar elastic solid (MES) are shown by
(a) solid line(——) for subsonic load velocity.
(b) solid line with centered symbols (x—x—x) for supersonic load velocity.
(c) solid line with centered symbols (o—o—o) for transonic load velocity.
(ii) Elastic solid (ES) are shown by
(a) dashed line(——) for subsonic load velocity.
(b) dashed line with centered symbols (x—x—x) for supersonic load velocity.

(c) dashed line with centered symbols (o—o—o) for transonic load velocity. These variations are shown in Fig (2)-(5).

Discussions for various cases

The values of normal displacement for ES lie in a short range as compared to the values for MES. If we compare the variations among various load velocities, then the variation of normal displacement is least oscillatory for subsonic load velocity and most oscillatory for transonic load velocity for MES. In case of ES, the variations are of comparable magnitude for different load velocities. Very close to the point of application of source, the values of normal displacement for both ES and MES are quite close to each other irrespective of the magnitude of moving load velocity. These variations of normal displacement are shown in Figure 2.

The variations of normal force stress are similar to the variations of normal displacement with difference in magnitude. The discussions for the variations of normal force stress and different load velocities are similar in nature to the discussions given in case of normal displacement. The only point of concern being that the difference in values of normal force stress for subsonic and transonic load velocities (for ES) is very less whereas this difference is quite significant in case of normal displacement. The variations of normal force stress for different load velocities and both ES and MES are shown in Figure 3.

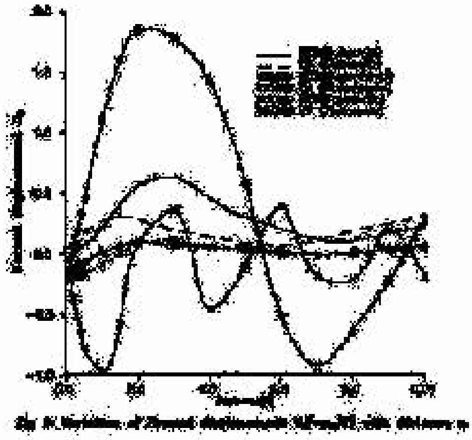
It is observed from Figure 4 that the values of tangential couple stress for subsonic load velocity lie in a very short range. However, near the point of application of source,

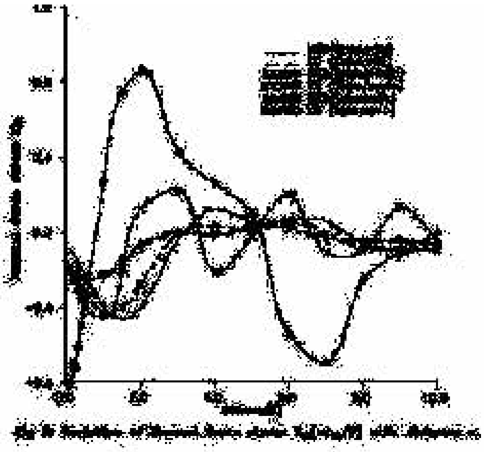
the value of tangential couple stress is maximum for supersonic load velocity and minimum for transonic load velocity. Initially, the values of tangential couple stress for supersonic and transonic load decreases with increase in horizontal distance x. However, this decrease is sharper for supersonic load velocity.

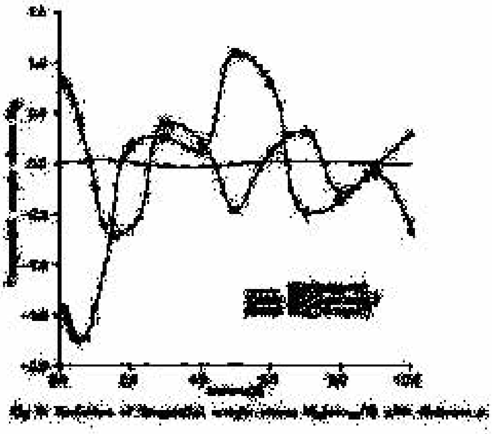
The variation of fluid pressure for different load velocities is similar in nature for both ES and MES with difference in magnitude. It is however observed from Figure 5 that this difference in magnitude is least for supersonic load velocity but the difference is quite significant in nature for both subsonic and transonic load velocities. Also for a particular load velocity, the value of fluid pressure for ES is less in comparison to the value for MES. The value of fluid pressure for ES and in case of transonic load velocity has been magnified by 10.

