A Coating Technique for Mass Transfer Spheres

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This note reports a new method for producing spherical particles which are suitable for mass transfer studies in packed beds. The new method is characterized by its speed, simplicity, and convenience as compared to previously used compression and casting methods. The coating technique described here can be used to produce large numbers of particles in a comparatively short time. Earlier investigations have used mass transfer spheres produced by melting the solid and casting into spheres with the aid of a suitable mold (Williamson et al., 1963; Wilson and Geankoplis, 1966; Linton and Sherwood, 1950; Steinberger and Treybal, 1960). While this technique produces good spheres, the production of the molds requires careful machining, and obviously a new mold must be made for each size of sphere desired. Other investigators have compressed the granular solid powder to produce mass transfer particles; however, the resulting particles are usually pellets which are only approximately spherical in shape (Kataoka et al., 1972; Dryden et al., 1953; McCune et al., 1949; Garner and Suckling, 1958). The new technique presented here may be used to produce essentially any size of spherical particle desired quickly without the use of either a mold or a compression apparatus.

EXPERIMENTAL TECHNIQUE

The experimental method is essentially a coating technique in which spherical particles (marbles, ball bearings, etc.) are projected through a molten pool of the mass transfer solute into the air where the coating solidifies thus producing a spherical particle suitable for mass transfer studies. The experimental equipment required is shown in Figure 1. The central piece of apparatus is a 31.7-mm diam. pyrex glass tube having a smooth bend near one end so that a pool of molten solid can be contained. The tube is wound with a heating tape and insulated. The temperature inside the tube is controlled with a powerstat to avoid overheating of the melted solute. A heating lamp is directed on the exit of the tube to prevent any solidification of the solid on the tube surfaces near the very end. The coating operation consists simply of rolling a marble (or equivalent) down the tube so that it passes through the pool of melted solute and exits from the tube into the air. The coating solidifies upon exit from the tube and the finished product is caught on a soft cloth to avoid chipping. Thicker coatings may be obtained by repetition of the process, if desired. It is not necessary that the pool of liquid solute be as deep as the marble diameter, as the surface wetting properties tend to produce a uniform coating.

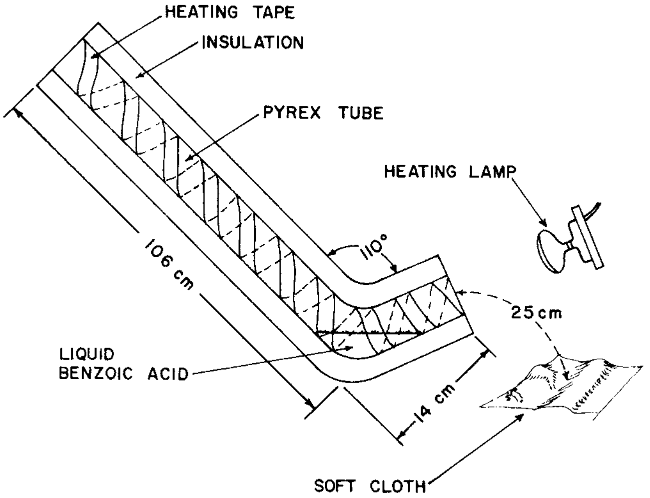

Fig. 1. Sphere coating apparatus.

EXPERIMENTAL RESULTS

Using the technique outlined above, the authors have produced benzoic acid coated spheres with nominal diameters of 9.5 mm, 14.3 mm, and 22.2 mm. The substrate for the coated spheres was clear glass marbles obtained from the Vitro-Agate Company, Parkersburg, West Virginia. A single pass through the apparatus resulted in a benzoic acid coating about 0.1 mm thick. Approximately 500 coated spheres could be produced per hour. The coating was found to be hard and smooth; however, in order to verify further the quality of the coating, mass transfer experiments were performed using a 10-cm I.D. packed plexiglass column. The procedures used in these experiments were essentially the same as those of earlier investigators including a section of inert spheres above and below the active bed section. The data obtained are shown in Figure 2, together with the correlation of Wilson and Geankoplis (1966). While there is some scatter, the agreement is satisfactory for a verification of the coating technique.

CONCLUSION

A new coating technique for producing mass transfer spheres has been developed and tested. The method requires no special equipment and is believed to be more convenient than previous casting and compression methods.

