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Study of Axial Fluid Velocity and particle velocity in an Axially Symmetrical Jet Mixing of a compressible Fluid

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Abstract

The study of heat transfer of dusty fluid of an axially symmetrical jet mixing of a compressible fluid has been received considerable attention in the past due to its applications in the industries. The present study focused on the solution of an axially symmetrical jet mixing of a compressible dusty fluid . Assuming the velocity and temperature in the jet to differ slightly from that of the surrounding stream, a perturbation method has been employed to linearize the basic equations. The resulting equations are then solved by Hankel's and Laplace transformation technique. It has been observed that the axial fluid velocity is more than the axial particle velocity near the nozzle exit.

Keywords:

Particulate suspension;
Boundary layer characteristics;
volume fraction;
Compressible fluid.

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1. Introduction

There are number of areas in which a valid feasible model is of great importance. In the long term planning for a growing community it is desirable to earmark some areas suitable for industrial activity and some others for residential use with a view to minimize the pollution load in the residential complex. But many of the physical phenomena in nature with special reference to boundary layer flows associated with suspended particulate matter.

Compressible jet mixing of a dusty fluid originating from a circular jet has been studied by Dutta and Das [1991].in case of negligible volume fraction of SPM. But this assumption leads to an error which ranges from insignificant to very large. Also this type of assumption is not justified when the fluid density is high or particle mass fraction is large. In the present paper the effect of finite volume fraction in an axially symmetrical jet mixing of a compressible fluid with SPM has been studied. Assuming the velocity and temperature in the jet to differ only slightly from that of the surrounding stream, a perturbation method has been employed to linearize the governing differential equations. The resulting equations are then

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solved by Hankel's and Laplace transformation technique. Attention has been given to get the solution of the longitudinal perturbated fluid velocity and particle velocity.

2. Analysis of the Problem

The equation governing the study of compressible two-phase boundary layer flow in axisymmetric case can be written as

$$u\frac{\partial \rho}{\partial z} + v\frac{\partial \rho}{\partial r} + \rho\left(\frac{1}{r}\frac{\partial}{\partial r}(rv) + \frac{\partial u}{\partial z}\right) = 0 \qquad (1.2.1)$$

$$(1-\phi)\rho\left(u\frac{\partial u}{\partial z}+v\frac{\partial u}{\partial r}\right) = \frac{1}{r}\frac{\partial}{\partial r}\left(\mu r\frac{\partial u}{\partial r}\right) + \frac{\rho_p}{\tau_m}(u_p-u) \qquad (1.2.2)$$

$$(1-\phi)\rho C_p\left(u\frac{\partial T}{\partial z}+v\frac{\partial T}{\partial r}\right) = K\left(\frac{\partial^2 T}{\partial r^2}+\frac{1}{r}\frac{\partial T}{\partial r}\right) + \rho_p C_s\frac{(T_p-T)}{\tau_t} \qquad (1.2.3)$$

$$u_p\frac{\partial \rho_p}{\partial z} + v_p\frac{\partial \rho_p}{\partial r} + \rho_p\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_p) + \frac{\partial u_p}{\partial z}\right) = 0 \qquad (1.2.4)$$

$$\rho_p\left(u_p\frac{\partial u_p}{\partial z}+v_p\frac{\partial u_p}{\partial r}\right) = -\rho_p\left(\frac{u_p-u}{\tau_m}\right) \qquad (1.2.5)$$

$$\rho_p\left(u_p\frac{\partial v_p}{\partial z}+v_p\frac{\partial v_p}{\partial r}\right) = -\rho_p\left(\frac{v_p-v}{\tau_m}\right) \qquad (1.2.6)$$

$$\rho_p C_p\left(u_p\frac{\partial T_p}{\partial z}+v_p\frac{\partial T_p}{\partial r}\right) = -\rho_p C_s\frac{(T_p-T)}{\tau_T} \qquad (1.2.7)$$

and equation of state is $P = \rho RT$ (1.2.8)

Since the pressure is assumed to be constant and the carrier fluid is considered to be compressible so ρ, μ and k can not be regarded as constants but very with gas temperature T. Therefore we write

$$\rho = \frac{1}{T},\quad \mu = \sqrt{T},\quad \upsilon = \frac{\mu}{\rho} = (T)^{\frac{3}{2}} \ \text{ and } \ k = \frac{\mu C_p}{P_r} \qquad (1.2.9)$$

