EXPERIMENTAL STUDY ON NANOPARTICLE DEPOSITION IN STRAIGHT PIPE FLOW

by

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Loss of the number of nanoparticles within pipe may lead to significant change of particle number distribution, total mass concentration and particles mean size. The experiments of multiple dispersion aerosol particles ranging from 5.6 nm to 560 nm in straight pipe are carried out using a fast mobility particle sizer. The particle size number distribution, total number concentrations, geometric mean size and volume are acquired under different pipe lengths and Reynolds numbers. The results show lengthening the pipe and strengthening the turbulence can promote the particle deposition process. The penetration efficiency of smaller particle is lower than the larger one, so the particle mean size increases in the process of deposition.

Key words: *nanoparticle, pipe flow, deposition, penetration efficiency*

Introduction

Nanoparticles suspended in pipes have lots of applications, such as enhanced heat transfer in heat exchangers, toxic particle transport in human lung contamination, pollutant particle emission from coal combustion in power plants and the rail pipe of a moving car [1-9]. For badly stable suspension of micro-sized particles, nanoparticles suspended inside a pipe may coagulate or deposit on the wall due to various mechanisms that may act combination with Brown motion or fluid turbulence. The phenomenon of coagulation is characterized by the formation of particle cluster, *i. e.* particles are in contract with each other and cohesion take places, then the clusters grow up. Many researchers investigated the coagulation effect of particle by Brownian dynamics simulation [10-12]. The processing of coagulation causes the particle clusters to grow up, and then the large clusters are more prone to breakage than that of small clusters. As far as particle deposition concerned, there are five main mechanisms which may lead to particle losses on the surface of a pipe, *i. e.*, gravitation, thermophoresis, electrostatics, inertial impaction and diffusion. The diffusion, inertial impaction and turbulence (for particle larger than 100 nm) are most important for deposition process [13, 14].

In recent years the transport, deposition and coagulation of nanoparticles in pipe are of increasing concern since nanoparticles are more toxic and diffusible than larger particles, while its utilization may improve the therapeutic delivery efficiency of the drugs. The analyses of the forces

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acting on nanaoparticle in flow and its deposition processes have been made by many researchers [15-17]. In the research of particle deposition, the penetration efficiency through a pipe η_N was defined as the ratio of downstream number concentration to upstream concentration. The penetration efficiency has been studied by some researches, for example, in bends [18] and a rotating curved pipe [19], respectively. However, the researches on the penetration efficiency experimentally are limited. Therefore, the aim of the study was to investigate the particles ranging from 5.6 nm to 560 nm number concentration losses under different conditions using the FMPS3091. The experimental results are compared with particle loss models for laminar flow. This mechanism is important when determining particle losses in aerosol sampling and transport system.

Experimental techniques

A sketch of the experimental setup is shown in fig. 1.The flow under consideration is a particle-laden pipe-flow. A cylindrical pressure vessel with diameter of 1.5 m and high of 2 m is used to support the nanoparticle-laden gas. The nanoparticles are produced by incense burning, which was injected by fans B into the pressure vessel and placed twenty four hours for mixture uniform in the vessel. The pipe is made from plexiglass. The measurement is carried out in the laboratory with temperature of 20 °C. Fans A is used to transport filtered gas into the pressure vessel. The sampling particles were multiple dispersion aerosol. A sampling frequency is 1 Hz and continuously for 1 minute in each measurement. The sample flow rate is 0.01 m^3 per minute, which is 1.47 m/s corresponding to the pipe inner diameter of 12 mm. So the experimental velocity must be larger than this value. The geometric mean size of particles is near 80 nm, and the total number concentration per cubic centimeter is 10^4.