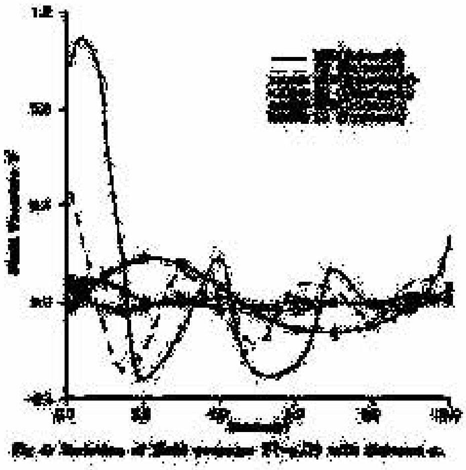
Conclusion

The variations of all the quantities are quite significant for different load velocities. Also due to the presence of micropolarity effect the variations of all the quantities are more for MES in comparison to the variations for ES. The variations of normal displacement, normal force stress and tangential couple stress are more oscillatory for transonic load velocity as compared to the variations for subsonic and supersonic load velocities. Also it is observed that these variations are least oscillatory for subsonic load velocity. The values of normal displacement, normal force stress and fluid pressure for ES are less in comparison to the values for MES. In case of fluid pressure, the variation is more oscillatory for subsonic load velocity.









R E F E R E N C E S

1. Eason,G., 1965. The stresses produced in a semi-infinite solid by moving surface force. Int. J. Engg. Sci. 2, 581-609.

2. Eringen, A.C., 1966a. Linear theory of Micropolar Elasticity. J. Math. Mech. 15, 909-923.

3. Eringen, A.C., 1966b. Theory of Micropolar fluids. J. Math. Mech. 16, 1-18.

4. Eringen, A.C., 1984. Plane waves in non-local micropolar elasticity. Int. J. Engg. Sci. 22, 1113-1121.

5. Ewing,W.M., Jardetzky and Press, F., Elastic waves in layered media, Mcgraw Hill, 1957.

6. Fung, Y.C., 1968. Foundations of solid mechanics. Prentice Hall, New Delhi.

7. Gakenheimer, D.C and Miklowitz, J., 1969. Transient Excitation of elastic half space by a point load traveling on the surface. J. Appl. Mech.36, No 3, Trans ASME , Vol. 91, Series E, 505-515.

8. Halpern, M.R and Christiano, P., 1986. Steady state harmonic response of a rigid plate bearing on a liquid saturated poroelastic half-space. Earthquake. Engg. and Structural Dynamics, Vol 14,

439-454.

9. Katz, R., 2001. The dynamic response of a rotating shaft subject to an axially moving and rotating load. J. of Sound and Vibration. 246(5), 757-775.

10. Kennedy, T.C and Hermann, G., 1973. Moving loads on a fluid-solid interface. J. Appl. Mech. 137-142.

11. Kumar, R and Ailawalia, P., 2003. Moving load response at thermal conducting fluid and micropolar solid interface. Int. J. Appl. Mech. Engg. Vol.8, No.4, 621-636.

12. Kumar, R and Deswal, S., 2000. Steady state response of a micropolar generalized thermoelastic half-space to the moving mechanical/thermal loads. Proc. Indian. Acad. Sci.(Math.Sci.) 110, No.4, 449-465.

13. Kumar,R and Deswal, S., 2002. Steady State Response to moving loads in a micropolar generalized thermoelastic half-space without energy dissipation. Ganita, Vol 53, No 1, 23-42.

14. Kumar, R and Gogna, M.L., 1992. Steady state response to moving loads in micropolar elastic medium with stretch. Int.J. Engg. Sci. 30, 811-820.

15. Nath, S and Sengupta, P.R., 1999. Steady state response to moving loads in an elastic solid media. Indian . J. Pure. Appl. Math. 30, 317-327.

16. Payton, R.G., 1964. An application of the dynamic Betti-Rayleigh Reciprocal Theorem to moving point loads in Elastic media. Quarterly of Applied Mathematic, 21, 299-313.

17. Press, W.H, Teukolsky, S.A, Vellerling, W.T and Flannery, B.P., 1986. Numerical Recipes, (Cambridge: Cambridge University Press).

18. Verruijt, A and Cordova, C.C., 2001. Moving loads on an elastic half plane with hysteretic damping. J. Appl. Mechanics, Vol 68, 915-922. Steady State Response To Moving Load at Fluid .
Rajneesh Kumar and Praveen Ailawalia*