Flying Trajectories of Fine Powder during Centrifugal Atomizing

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Abstract

Flying trajectories of fine particles within a size range of 10~60μm were studied during centrifugal atomizing processes. A FORTRAN program was written by using increment method. Calculation results revealed that the drag force might reach very high value of 522-7800 g for fine powder of 10~60μm. Flying distance in horizontal direction could be shortened if the particles fly obliquely due to the huge drug force. On the other hand, very fine powder could be projected to far distances when the atmosphere flow velocity is much stronger. Fortunately such particles could be contracted within a cylinder closed to the atomizer when the atmosphere flow was weaken or retained in a limited diameter.

Keywords: Flying Trajectories, Fine Powder, Centrifugal Atomizing

1. Introduction

During centrifugal atomization the liquid droplet will fly in a tank filling Ar or N_2 and cool down to form fine powder. In order to design atomizing device with suitable size and to control its flying process, an important subject is to describe the flying trajectories. In 1973 D.J.Hodkin et al published their calculation results for 50-2000 μm powder [1]. The aim of this work is to investigate more fine powder and to estimate the effect of moving atmosphere.

2. Kinetic Equation and its Solution

A flying particle as a velocity V in a fluid should be acted by a drug force F_L in the opposite direction to their instantaneous velocity [2]. The force is a function of its dimension, velocity and the Renoulds number $\mathrm{Re} = d\rho_L V/\mu$ as described in equation (1). A fitting relation between the drag coefficient C of the particle and the Re in terms of double logarithmic scale was established with third order polynomial as in Fig. 2.

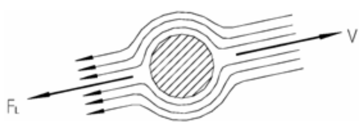

Fig. 1. Drog force in a fluid.

$$F_L = -C \cdot (\frac{1}{2}\rho_L V^2) \cdot A \tag{1}$$

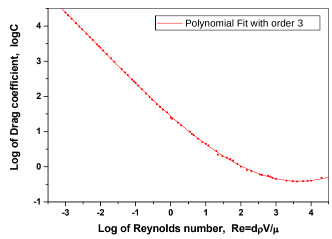

Fig. 2. Relationship between drog coefficient *C* and Re.

When the paticle flies in oblique direction as shown in Fig.3, it's a
ccelerations in horizontal and vertical direction are decribed in Equations (2) and (3). Flying distances in two directions can be written in the incremental form as in Euqations (4) and (5) if taking very small Δt , for exaple, 0.001-0.0001 sec.

$$a_{LX} = -\frac{3}{4}C\frac{\rho_L}{\rho_S}V^2 \cdot \cos\alpha \tag{2}$$

$$a_{LY} = -\frac{3}{4}C\frac{\rho_L}{\rho_S}V^2 \cdot \sin\alpha \tag{3}$$

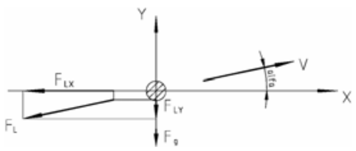

Fig. 3. A particle flying in oblique direction.

$$X_{i+1} = X_i + \left(V_{Xi} + \left(-\frac{3}{4}C\frac{\rho_L}{\rho_S}V_i^2 \cdot \cos\alpha_i\right)\Delta t/2\right)\Delta t \tag{4}$$

$$Y_{i+1} = Y_i + \left(V_{Yi} + \left(-g - \frac{3}{4} C \frac{\rho_L}{\rho_S} V_i^2 \cdot \sin\alpha_i \right) \Delta t/2 \right) \Delta t \qquad (5)$$

More complicated phenomenal is a moving atomospher – a wind field V_W resulting from high speed rotating disk and/or flying particles. Its strength and direction will be a fuction of distance as shown in Fig.4. Considering bide particle velocity V_P and wind velocity V_W as in Fig.5, acting force F should be a vector sum of F_P and F_W. Based on this principle a FORTRAN program was written as in Fig.6 by using increment method.

