Analysis of motion of micro and nano-particle in non-isothermal flow using integral method

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Abstract: *In current work using integral conditions for non-isothermal turbulent jets is making comparison of the main parameters of distribution of nano- and microparticles. It was establish that at nanoparticles their velocity is become quite slowly, because of their small volume. Analogically is the influence of the velocity of gas phase.*

Key words: *micro particle, nanoparticle, numerical solution, integral method*

INTRODUCTION

Nanoparticles are particles between 1 and 100 nanometres in size. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Particles are further classified according to diameter. Ultrafine particles are the same as nanoparticles and between 1 and 100 nanometres in size, fine particles are sized between 100 and 2,500 nanometres, and coarse particles cover a range between 2,500 and 10,000 nanometres. Nanoparticle research is currently an area of intense scientific interest due to a wide variety of potential applications in biomedical, optical and electronic fields.

MATHEMATHICAL MODEL. METHOD OF SOLUTION

It is considering a two-phase vertical non-isothermal flow leakage in environment with different temperature. In the performance of mathematical model is applied following formulation: each one of the phases is consider as a separate fluid medium which motion is described by a separate system of partial differential equations in Reynolds type. It is assumed that the carrier medium (in this case the air) and the phase of impurities have their own, distinct from each another, velocity, density and temperature. The phase of impurities in the conditions of continuity has no internal stress tensor. In the model is ignoring collisions between particles.

The connections between the two systems of equations of motion are the phases of the interfacial interaction forces. In this case they are: drag force, lift force, body force, force of Saffman, force of thermophoresis.

For described above mathematical model of the flow is possible following methods of investigation:

- method of Lagrange for single particle
- numerical investigation using finite difference method
- integral method

Solution of the problem is realized through the integral method described in detail in our developments []. Conditions for conversation the amount of motion, the content of impurities and heat energy of flow; taking into account the turbulence is used. The solution is consisting of process of integral conditions, which are reduced to algebraic equation of the seventh degree on the dimensionless value of the velocity of the carrier phase:

$$\begin{aligned}
&\left(L_{17}\overline{\rho_{gm}}^3+L_{18}\overline{\rho_{gm}}^2\right)\overline{U_{gm}^*}^7+\\
&+\left(L_{19}\overline{\rho_{gm}}^3+L_{20}\overline{\rho_{gm}}^2\right)\overline{U_{gm}^*}^6+\\
&+\left(L_{23}\overline{\rho_{gm}}^3+L_{26}\overline{\rho_{gm}}^2+L_{27}\overline{\rho_{gm}}\right)\overline{U_{gm}^*}^5+\\
&+\left(L_{31}\overline{\rho_{gm}}^3+L_{36}\overline{\rho_{gm}}^2+L_{37}\overline{\rho_{gm}}\right)\overline{U_{gm}^*}^4+\\
&+\left(L_{41}\overline{\rho_{gm}}^3+L_{47}\overline{\rho_{gm}}^2+L_{51}\overline{\rho_{gm}}+L_{52}\right)\overline{U_{gm}^*}^3+\\
&+\left(L_{55}\overline{\rho_{gm}}^3+L_{61}\overline{\rho_{gm}}^2+L_{67}\overline{\rho_{gm}}+L_{68}\right)\overline{U_{gm}^*}^2\\
&+\left(L_{69}\overline{\rho_{gm}}^3+L_{73}\overline{\rho_{gm}}^2+L_{79}\overline{\rho_{gm}}+L_{83}\right)\overline{U_{gm}^*}+\\
&+\left(L_{84}\overline{\rho_{gm}}^3+L_{85}\overline{\rho_{gm}}^2+L_{88}\overline{\rho_{gm}}+L_{91}\right)=0
\end{aligned} \tag{1}$$

The equation is solved using method of Newton-Raphson, where consistently are define integral parameters of the flow.

RESULTS FORM NUMERICAL EXPERIMENT

The efficiency of program for calculating two-phase non-isothermal flow using integral method is developed by our team in the nineties and it has proven its accuracy in verification with experimental data of Grishovich and Abramovich []. The results of numerical experiments can be considered completely reliable and on this basis analyze of problems is done.

It is investigate two-phase non-isothermal flow at following condition:

- for micro particle with diameter $D_p = 100\mu m$

- for nanoparticle with diameter $D_p = 1.10^{-9} m$

- at heated $T = 453K$ and cooled temperature $T = 253K$. Temperature of environment is $293K$

As regards external jets boundary can be mention the following (figure 1a, b, c):

- extension of temperature boundary R_t is significantly higher compared with that in the impurities R_p and velocity R_u.