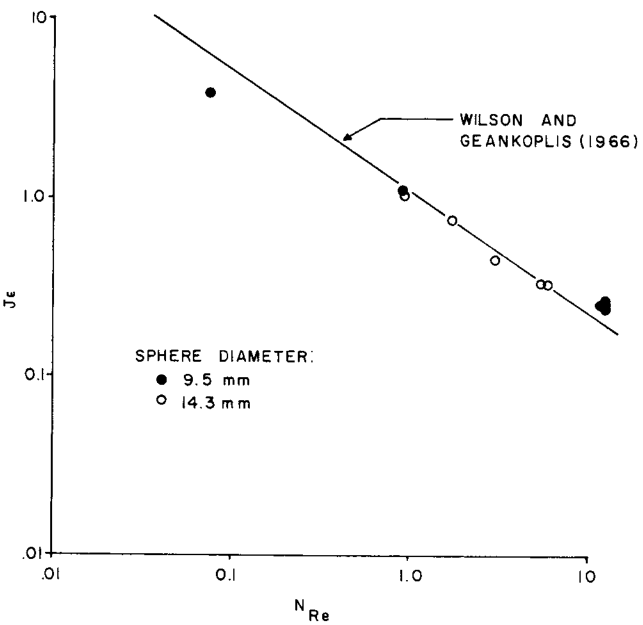

Fig. 2. Experimental results using coated spheres in a packed column.

ACKNOWLEDGMENT

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NOTATION

D = molecular diffusivity, cm^2/s
D_p = particle diameter, cm
J = $(k_L/U)\ (N_{Sc})^{2/3}$
k_L = mass transfer coefficient, cm/s
N_{Sc} = Schmidt number, ν/D
N_{Re} = Reynolds number, D_pU/ν
U = superficial velocity, cm/s
ϵ = porosity
ν = kinematic viscosity, cm^2/s

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Turbulent Drag Reduction By Polyacrylic Acid

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In this note we offer further observations on the role of polyacrylic acid in drag reduction of turbulent flows. Savins (1967) reported that polyacrylic acid in aqueous solution, at several degrees of neutralization up to and including the completely ionized sodium salt, was not drag reducing while polyacrylamide of comparable molecular weight was drag reducing. Hand and Williams (1971) later reported finding maximum drag reduction of aqueous polyacrylic acid solutions over the *p*H range 1 to 3 with insignificant drag reduction over the *p*H range 3 to 9.

More recently Kim et al. (1973) and Ting et al. (1973) restudied the effects of hydrogen ion concentration (and thus degree of salt formation) of polyacrylic acid. Their conclusions indicate that polyacrylic acid, contrary to Hand and Williams (1971), is more effective in the ionized form, at *p*H levels in the alkaline range. It is of course well recognized that a polyelectrolyte such as the sodium salt of polyacrylic acid will become extended in aqueous solutions as the ionic strength is lowered and that the drag reducing qualities become somewhat enhanced on this account. We sought to clarify the behavior of polyacrylic acid and its sodium salt in aqueous solutions by synthesizing a polymer of higher molecular weight than previously reported, characterizing it by light scattering under various *p*H conditions, and determining the drag reducing properties of the polymer as a function of *p*H and ionic strength.

EXPERIMENT

Polymerization

Acrylic acid was polymerized by ultraviolet irradiation (300 watt mercury source) of an aqueous solution of the monomer under nitrogen.

The monomer previously had been purified by redistillation at 16 mm of mercury. The temperature of reaction was 25°C. Concentration of the acrylic acid in water was 20% by volume. After one hour a transparent, nearly-gelled continuum was obtained. This was transferred into distilled water and subjected to gentle agitation for several hours to form a viscous solution. No residual gel was found after this treatment. The solution was placed in a vacuum oven at partial vacuum (35 mm mercury) at 75°C for 16 hours to volatilize the residual unreacted monomer. The final polymer concentration in the solution following monomer removal, was determined by two independent methods: (1) drying to constant weight, and (2) titration with 1 Normal NaOH. The two methods agreed to within 5%.

Characterization of Polymer

The polymer was analyzed by light-scattering at 25°C in three different solvent media:

1. 1.0 M NaCl solution adjusted to a *p*H of 10 by addition of NaOH;
2. 0.5 M NaCl solution and *p*H of 4.1;
3. distilled water adjusted to a *p*H of 2 by addition of concentrated HCl.

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