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A Novel Method for Establishing Collection Efficiency of Electrostatic Scrubber as a Function of Stokes Number

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Abstract: With the present need to control the air pollution, electrostatic scrubber is one of the most popular pollution abatement devices. Thus we need to optimize its efficiency within the given constrains. For this we need to study the effect of various parameters that may be used for its optimum design. In this paper we report the effect of Stokes number on its particle collection efficiency. The analysis shows that, for smaller collector radii, the collection efficiency decreases with increase in Stokes number while for larger radii it practically remains constant.

***Keywords**:* Electrostatic scrubber, Runge-Kutta method, Collection efficiency, Stokes number.

1. INTRODUCTION

For the removal of dust particles entrained in the air stream many different methods are being used. One of the methods used is electrostatic force of attraction. The system using this force is known as electrostatic scrubber. In this equipment, the dust particles and the collector droplet are charged with opposing polarity charges [1]. The collector droplet collects the opposite polarity dust particles and then are removed from the system [2]. This electrostatic system shows far better performance as compared to other conventional scrubbers [3]. Thus in past, several researchers have simulated and studied the performance and collection efficiency of the system using stream function and finite element method [4].

2. PROBLEM DEFINITION

To study and design the electrostatic scrubber we need to study its behaviour and performance. The performance of the scrubber can be studied with respect to one of the many variable parameters. One such variable parameter is the Stokes number which defines the drag force acting on the dust particle. Thus the collection efficiency of the scrubber can be studies for various values of the Stokes number which is constant for a given set of conditions. This variation can be studied for different collector droplet sizes to study the high efficiency conditions. The novelty of this method is that we here use a simple Runge-Kutta method instead of complex techniques for solving the differential equations.

3. METHOD

As stated in earlier studies the charged collector droplet collects the dust particle of opposite polarity [5]. The motion of particle is affect by large number of forces, while only few of them mainly affect the particle motion and rest of them can be neglected. The forces considered here are Stokes drag force, gravitational force and Coulombs force [6]. The differential equations for the collector droplet are calculated as per the method used by the authors in their previous research work wherein particle trajectories have been plotted and collection efficiency is studied with respect to the Coulomb number. The normalized vector differential equation for the dust particle can be written as a system of 2 scalar equations in the system of coordinates:

$$\frac{d^2x}{d\,t^2} = \frac{C_d R_{ep}}{24\,S_t}\left(u_x - \frac{dx}{dt}\right) + \frac{K_c x}{S_t r^s} \quad (1)$$

$$\frac{d^2y}{d\,t^2} = \frac{C_d R_{ep}}{24\,S_t}\left(u_y - \frac{dy}{dt}\right) + \frac{K_c y}{S_t r^s} + g\frac{R_c}{u_0^2} \quad (2)$$

The particle trajectories are affected by non-dimensional parameters, Stokes number is one such parameter. The inertial deposition is proportional to the Stokes number, given as [7]:

$$S_t = \frac{2C_c R_p^2\,\rho_p u_0}{9\eta_g R_C} \quad (3)$$

where ρ_p is the particle density, C_c is the Cunningham slip correction factor, η_g is gas viscosity, Re_p Reynolds numbers based on the particle diameter, C_d drag coefficient, K_c is Coulomb number, r is the distance between the particle and the droplet centers. Similarly the differential equations for the collector droplet provide information on the complex nature of the scrubbing process and allow determination of the particles being captured [8].

Collection efficiency: The collection efficiency of the collector droplet varies with the value of stokes number. This efficiency trend with respect to stokes number can be studied for collector droplets of different sizes. We can calculate the collection efficiency by taking the ratio of the number of particles collected by the droplet to the number of particles entering the system for different set of conditions. The differential equations have been solved using Runge-Kutta algorithm. The numerical algorithm calculates the number of particle depositing on the collector thus collection efficiency is now studied for different collector Stokes number values.

4. RESULT AND DISCUSSION

Here to study the effect of Stokes number on collection efficiency, the graphs are plotted by varying the Stokes for different collector sizes keeping all other parameters constant. Thus we can see that the collection efficiency is maximum for smaller values of stokes number and decreases with increase in Stokes number.

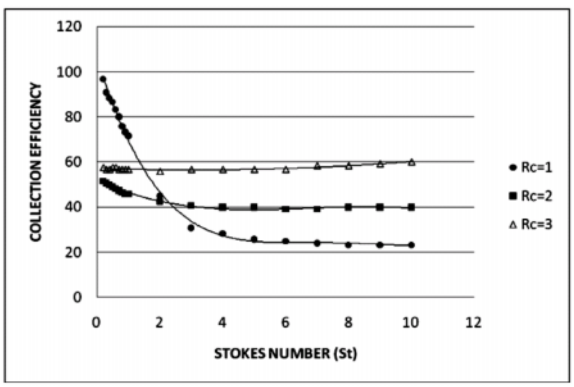

Figure 1: Stokes Number (St) Vs Collection Efficiency

5. CONCLUSION

To study the performance of the electrostatic scrubber, we have plotted the variation of collection efficiency with respect to various parameters. Thus for this, the study was divided into four main parts. In the first part we studied the particle trajectories for various set of conditions. In second and third part we studied the effect of the collection efficiency of the scrubber with respect to parameters such as collector radius and Coulomb number respectively. In this fourth part we study the effect of Stokes number on the collection efficiency. From the graph in Figure 1 we can safely conclude that the collection efficiency decreases with the increase in Stokes number for given set of conditions. But this decrease is high for lower values of the radius and remains almost constant for higher collector radius sizes.

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