$R_t > R_u > R_p$

- the cooled jet is expanded more rapidly than heated because of the fact $\rho_{cool} > \rho_{env.}$ respectively $\rho_{env.} > \rho_{heated}$.The cooled jet "pushed" the light environment. Heated jet which density is lower than the density of environment is shrinking under its influence.
- the jet which carrier nanoparticles are expands significantly less than that of the micro particles. This can be explained by the lower density of the total stream of nanoparticles.

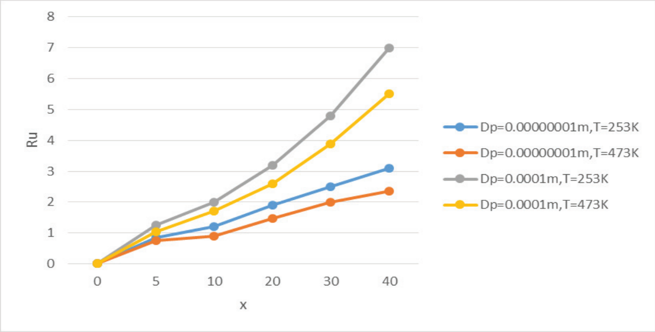

Fig.1a –Extension of velocity boundary

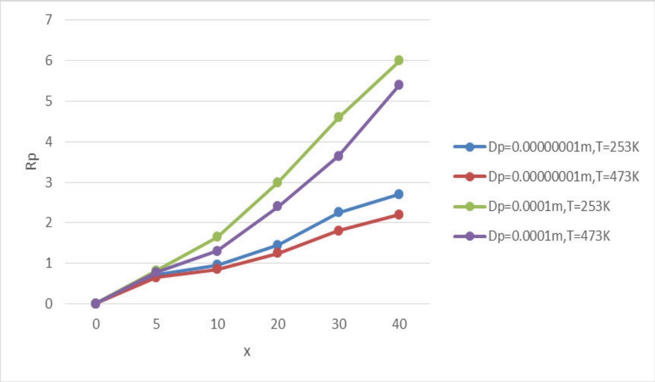

Fig.1b – Extension of impurities boundary

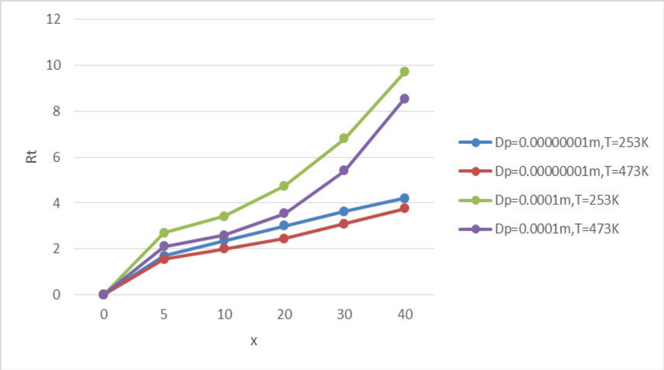

Fig.1c - Extension of temperature boundary

Extension of both cases for diameters and temperatures mention above corresponds to the attenuation of maximum velocity for the two phases: gases and impurities shown at Fig. 2 a and b.

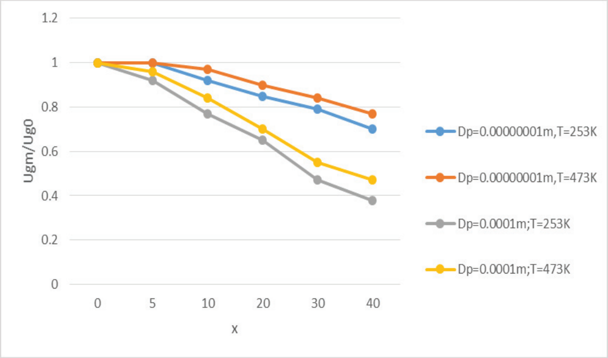

Fig.2a

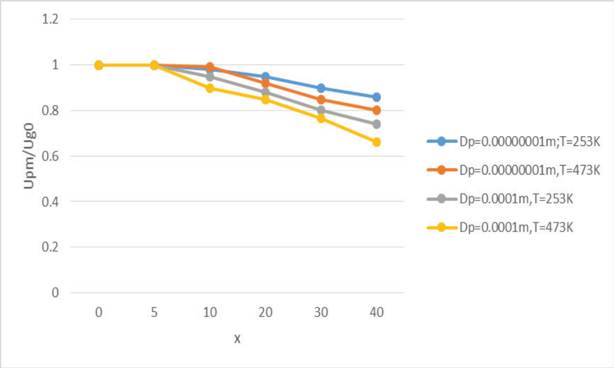

Fig.2b

The influence of the initial concentration of impurities χ_0 on the attenuation of the gas phase is shown at Figure 3a, b, c. When concentration χ_0 is reduced the reduced and maximum value of the velocity $\overline{U_{gm}}$ also is reduced. Nanoparticles become quite slowly so they have less resistance than carrier medium.

