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Modeling the Coating of Lactose on a Single Particle through Fluidized Bed Spray Granulation Process

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***Abstract*—Fluidized bed spray granulation is used to produce coarse granular solid particles by spraying liquids in the form of fine droplets on a fluidized particle followed by drying in a stream of fluidizing air. The quality and thickness of granulation or coating on the particle should be uniform. In this work, experimental data obtained during the study of influence of process parameters i,e., drying conditions, impact velocities and physical properties of sprayed solutions on the kinetics of granulation and on the morphology of the end product, is modeled. In this theoretical modeling,, an attempt is made, for a single particle to relate collision and adhesion of sprayed droplets with particle growth for 16% aqueous solution of lactose using correlation modeling and artificial neural network techniques. The present paper reports and compares the results obtained by the two types of modeling. The results are useful in understanding the growth in spray-coating process..**

***Index Terms*—Modeling, Fluidization, Granulation, Artificial neural network**

I. Introduction

Fluidized bed spray granulation is a widely used process to produce coarse solid particles from raw materials like solution, suspension or molten liquids. Spraying and drying take place simultaneously in a fluidized bed and give rise to growth of the particle. After achieving a desired size, the product is taken out of the bed. The size of the end-product varies from 0.3 to 10 mm. Coating and granulation are used in manufacturing catalysts, sealing of hygroscopic or toxic products and also in retarding a reaction. The properties of the products and coating agents to be applied are important for the design of the equipment and the quality of coating. Growth kinetics in granulation process is studied by spraying coating liquid (using sod. Chloride & lactose) on a single fluidized particle [3] and also on a laboratory scale [4]. It is necessary to relate growth rate or rate of deposition of coating solution on particle. Growth rate depends on operating parameters, namely, droplet diameter, velocity, viscosity, temperature, inert particle diameter etc. Hence, in this work, efforts are made to correlate growth rate (lactose) with dimensionless numbers (i,e, Reynolds and capillary). The paper is arranged as follows: formulation of dimensionless groups and process modeling are discussed in next section. Results are explained in section 3. Then a conclusion is drawn at the end.

II. Process Modelling

Mathematical modeling of growth kinetics for 20% NaCl solution in fluid spray granulation is discussed [2]. The schematic is shown in Figure 1. Inert material (an aluminium ball) is fluidized in a narrow jet of hot air while the coating solution is being sprayed over it till the coat dries up; and the dried particle comes out of fluidization chamber automatically. In this process [3], the tiny droplets strikes the fluidized-ball, a few of which bounces back from the surface of ball and remaining gets adhered to the surface due to which growth phenomena is observed. The theoretical modeling of the present process (lactose) was attempted with the experimental data available for 16% aqueous lactose solution, using the following techniques, viz:

1) Correlation modeling
2) Artificial neural network modeling.

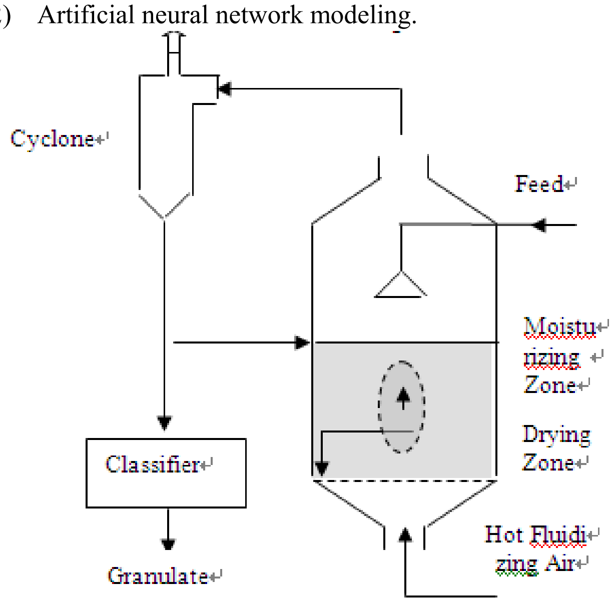

Figure 1. Schematic diagram of experimental set up for fluidized bed granulation process Since the value of droplet diameter $d_{Tr} = 80\text{x}10^{-6}$.m was available only for one value of droplet velocity u_{Tr}= 31 cm/s, the modeling equations were based on these values.

A. Correlation Modeling

The amount of droplet deposition (Δm) may be defined as

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the numerical product of the amount of collision (η) and the amount of adhesion *h*, i.e.

$$\Delta m = \eta . h. \tag{1}$$

Dimensional analysis was carried out to correlate "η"and "h" with the dependent process variables and physical properties of materials.

$$\eta = f(N_{\mathrm{Re}} d_{Tr} / D_K) = N_{\mathrm{Re}}^a (d_{Tr} / D_K)^b \tag{2}$$

where Renolds number

$$N_{\mathrm{Re}} = u_{Tr} d_{Tr} \rho_a / \mu_a \tag{3}$$

This equation was solved for two different temperatures of the fluidizing air (T=60 ^{0}C, 70 ^{0}C, 1 atm). The density of air "ρ_a" was calculated using the equation

$$\rho_a = 1.293(273/T)P \tag{4}$$

where 'T' is in Kelvin and ' P' is in atmospheres. The viscosity of air (μ_a) was found out from Perry's handbook (air thermodynamic properties). The value of η (=Δm/h) was calculated from Link [1]. The correlation thus obtained was

$$\eta = N_{\mathrm{Re}}^{-1} (d_{Tr} / D_K)^{-0.314} \tag{5}$$

similarly,

$$h = f(N_{Ca}, N_{\mathrm{Re}}, d_{Tr} / D_K) = (N_{Ca})^p (N_{\mathrm{Re}})^q (d_{Tr} / D_K)^r \tag{6}$$