∴ Using (1.2.9) in equation (1.2.1) to (1.2.7) we can write as

$$u\frac{\partial T}{\partial z} + v\frac{\partial T}{\partial r} = T\left(\frac{\partial u}{\partial z} + \frac{\partial v}{\partial r}\right) + \frac{Tv}{r} \qquad (1.2.10)$$

$$(1-\phi)\left(u\frac{\partial u}{\partial z}+v\frac{\partial u}{\partial r}\right) = \frac{T}{r}\frac{\partial}{\partial r}\left(\sqrt{T}\, r\frac{\partial u}{\partial r}\right) + \frac{\rho_p T}{\tau_m}(u_p-u) \qquad (1.2.11)$$

$$(1-\phi)\left(u\frac{\partial T}{\partial z}+v\frac{\partial T}{\partial r}\right) = \frac{\upsilon}{P_r}\left(\frac{\partial^2 T}{\partial r^2}+\frac{1}{r}\frac{\partial T}{\partial r}\right) + \frac{\rho_p}{\rho}\frac{C_s}{C_p}\frac{(T_p-T)}{\tau_t} \qquad (1.2.12)$$

$$u_p\frac{\partial \rho_p}{\partial z} + v_p\frac{\partial \rho_p}{\partial r} + \frac{\rho_p}{r}\frac{\partial}{\partial r}(rv_p) + \rho_p\frac{\partial u_p}{\partial z} = 0 \qquad (1.2.13)$$

$$u_p\frac{\partial u_p}{\partial z}+v_p\frac{\partial u_p}{\partial r} = \frac{u-u_p}{\tau_m} \qquad (1.2.14)$$

$$u_p \frac{\partial v_p}{\partial z} + v_p \frac{\partial v_p}{\partial r} = \frac{v - v_p}{\tau_m} \qquad (1.2.15)$$

$$u_p \frac{\partial T_p}{\partial z} + v_p \frac{\partial T_p}{\partial r} = \frac{C_s}{C_p} \frac{(T - T_p)}{\tau_T} \qquad (1.2.16)$$

To study the boundary layer flow, we introduce the dimensionless variables are

$$z^* = \frac{z}{\lambda},\ r^* = \frac{r}{(\tau_m \upsilon_0)^{\frac{1}{2}}}, u^* = \frac{u}{U}, v^* = v\left(\frac{\tau_m}{\upsilon_0}\right)^{\frac{1}{2}},\ u_p^* = \frac{u_p}{U}, v_p^* = v_p\left(\frac{\tau_m}{\upsilon_0}\right)^{\frac{1}{2}}, \alpha = \frac{\rho_{p_0}}{\rho_0},\ \rho^* = \frac{\rho}{\rho_0}$$

$$\rho_p^* = \frac{\rho_p}{\rho_{p_0}},\ T^* = \frac{T}{T_0},\ T_p^* = \frac{T_p}{T_0},\ \lambda = \tau_m U,\ \tau_m = \frac{2}{3}\frac{C_p}{C_s}\frac{1}{p_r}\tau_T, p_r = \frac{\mu C_p}{K},\ \upsilon^* = \frac{\upsilon}{\upsilon_0}.$$

Assuming the flow from a circular, opening under full expansion i.e. no pressure variation occurs throughout the flow, and flow variables of the jet differ only slightly from that of the surrounding stream, it is possible to write the velocities, temperatures and particle density in the following form as $u = u_0 + u_1,\ v = v_1, u_p = u_{p_0} + u_{p_1},\ v_p = v_{p_1}, T = T_0 + T_1, T_p = T_{p_0} + T_{p_1},\ \rho_p = \rho_{p_0} + \rho_{p_1}$ where $u_1 \ll u_0, u_{p_1} \ll u_{p_0}, T_1 \ll T_0,\ T_{p_1} \ll T_{p_0},\ \rho_{p_1} \ll \rho_{p_0}$.