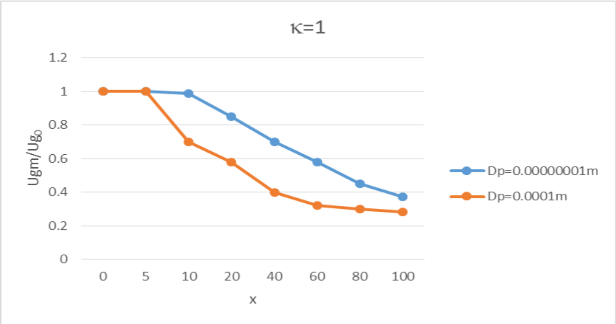

Fig.3a

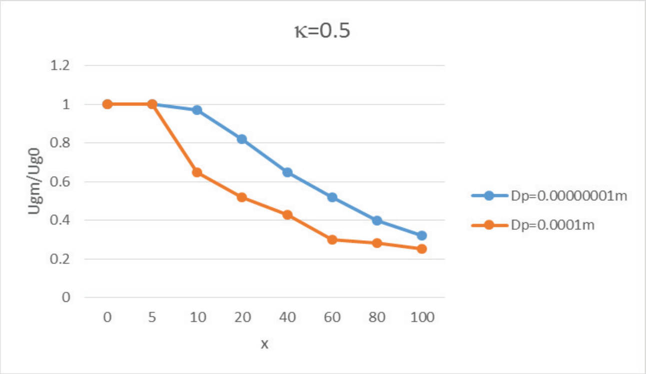

Fig.3b

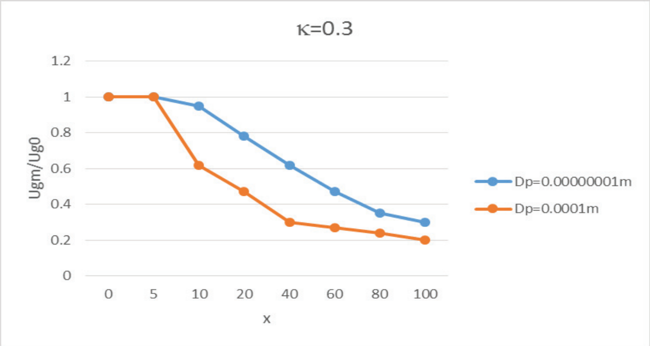

Fig.3c

The picture is similar at $\overline{U_{pm}}$ at Figure 4 a,b. It should be noted that the maximum velocity of impurities become quite considerably slower, almost double compared to the carrier medium

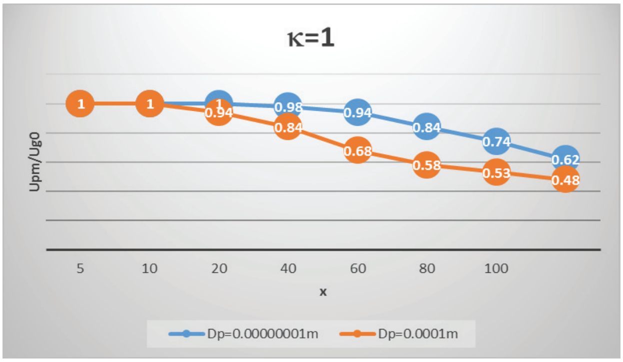

Fig.4a

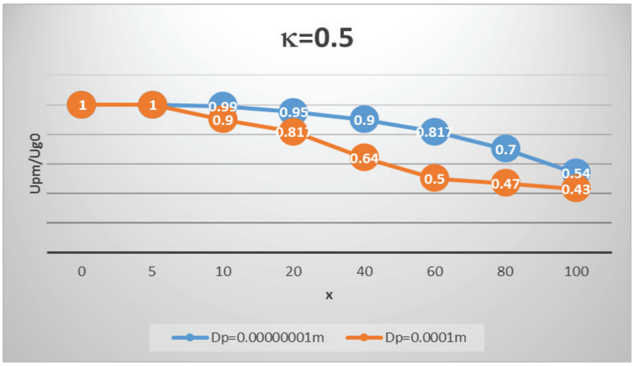

Fig.4b

CONCLUSION

The first and main conclusion is that the results form experimental results mention above and the method which is used is fully applicable in the study of flows with nanoparticles.

As a result of the solution in the way of the numerical simulation are found main integral parameters. They described the whole picture, which is enough for a quick and qualitative analysis of the flow.

All this determines the application of the integral method for specific tasks related to the distribution of flows with nanoparticles.

Literature

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This paper has been reviewed.