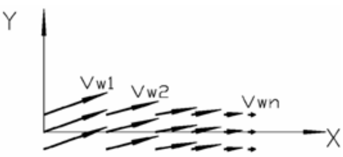

Fig. 4. A moving atomospher – wind field.

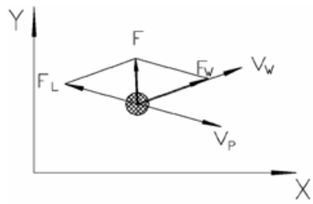

Fig. 5. Acting force on flying particle.

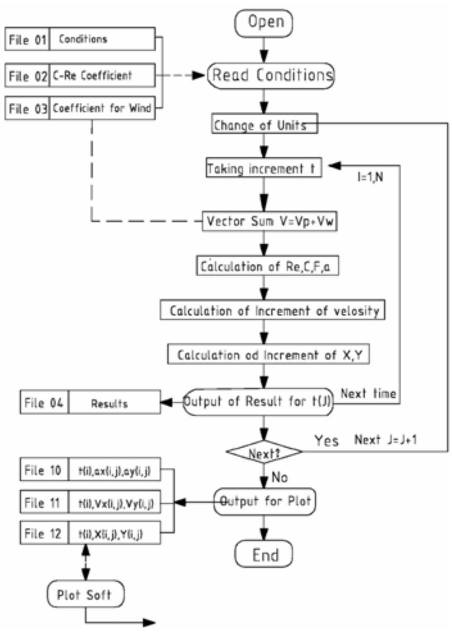

Fig. 6. Schematic programming for calculation of flying.

In order to estimate the effects of processing parameters on the flying trajectories, a series calculation has been made for different particle size, initial flying velocity and angle, different density of powder, pressure and flow patterns of the wind. Some typical calculation results can be seen in Fig.7-9. For fine sphere powder of 10-60 μm it has different a trajectories as shown in Fig.7. Flying distance in horizontal direction could be shortened if the particles fly obliquely due to the huge drug force (Fig.8). Very fine powder of 10-20 μm could be projected to far distances when the atmosphere flow velocity is much stronger (Fig.9).

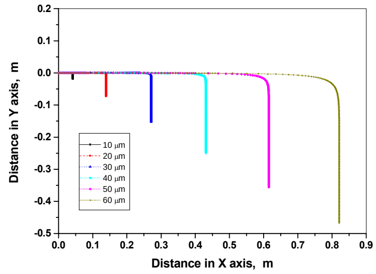

Fig. 7. Flying trajectories of different particle size.

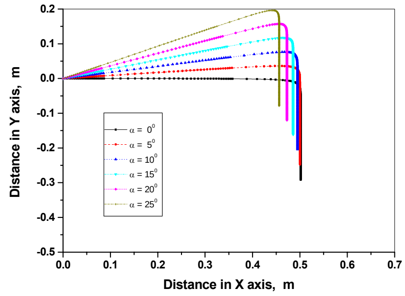

Fig. 8. Oblique flying trajectories as different angle.

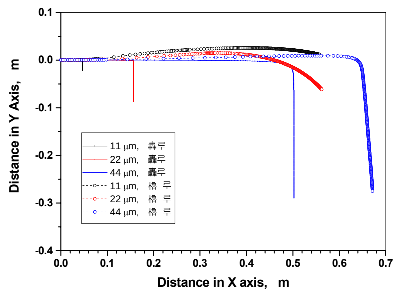

Fig. 9.

3. Summary

Flying trajectories of fine particles can be calculated by a program and the effect of wind can be estimated.

4. References

[1] D.J.Hodkin, P.W.Sutcliffe, P.G.Mardon and L.E.Russell, Powder Metallurgy, 16(32):277-313, 1973

[2] E. John Finnemore and Joseph B.Franzini, Fluid Mechanics with Engineering Applications, Tsinghua University Press, 2003, p.376

[3] Frank M White, Fluid Mechanics, Tsinghua University Press, 2003, Table 5.2, Fig 7.16, Table A.2, A.4