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Heterogeneous Condensation on Fine Particles of Water Vapor in a Moderated Growth Tube

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Abstract

A novel process of heterogeneous condensation of water vapor on fine particles was presented in this paper. In order to improve the performance of heterogeneous condensation of water vapor on fine particles, a moderated experimental scale growth tube was developed. The essential supersaturated environment was established by adding hot water into the cooled gas in the growth tube. The supersaturation profiles in the growth tube was described and the performance of particle enlargement in the original growth tube and in the moderated growth tube both were experimentally investigated. The results showed that the performance of particle enlargement could highly be improved by the moderated approach. A comparison between the performance of the original approach and the moderated approach was presented; also, the different growth mechanisms in different growth tube were elucidated.

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Keywords: heterogeneous condensation; vapor; fine particles; growth tube

1. Introduction

At present, coal fired power plants are considered as one of the major source of particulate pollution in the ambient atmosphere [1, 2]. The emission of particulate matter entrained in coal fired power plants exhausted gases have caused many problems for environment and human health [3, 4]. However, although the traditional dust removal equipment have a good performance on the coarse particles abatement, the removal efficiency for particles

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diameter ranging from 0.1-1 μm decreases to approximately 25% [5]. It has reported that heterogeneous condensation of water vapor on fine particles was one of the most promising preconditioning technique for fine particles abatement [6, 7]. The heterogeneous condensation can be divided into nucleation and growth process, since last century, many researchers have focused on the process of nucleation of the fine particles [8-10], and the other part of researchers have focused on the collection efficiency of particles after that the heterogeneous condensation preconditioning technique was used in the conventional particles collection processes [11-14].

Indeed, heterogeneous condensation is a promising technique to improve the performances of the traditional particle collection devices. The purpose of this technique is going to enlarge the size of the fine particles larger than the upper limit of the Greenfield Gap (about 2 μm). Many workers [11, 15, 16] reported that high efficiency could be obtained by a separation process with heterogeneous condensation. In these processes, the essential supersaturated environment was established by adding steam. Due to the collection efficiency increased with the addition of steam increasing, which meant the higher collection efficiency, the higher cost of the energy for steam produce. Hence, it is very important to improve the performance of the particle enlargement under certain supersaturated environment.

Tammaro's work [17] and our previous work [18, 19] showed that the particles could be enlarged in the growth tube efficiently, however, there was still some part of submicron particles could not be enlarged after the growth process taken place. In order to improve the performance of the particle enlargement with heterogeneous condensation process, we developed a moderated growth tube. During our processes, the particles would be enlarged under the vapor supersaturated environment and then partial gas would extract from the top of the growth tube, this part of gas containing droplets was sent to the bottom of the growth tube. We hoped that the coagulation between droplets and new sending particles would take place, or the droplets would capture the new sending particles. After the coagulation, the size of the small particles would be increased, and then the critical supersaturation of the new formed particles would reduce, which would improve the performance of the particle enlargement.

In this paper, the performance of particle enlargement in a new, moderated growth tube was shown, the supersaturation and the proportion of partial gas circulation effect was investigated, a comparison of particle enlargement in original growth tube and in moderated growth tube was presented, also, the different mechanisms of particle enlargement with different approaches were elucidated.

2. Moderated growth tube with partial gas circulation concept

Fig. 1(a) illustrates the original, hot laminar flow water condensation growth tube first described by Tammaro [20], and used for the particle enlargement. It consists in a 40 cm long and 1.5 cm internal diameter glass cylinder. The tube diameter was determined taking account the diffusion rate of vapor from the walls to the centerline and the need of minimizing the interferences between the gas and the liquid flows. The water inlet to the growth tube was designed as tangential so to assure a perfect adhesion of water with the tube walls. Certainly, vapor condensation occurred until the temperature of the gas was lower than that of the liquid film. To this aim, the liquid film temperature was kept at the desired value, T_w, by means of a thermostatic bath.

Fig. 1(b) illustrates our new, moderated growth tube. The new growth tube also consists in a 40 cm long and 1.5 cm internal diameter glass cylinder. The essential supersaturated environment also established by adding hot water into the growth tube that would meet the cooled gas. Unlike the original growth tube, a gas flow circuit was set beside the growth tube which would extract partial gas circulation from the top of the growth tube to the bottom of the growth tube. And then this part of gas would mix with the new particles sending with gas flow that had not be enlarged by heterogeneous condensation of water vapor.