The quantities with suffix '0' are the values at the opening and those with suffix '1' are perturbed quantities. Again, the suffix p denotes those variables for the particle. Under the above assumption the governing equation (6.2.10) to (6.2.16) can be written after dropping the * and suffix one in the non-dimensional linearized form as follows

$$u_0 \frac{\partial T}{\partial z} = T_0\left(\frac{\partial u}{\partial z} + \frac{\partial v}{\partial r}\right) + \frac{T_0 v}{r} = 0 \qquad (1.2.17)$$

$$(1-\phi)u_0 \frac{\partial u}{\partial z} = \frac{(T_0)^{\frac{3}{2}}}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right) + \alpha\rho_{p_0} T_0 (u_p - u) \qquad (1.2.18)$$

$$(1-\phi)\ u_0 \frac{\partial T}{\partial z} = \frac{(T_0)^{\frac{3}{2}}}{p_r}\left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r}\right) + \frac{2\alpha\rho_{p_0} T_0}{3p_r}(T_p - T) \qquad (1.2.19)$$

$$\rho_{p_0}\frac{\partial u_p}{\partial z} + u_{p_0}\frac{\partial \rho_p}{\partial z} + \frac{\rho_{p_0}}{r}\frac{\partial}{\partial r}(r v_p) = 0 \qquad (1.2.20)$$

$$u_{p_0}\frac{\partial u_p}{\partial z} = (u - u_p) + (u_0 - u_{p_0}) \qquad (1.2.21)$$

$$u_{p_0}\frac{\partial v_p}{\partial z} = (v - v_p) \qquad (1.2.22)$$

$$u_{p_0}\frac{\partial T_p}{\partial z} = \frac{2}{3p_r}\left[(T - T_p) + (T_0 - T_{p_0})\right] \qquad (1.2.23)$$

The boundary conditions for u, v, u_p and v_p are

$$u(0,r)=u_{1_0}\,,\ u_p(0,r)=u_{p_{10}}\,,\ T\ (0,r)=T_{10}\,,\ T_p(0,r)=T_{p_{10}}\,,\ \rho_p(0,r)=\rho_{p_{10}}$$

for $r \le 1$

$$u(0,r)=u_p(0,r)=\ T\ (0,r)=\ T_p(0,r)=\rho_p(0,r)=0 \text{ for } r>1$$

and $v(0,r)=v_p(0,r)=\dfrac{\partial u}{\partial r}\ (z,0)=\dfrac{\partial T}{\partial r}(z,0)=0$

$$u\ (z,\infty)=u_p\ (z,\infty)=T\ (z,\infty)=T_p\ (z,\infty)=\rho_p\ (z,\infty)=0 \qquad (1.2.24)$$

3. Solution of the Problem

Taking Hankel and Laplace transforms respectively of both sides of the equation (1.2.18) and (1.2.21) and using the conditions (1.2.24) we obtain.

$$\bar{u}^* = \frac{J_1(p)\left[B u_{p_{10}} + (C+S)u_{10}\right]}{P F(S)} \qquad (1.3.1)$$

$$\bar{u}_p^* = \frac{J_1(p)\left[C u_{10} + (A+S)u_{p_{10}}\right]}{P F(S)} \qquad (1.3.2)$$

Where

Hankel transform with respect to the variable r is denoted by * and Laplace transform with respect to the variable z is denoted by –

$$H[u]=u^* = \int_0^\infty r\,u\,J_0(pr)\,dr \qquad H[u_p]=u_p{}^* = \int_0^\infty r\,u_p\,J_0(pr)\,dr \quad (1.3.3)$$

$$L[u^*]=\bar{u}^* = \int_0^\infty u^*\,e^{-sz}\,dz \qquad L[u_p{}^*]=\bar{u}_p{}^* = \int_0^\infty u_p{}^*\,e^{-sz}\,dz \quad (1.3.4)$$

$$F(S)=S^2+S(A+C)+C(A-B)$$

$$A=\frac{P^2\,T_0^{\frac{3}{2}}+\alpha\,\rho_{p_0}T_0}{(1-\phi)u_0},\ B=\frac{\alpha\,\rho_{p_0}T_0}{(1-\phi)u_0},\ C=\frac{1}{u_{p_0}} \qquad (1.3.5)$$

