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A Fluidized Bed Polymer Coating Experiment and Practical Aspects of Design in Chemical Engineering and Pharma Industry

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ABSTRACT

This experiment, first developed for a NSF Novel Process Workshop, is a highly visual experiment in chemical engineering processes and experimentation. In addition, it the coating process is environmentally benign because it has essentially no volatile emissions. The object of the experiment is to place a protective coating on a pellets, tablets, and metal object. The metal object is coated by first heating in a hot air stream and then dipping the object into a fluidized bed of thermoplastic powder. This experiment can be used throughout the curriculum. For recruitment at the precollege and freshman level the fluid motion of the gas and particles can be observed through the clear plastic walls of the fluidized bed. Using brightly colored particles gives the fluid bed the look of an executive desk amusement. Prospective students and freshman can also feel the water like quality of the bed using a rod or ruler. Freshmen use the fluidized bed as an example of the engineering measurements of flow rate, temperature, pressure and coating thickness. They design an experiment to determine the desired coating thickness by varying the dipping time and temperature of the object.

Keywords: Fluid Bed Coating, Volatile Organic Emission, Vertical Integration

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INTRODUCTION

The use of polymers continues to expand. Advanced polymers are being developed for use in emerging areas of technology such as medical devices, smart packaging systems, fuel cells, and electronic device fabrication. Conventional plastics find extensive use as a material of construction for many products common in daily life [5]. Their low weight, resistance to weather and wear, and economical production, make them attractive alternatives to glass, metal, and wood for use in products ranging from food and beverage containers to recreational equipment to automobile components to building materials. Fluidized bed coating is a commercially important process which was developed for application of plastic coatings on metal substrates. It provided the basis for more advanced powder processes such as electrostatic coating and flame spraying. Dry powder coating processes use no solvents and thus provide an environmentally friendly alternative to older techniques such as dipping, brushing, and spraying [7]. Fluidized bed coating is a novel process which offers the advantages of efficient utilization of materials (near 100%), the ability to coat irregular shapes, high coating rates, simple and inexpensive equipment requirements, process automation, and smooth and continuous coating applications[2].

Industrial Application [1, 3]

Fluidization finds application in many important industrial processes. Examples of fluidization are given in the Table 1.

Table 1: Industrial Applications

Process	Applications
1. Physical Operations	coating , drying of solids and Adsorption of solvents
2. Biochemical	cultivation of microorganisms for the food and pharmaceutical industries
3. Polymeric Materials	The gas phase polymerization of polyethylene production of silicon for the semi-conductor industry

In fluidization, a gas or liquid is passed through a bed of solid particles which is supported on a perforated or porous plate. In the case of fluidized bed coating, air is passed through a bed of polymer particles. When the frictional force acting on the particles, or pressure drop, of the flowing air through the bed equals or exceeds the weight of the bed, the powder particles become suspended, and the bed exhibits liquid-like behavior. The air velocity corresponding to a pressure drop that just equals the weight of the bed is referred to as the minimum fluidization velocity. At this air velocity or flow rate all of the bed particles are completely suspended by the air stream. For a given system, minimum fluidization velocity can be determined from a pressure drop versus air velocity diagram. As air flow is increased above the minimum fluidization velocity, the bed may exhibit behaviors ranging from smooth fluidization to bubbling fluidization to dilute fluidization in which powder can be transported by the air stream. Smooth fluidization is desirable for optimal performance in the powder coating process. The liquid-like nature of the fluidized powder bed allows a metal object to easily be dipped into it. The metal object is preheated to a temperature above the melting point of the polymer prior to being dipped.

Scope and Objectives

The purpose of this experiment is to introduce students to basic measurements of temperature, pressure, flow rate, film thickness using a fluidized bed coating unit. By conducting this experiment you will also be introduced to the chemical engineering operation of fluidization. The experiment is broken into two parts. The first is a demonstration of the basic fluidization regimes. You will operate a laboratory fluidized bed and take measurements to generate a classical pressure drop vs. flow rate diagram to determine the minimum fluidization flow rate for the system [3, 4]. During this part of the exercise, you will get a chance to observe the behavior of the fluidized bed over a wide range of air flow rates. In the second part of the experiment, the participants will be charged with conducting coating trials to determine process conditions (preheat temperature & dip time) necessary to achieve a specified coating thickness on sample [5].

Experimental Objectives [7]

1. Using a calibration curve, convert the rota meter readings in mm's to a flow rate in mL/min.
2. Measure the temperature of an object using a bare wire thermocouple.
3. Measure the pressure of the inlet air stream using a Bourdon gauge.
4. Measure the pressure difference across a fixed and fluidized bed using a liquid filled manometer.
5. Estimate the thickness of a polymer coating from knowledge of the surface area of an object and the masses of the coated and uncoated objects.
6. Determine the optimum temperature; dipping time and fluidization regime to obtain an average coating of 0.025 inches 3.7 and explain the effect of temperature and dipping time on the coating thickness of an object.

PHYSICS AND CHEMICAL ENGINEERING EVALUATION OF DATA [7]

Coating Material

Functionalized polyethylene copolymer-based powder:

$$\textbf{Polymer Density} = \rho = 0.934 \text{ g/cm}^3$$

Polymer Melting Point = 221°F or 105°C hence the polymers having different properties and melting point to be noted in the experiment to characterize the coating efficiency in pharma sector of product and metal objects.