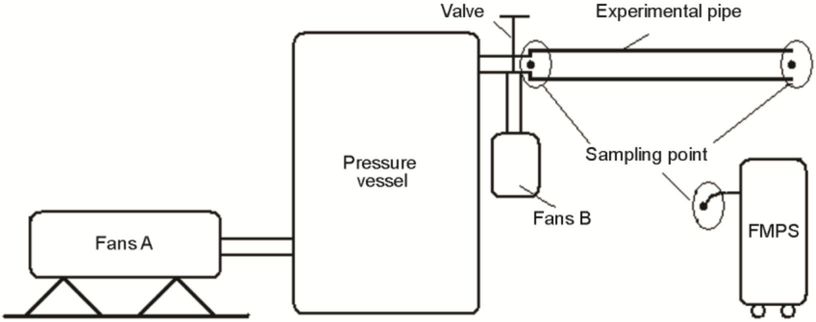

Figure 1. A sketch of the experimental apparatus

Results and discussion

The Brownian motion is the main mechanism leading to deposition on pipe surface of nanoparticle-laden multiphase laminar flow (when Re < 2300). A comparison of the penetration efficiencies η_N through pipes is shown in fig. 2(a) as a function of the particle diameter *D*p. In this graph, the data points with error bars are the measured penetration efficiencies through pipes for $l/d = 375$ and Re = 1700, where l is the length and d is the inner diameter of the pipe. The previous similar condition experimental results are shown using triangle. The lines represent the penetration efficiencies through the straight pipe predicted by Gormley and Kennedy [20]. Because of only concerning Brownian diffusion the results show higher penetration efficiencies than experimental for ignoring surface effect [17]. So the results of fig. 2(a) show the rationality results of this paper. The penetration efficiency through the pipe is found to increase with increasing particle size. The losses efficiencies for particles below 20 nm are larger than 10% due to the higher diffusivity of smaller particles.

The pipe length and flow type effects on penetration efficiency with different particle size have been shown in fig. 2(b). Particles are larger than 100 nm which diffusivity affected both by Brownian motion and turbulence. The change of the deposition with particle diameter is weak in this size range. Most of particles larger than 200 nm have high penetration efficiency (>90%) with l/d = 375. But the change of penetration efficiency is obvious with the pipe length. As the pipe length increasing, the loss of particles in pipe surface increases comparing l/d = 375 to l/d = 500 in fig. 2(b). Turbulence will enhance deposition, especially for larger particles in long pipe.

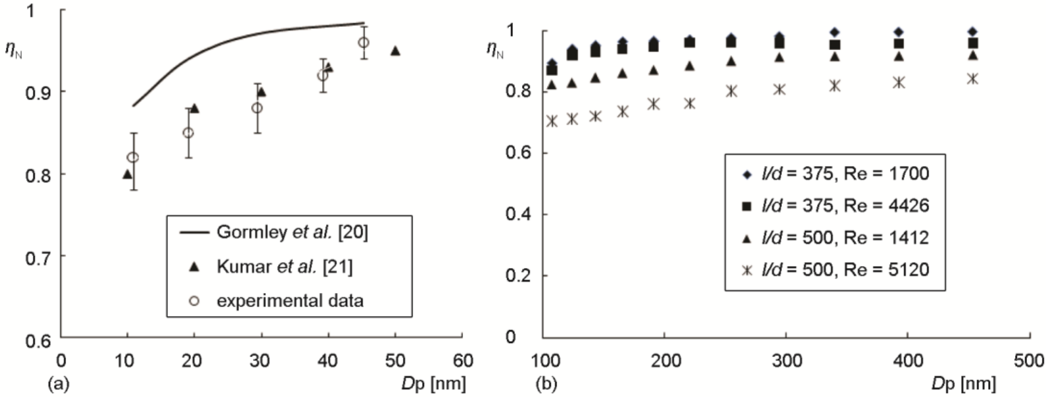

Figure 2. Experimental results of penetration efficiencies according to particle size

Conclusions

Experiments have been made under different operating conditions with FMPS3091. It is found that particle losses for nanoparticle-laden multiphase pipe flow are affected by particle diameter, pipe length and flow pattern. Maximal losses are found for particles size smaller than 30 nm. The penetration model of Gormley described particle smaller than 50 nm in laminar flow losses well. The mechanism may find many potential applications in the future for thermal science.

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