The inversion of (1.3.1) and (1.3.2) gives

$$u=\int_0^\infty \left[u_{10}\cosh QZ+\frac{1}{Q}\left\{\frac{(C-A)}{2}u_{10}+B\,u_{p_{10}}\right\}\sinh QZ\right] e^{-\frac{(A+C)Z}{2}}\,J_0(pr)J_1(p)dp \quad (1.3.6)$$

$$u_p=\int_0^\infty \left[u_{p_{10}}\cosh QZ+\frac{1}{Q}\left\{C u_{10}+\frac{(A-C)}{2}u_{p_{10}}\right\}\sinh QZ\right] e^{-\frac{(A+C)Z}{2}}\,J_0(pr)J_1(p)dp \quad (1.3.7)$$

where $Q=\sqrt{BC+\left(\dfrac{A-C}{2}\right)^2}$

Taking Hankel and Laplace transforms respectively of both sides of the equation (1.2.17) and using (1.3.1), (1.3.7) and boundary conditions we get

$$\bar{v}^* = \frac{J_1(p)}{P}\left[T_{10}\left(\frac{S(S+D)u_0 r}{F_1(S)(ST_0 r+T_0)} - \frac{u_0 r}{(ST_0 r+T_0)}\right) - u_{10}\left(\frac{u_0 r T_0}{(ST_0 r+T_0)} + \frac{S(C+S)T_0 r}{F(S)(ST_0 r+T_0)}\right)\right.$$

$$\left. - \frac{v_{10}\, u_0 r T_0}{(ST_0 r+T_0)} - \frac{Bu_{p_{10}} S T_0 r}{(ST_0 r+T_0)F(S)} + \frac{SE\, T_{p_{10}}\, u_0 r}{(ST_0 r+T_0)F_1(S)}\right] \quad (1.3.13)$$

The inversion of (1.3.13) gives

$$v = \int_0^\infty \left[e^{MZ}\left(\frac{E\,T_{p_{10}} u_0}{T_0} - Bu_{p_{10}} - v_{10}u_0 - u_{10} - u_{10}u_0\right) + e^{KZ}\left(\frac{T_{10}u_0}{T_0} + \frac{E\,T_{p_{10}} u_0}{T_0}\right)\right.$$

$$\left. e^{LZ}\left(\frac{T_{10}u_0}{T_0} + \frac{E\,T_{p_{10}} u_0}{T_0}\right) + e^{K_1 Z}\left(-u_{10} - Bu_{p_{10}}\right) + e^{L_1 Z}\left(-u_{10} - Bu_{p_{10}}\right)\right]$$

$$J_0(pr)\, J_1(p) dp \quad (1.3.14)$$

where

$$M = -\frac{1}{r},\ k = \frac{M_1 - N_1}{2},\ M_1 = -(F+D),\ N_1 = \sqrt{(F+D)^2 - 4(FD-DE)},\ L_1 = \frac{M_2 + N_2}{2}$$

$$L = \frac{M_1 + N_1}{2},\ K_1 = \frac{M_2 - N_2}{2},\ M_2 = -(C+A),\ N_2 = \sqrt{(C+A)^2 - 4(CA-BC)}$$

Taking Hankel and Laplace transforms respectively of both sides of the equation (1.2.22) and using (1.3.13) and boundary conditions we get

$$\bar{v}_p^* = \frac{J_1(p)}{P}\left[T_{10}\left(\frac{S(S+D)u_0 rC}{F_1(S)(ST_0 r+T_0)(S+C)} - \frac{u_0 rC}{(ST_0 r+T_0)(S+C)}\right)\right.$$

$$- u_{10}\left(\frac{u_0 r T_0 C}{(ST_0 r+T_0)(S+C)} + \frac{S(C+S)T_0 rC}{F(S)(ST_0 r+T_0)(S+C)}\right) - \frac{v_{10}\, u_0 r T_0 C}{(ST_0 r+T_0)(S+C)}$$

$$\left. - \frac{Bu_{p_{10}} S T_0 rC}{(ST_0 r+T_0)F(S)(S+C)} + \frac{SE\,T_{p_{10}}\, u_0 rC}{(ST_0 r+T_0)F_1(S)(S+C)} + \frac{v_{p_{10}}}{S+C}\right] \quad (1.3.15)$$