where capillary number

$$N_{Ca} = u_{Tr} \eta_L / \sigma_L \tag{7}$$

This equation was solved for three different temperatures of the fluidizing air (T=60 ^{0}C, 70 ^{0}C, 40 ^{0}C 1 atm). The value of σ_L at any temperature, 'T' was determined using the equation

$$\sigma_L(T) = \sigma_{water}(T)\ [1.02 + 0.024\ C^*] \tag{8}$$

where C* is the concentration of spraying liquid, and σ_{water} *(T)* is the surface tension of water at temperature 'T'. The simpler form of Andrade equation was used for finding the viscosity of the liquid, η_L, and is given by :

$$\ln\ \eta_L = -7.70 + 2376/T \tag{9}$$

where 'T' is in Kelvin

The correlation thus obtained was

$$h = N_{Ca}^a N_{\mathrm{Re}}^b (d_{Tr} / D_K)^c \tag{10}$$

$$\Delta m_{cal} = N_{\mathrm{Re}}^a N_{Ca}^b (d_{Tr} / D_K)^c \tag{11}$$

These equations can be used to calculate growth rate on particle.

B. Artificial Neural Network Modeling

A feedforward network with one input, air inlet temperature, and bias (=1) and one output Δ*m* was trained using the back-propagation algorithm. The experimental values available were used for training the network. A part of the experimental values was used for testing the network with a tolerance value of 0.001. Number of epochs (iterations) 1000, was chosen as the termination criteria. The minimum possible values of error were obtained for the network with the following topology.

One hidden layer with five neurons is selected as this architecture yields minimum error. The values of learning and momentum rates, in back propagation algorithm, were 0.7 and 0.3, respectively.

III. Results and Discussion

A. Correlation Modeling

Using equations presented in section 2 above, the values of Δm_{Cal} was calculated for different values of temperature (T= 20 to 70 ^{0}C). The maximum error obtained (Fig. 2) was 7% and the minimum error obtained was 1%. The experimental set of data is available only in the temperature range of 20 to 70 ^{0}C.

A correlation model given by eqn. (11) is established as

$$\Delta m = N_{\mathrm{Re}}^{7.85} N_{Ca}^{3.72} \left(\frac{D_{Tr}}{D_P} \right)^{-12.8} \tag{12}$$

This relation gives growth (droplet deposition on the inert particle) rate as a function of dimensionless numbers in the transport process.

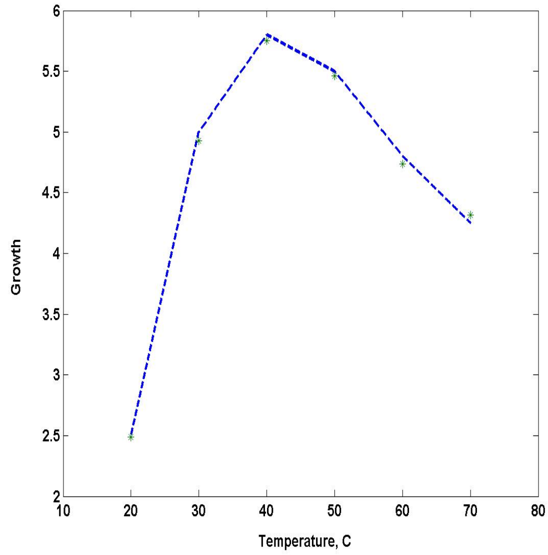

Figure 2. Comparison of growth of particle (experimental ('*') and theoretical ('---') from correlation modelling)

Calculated variance is found to be1.25 and standard deviation is 1.18

B. Artificial Neural Network Modeling

In this method, results are obtained with network topology described in section II.B above. The ISE value obtained was 0.0005. The maximum error obtained was 15.12% and the minimum was 1.05%.

Fig. 3 shows a comparison between the results obtained using prediction through formulated models and the experimental values. Error analysis reveals the better validity of artificial neural network model in predicting the particle growth rate at other operating conditions.

IV. Conclusion

The experimental results show that the droplet deposition is specifically dependent on physical properties of material. The drying temperature and droplet-velocity influence the granulation kinetics. These results, with a single particle are useful in the case of fluidized bed spray granulation. The effect of binder addition changes the physical properties of the solution and also influences droplet deposition. Changes in surface tension properties also play an important role in

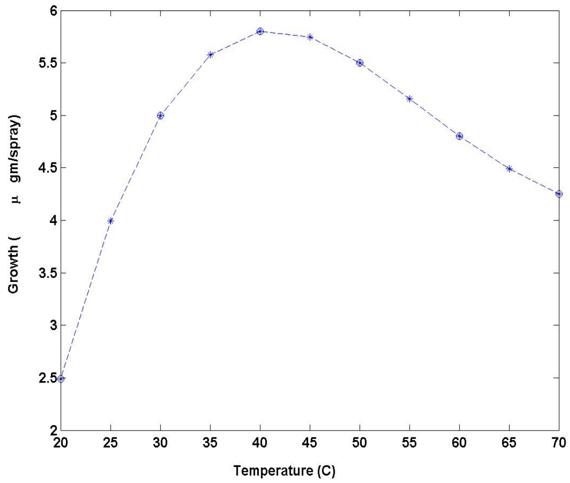

Figure 3. Comparison of growth of particle (experimental ('o') and theoretical ('*') from ANN modelling) the coating process. The effect of viscosity of solution on the spray granulation process is supposed to be less significant. Error analysis reveals the better validity of artificial neural network model in predicting the particle growth rate at other operating conditions.

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