Chemical Substrate:

Example:

Given: The Steel Washer from Sears Hillman Brand 1/2 inch nominal size.

Item Codex No- 270067

(Outer Diameter (OD) 1.376 in, Internal Diameter (ID) 0.563 in, Thickness (T) 0.117 in)

Substrate Surface Area (SSA) = 3.19 in^2 = 20.6 cm^2

Experimental Apparatus [7]

The fluidized bed can be fabricated from clear plastic (acrylic) tubing and sheets. The clear plastic tube is glued to a flat sheet flange and a rubber gasket material is used to seal the distributor plate to the unit. The distributor plate is a porous polyethylene sheet manufactured specifically for heat treating fluidized beds [5]. This plate can be obtained from POREX Technologies. The drop mechanism for the metal samples was fabricated by bending stainless steel tubing into a U-shape and running a thin metal cable through the center of the tubing [6, 7]. An attachment device is placed at one end to hook a wire loop to it and the other end has an adjustable stop. The wire is weighted using washers to obtain a fast drop into the fluid bed. See Figure 1.

Figures:

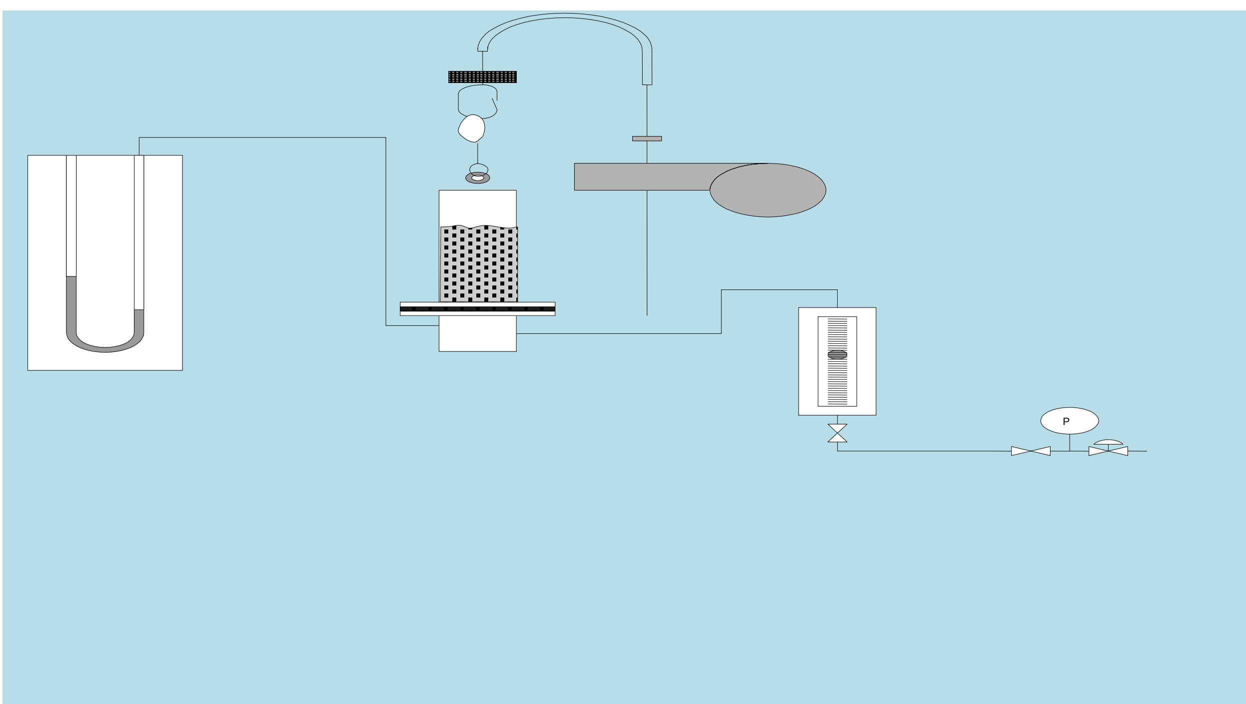

Figure 1: Experimental Design of Apparatus

Experimental Procedure of Polymer Coating [7]

The environment to which the part is exposed requires that the part be coated with polyethylene to protect against corrosion. Increasing the coating thickness increases corrosion protection, but decreases heat transfer rate. Initial calculations indicate that a coating thickness of 0.025 inches ± .001 inches will maximize corrosion protection while allowing for an adequate heat transfer rate. Based on this problem statement the students conduct a series of pilot runs in the fluidized bed coating system to determine values for the process variables (pre-heat temperature and dip time) which will produce the desired coating thickness. To examine the behavior of the coating process they conduct runs of constant temperature and constant time. They are given a range of temperatures that start below the melting point of the polymer (221°F) and extend to 450°F. The dip time ranges between 2 sec. and 10 sec.

CONCLUSION

It is necessary that the Polymer Coating system practice all over the world be oriented toward al1 pharmaceutical companies as well as Chemical Company. This Article will provide manufacturer's confidence to go for international level of Polymer Science. This article provides the valuable information about the Coating Evaluation and Critical factors to be considered while preparation of the Polymer Coating with a Mathematical models. The use of polymers continues to expand. Advanced polymers are being developed for use in emerging areas of technology such as medical devices, smart packaging systems, fuel cells, and electronic device fabrication.

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