The inversion of (1.3.15) gives

$$v_p = \int_0^\infty \left[e^{X_1 Z} + e^{X_2 Z}\left(\frac{T_{10}u_0 C}{r} + \frac{E\,T_{p_{10}} u_0 C}{T_0}\right) + e^{X_3 Z}\left(\frac{T_{10}u_0 C}{r} - u_{10} - Bu_{p_{10}} C + \frac{E\,T_{p_{10}} u_0 C}{T_0}\right)\right.$$

$$\left. + e^{X_4 Z}\left(\frac{T_{10}u_0 C}{r} - u_{10} - Bu_{p_{10}} C + \frac{E\,T_{p_{10}} u_0 C}{T_0} + v_{p_{10}}\right) + \left(e^{X_{11} Z} + e^{X_{12} Z}\right)\left(-u_{10} - Bu_{p_{10}} C\right)\right]$$

$$J_0(pr)\, J_1(p) dp \quad (1.3.16)$$

where

$$X_3 = -\frac{1}{r},\ X_1 = \frac{Y_1 + Y_2}{2},\ Y_1 = -(F+D),\ Y_2 = \sqrt{(F+D)^2 - 4(FD-DE)},\ X_{12} = \frac{Y_{11} - Y_{12}}{2}$$

$$X_2 = \frac{Y_1 - Y_2}{2},\ X_{11} = \frac{Y_{11} + Y_{12}}{2},\ Y_{11} = -(C+A),\ Y_{12} = \sqrt{(C+A)^2 - 4(CA - BC)},\ X_4 = -C$$

Taking Hankel and Laplace transforms respectively of both sides of the equation (1.2.20) and using (1.3.7), (1.3.16) and (1.2.24) we get

$$\bar{\rho}_p^* = \frac{J_1(p)}{P}\Bigg[\frac{\rho_{p_{10}}}{S} + \frac{\rho_{p_0} u_{p_{10}}}{S\,u_{p_0}} - \frac{\rho_{p_0}}{u_{p_0}}\left(\frac{C u_{10} + (A+S)u_{p_{10}}}{F(S)}\right) - \frac{p\rho_{p_0}}{S}\Bigg[T_{10}\left(\frac{S(S+D)u_0 rC}{F_1(S)(ST_0 r + T_0)(S+C)} - \frac{u_0 rC}{(ST_0 r + T_0)(S+C)}\right)$$

$$- u_{10}\left(\frac{u_0 r T_0 C}{(ST_0 r + T_0)(S+C)} + \frac{S(C+S)T_0 rC}{F(S)(ST_0 r + T_0)(S+C)}\right) - \frac{v_{10}\, u_0 r T_0 C}{(ST_0 r + T_0)(S+C)}$$

$$- \frac{Bu_{p_{10}} S T_0 rC}{(ST_0 r + T_0)F(S)(S+C)} + \frac{SE\,T_{p_{10}}\, u_0 rC}{(ST_0 r + T_0)F_1(S)(S+C)} + \frac{v_{p_{10}}}{S+C}\Bigg]\Bigg] \tag{1.3.17}$$

The inversion of (1.3.17) gives

$$\rho_p = \int_0^\infty \Bigg\{\rho_{p_{10}} + \frac{\rho_{p_0} u_{p_{10}}}{u_{p_0}} - \left[u_{p_{10}} \cosh QZ + \frac{1}{Q}\left\{C u_{10} + \frac{(A-C)}{2} u_{p_{10}}\right\}\sinh QZ\right] e^{-\frac{(A+C)Z}{2}}$$

$$- \frac{\rho_{p_0}}{u_{p_0}} e^{-(F+D)Z}\left(\frac{T_{10} u_0 C}{r} + \frac{E T_{p_{10}} u_0 C}{T_0}\right) - \frac{\rho_{p_0}}{u_{p_0}} e^{-z/r}\left(\frac{T_{10} u_0 C}{r} - u_{10} - Bu_{p_{10}} C + \frac{E T_{p_{10}} u_0 C}{T_0}\right)$$

$$- \frac{\rho_{p_0}}{u_{p_0}} e^{-CZ}\left(\frac{T_{10} u_0 C}{r} - u_{10} - Bu_{p_{10}} C + \frac{E T_{p_{10}} u_0 C}{T_0} + v_{p_{10}}\right) - \frac{\rho_{p_0}}{u_{p_0}} e^{-(C+A)Z}\left(-u_{10} - Bu_{p_{10}} C\right)\Bigg\}$$

$$J_0(pr)\, J_1(p)\, dp \tag{1.3.18}$$

4. Discussion of Result and Conclusion

The numerical computation have been made by taking $P_r = 0.72$, $u_{10} = up_{10} = T_{10} = Tp_{10} = \rho_{p10} = 0.1$, $\varphi = 0.01$. The velocity and temperature at the exit are taken nearly equal to unity.

Table 1: Values of longitudinal perturbation fluid velocity u1

ALPHA=0.1			ALPHA=0.2			ALPHA=0.3		
Z=0.25	Z=0.50	Z=1.0	Z=0.25	Z=0.50	Z=1.0	Z=0.25	Z=0.50	Z=1.0
1.00E-01	1.02E-01	1.06E-01	1.00E-01	1.02E-01	1.07E-01	1.00E-01	1.02E-01	1.07E-01
1.01E-01	1.02E-01	1.06E-01	1.01E-01	1.02E-01	1.06E-01	1.01E-01	1.02E-01	1.07E-01
1.01E-01	1.01E-01	1.02E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.00E-01
9.72E-02	9.09E-02	8.40E-02	9.63E-02	8.95E-02	8.27E-02	9.51E-02	8.78E-02	8.12E-02
4.75E-02	4.71E-02	4.74E-02	4.74E-02	4.70E-02	4.74E-02	4.72E-02	4.68E-02	4.75E-02
2.28E-03	7.64E-03	1.47E-02	3.00E-03	8.76E-03	1.59E-02	3.93E-03	1.01E-02	1.72E-02
-3.03E-04	5.29E-05	2.10E-03	-2.72E-04	2.24E-04	2.73E-03	-2.35E-04	4.93E-04	3.56E-03
-2.31E-04	-2.25E-04	-5.47E-05	-2.28E-04	-2.21E-04	5.53E-05	-2.27E-04	-2.10E-04	2.37E-04
-1.60E-04	-1.84E-04	-1.80E-04	-1.69E-04	-1.84E-04	-1.73E-04	-1.76E-04	-1.84E-04	-1.56E-04
-1.73E-04	-1.85E-04	-1.89E-04	-1.78E-04	-1.85E-04	-1.89E-04	-1.81E-04	-1.85E-04	-1.88E-04

Table 2: Values of longitudinal perturbation particle velocity UP1

ALPHA=0.1			ALPHA=0.2			ALPHA=0.3		
Z=0.25	Z=0.50	Z=1.0	Z=0.25	Z=0.50	Z=1.0	Z=0.25	Z=0.50	Z=1.0
6.62E-01	5.37E-01	3.66E-01	6.62E-01	5.37E-01	3.66E-01	6.62E-01	5.37E-01	3.67E-01
8.19E-01	6.59E-01	4.39E-01	8.19E-01	6.59E-01	4.40E-01	8.19E-01	6.59E-01	4.40E-01
8.32E-01	6.69E-01	4.45E-01	8.32E-01	6.69E-01	4.45E-01	8.32E-01	6.69E-01	4.45E-01
7.89E-01	6.34E-01	4.17E-01	7.89E-01	6.33E-01	4.17E-01	7.88E-01	6.33E-01	4.16E-01
3.84E-01	3.09E-01	2.05E-01	3.84E-01	3.09E-01	2.05E-01	3.84E-01	3.09E-01	2.05E-01
-2.41E-03	-7.20E-04	4.26E-03	-2.35E-03	-4.49E-04	4.90E-03	-2.25E-03	-1.15E-04	5.65E-03
-1.88E-02	-1.46E-02	-8.42E-03	-1.88E-02	-1.46E-02	-8.23E-03	-1.88E-02	-1.46E-02	-7.97E-03
-7.08E-03	-5.55E-03	-3.42E-03	-7.08E-03	-5.55E-03	-3.40E-03	-7.07E-03	-5.54E-03	-3.36E-03
3.49E-03	2.67E-03	1.54E-03	3.49E-03	2.67E-03	1.54E-03	3.49E-03	2.67E-03	1.54E-03
2.86E-03	2.18E-03	1.24E-03	2.85E-03	2.17E-03	1.24E-03	2.85E-03	2.17E-03	1.24E-03

Table 1 and table 2 shows the profiles of axial fluid perturbation velocity u and longitudinal perturbation particle velocity u_p for α =0.1, 0.2,0.3 and for different values of Z. It is observed that the axial fluid velocity u is greater than the axial particle velocity u_p near the nozzle exit

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