Chemical and Petroleum Engineering, Vol. 37, Nos. 11–12, 2001

DWELL TIME AND EFFECT OF LONGITUDINAL DISPLACEMENT OF POWDERS IN CONTINUOUSLY OPERATING SYSTEMS

A. V. Chuvpilo

UDC 621.762.2:66.011

Improvement of the operational reliability of continuous-action mixing equipment with a thin-layer feed of initial powders and quality preparation of the mixtures, including mixtures with a differential-variable ratio of components (for example, in the manufacture of heavy-duty starter batteries, powder metallurgy, chemical and construction industries, etc.) [1–6] is an urgent problem.

A precision thin-layer feed of components to a dual-shaft bladed mixer is accomplished in a unit designed for the continuous preparation of multicomponent powder mixtures. The ratio of the cross sections of the metered feed and the mixing is as follows: from 1:100 to 1:1050 for a laboratory mixer (an output of up to 200 kg/h of prepared mixture), and from 1:290 to 1:3000 for an industrial mixer (an output of up to 3500 kg/h of prepared mixture). A powder mass with a multiple-layer flow section falls into the mixer, where it is required to spread-out evenly in the radial direction of the mixer's section, maintaining the powder in a reciprocating motion in the longitudinal (axial) direction. Nonuniformity of the transport velocity of the particles of powder (disruption of the reciprocating regime of the process) and the nature of the powders may affect the dwell time of the particles in this system.

Diffusion (I) and convective-diffusion (II) models of the process and their variants (models I-1 and I-2, and II-1 and II-2 served as the theoretical basis of an investigation of the distribution of the dwell time and the effect of longitudinal mixing [7, 8].

The diffusion model is a stable monolithic form of powder in both the static and transport states, i.e., their are no significant separations of particles one from the other, and no local displacements of particles with respect to the shear planes.

The convective-diffusion model permits an unstable state of the powder, appreciable separations of particles one from the other, and local displacements of particles with respect to the shear planes.

Model I-1 assumes a uniform axial transport velocity, no stagnant zones, and the existence of a reciprocating process regime, i.e., is a function of the equipment's design. Model I-2 is characterized by relatively good cohesion between the rough-surfaced particles, i.e., as a function of properties of the powder. Models I-1 and I-2 ensure good mutual introduction of particles of the components, and the formation of a uniform mixture of components, even in the initial zone of the mixer.

Model II-1 is characterized by the existence of stagnant zones, nonuniformity of the flow section of the powder in the mixture, and the possibility of disruption of the reciprocating process regime. The movement of microvolumes of powder along slip planes is accounted for in model II-2.

The diversity of properties of powders and their combination during the preparation of mixtures causes indistinctness between the variants of Models I and II; in the general case, therefore, schemes of mixture preparation with minor natural segregation of components should be referred to Model I, and schemes with significant segregation to Model II. It is possible to propose repeated conversion from the states described by model I to those described by Model II; here, the probabilities of conversion will depend on the previous state, and are determined by Markovian chains.

MGUIÉ. Translated from Khimicheskoe i Neftegazovoe Mashinostroenie, No. 12, pp. 11–12, December, 2001.

Probability matrices of the states were formed; the mixing coefficient was then established for the matrices on the basis of Fick's second law, and the character of the kinetic process of variation in concentration, which can be given by a continuous metered feed in accordance with a specific program, determined.

Zinc and iron powders (a powder fineness of less than 160 μm) was used for the experiments on the continuous preparation of a dual-component mixture. The following type of functions were used for the metered feed of components: periodic sawtooth, equipitched roof, and straight line. The functions adopted made it possible to mark the medium under investigation, and establish accurately the pattern of the reaction to excitation in calculating the longitudinal-mixing coefficient. The experimental procedure called for periodic introduction of a powdery tracing substance (contrastingly colored magnetic iron of the same fineness as the basic component) and its sampling together with the mixture. The design of the experimental unit called for the discharge of prepared powder onto a sectional strip conveyer, the sections of which were formed by plane vertical walls, which permit clear-cut separation of the flow of mixture into discrete parts convenient for subsequent analysis.

Use of nonmagnetic and magnetic powders permitted reliable separation of the prepared mixture into component parts, including the tracing substance, and made it possible to establish fluctuations of the dwell time of the components in the system. The experimental data were processed by methods of mathematical statistics and the theory of probability.

It was established as a result of these experiments that both models of the process were observed during the mixing, but the diffusion model predominated. This is apparently associated with the design of the mixture. The residual dwell time of components in the system was 3–5% of the total time; this corresponded to a reciprocating process regime on the whole with a high (97–95%) longitudinal-mixing effect, i.e., rather reliable structural formation of the powder mixture was realized.

REFERENCES

1. V. V. Kafarov, E. N. Marina, and V. V. Shestopalov, "Analysis of packed vessels with allowance for longitudinal mixing," *Khim. Prom.*, No. 9 (1967).
2. P. I. Luk'yanov, V. A. Bityukov, and L. I. Khristianova, "Effect of layer structure on velocity distribution during the movement of granular material in a vessel," *Khim. Tekhnolog. Topoliv Masel*, No. 9 (1967).
3. V. A. Bityukov, Yu. V. Vvedenskii, and P. I. Luk'yanov, "Procedure for analyzing the dwell time of solid particles in the lower layer of a vessel with a moving layer of granular material," in: *Proceedings of the Moscow Institute of Chemical Machine Building* [in Russian], Moscow (1968).
4. G. D. Kavetskii and A. I. Planovskii, "On consideration of the mixing of a gas and solid granular material in packed columns," *Khim. Prom.*, No. 6 (1963).
5. I. Mori et al., "Distribution of dwell time and mixing characteristics of powder materials in ball mills," *Kagaku Kogaku*, **28**, No. 3 (1964) (Russian translation), All-Union Institute of Scientific and Technical Information 51537/5.
6. A. V. Chuvpilo, *Recent Advancements in the Theory and Technique of Preparing Powder Mixtures* [in Russian], VNIIMA, Moscow (1964).
7. A. V. Chuvpilo, "Dwell time and effect of longitudinal mixing of metallic and semi-conductor powders," *Theses of Papers Presented at the Scientific-Technical Conference "Analysis, Construction, and Investigation of Equipment for Production of Power Sources"* [in Russian], Kiev (1967).
8. A. V. Chuvpilo, "Influence of dwell time and effect of longitudinal mixing of powders on reliability of automation," in: *Collection of Works by the All-Union Scientific-Research Institute of Processing and Utilization of Fuel, Academy of Sciences of the USSR "Analysis, Construction, and Investigation of Equipment for Production of Power Sources"* [in Russian], No. 2, Moscow (1969).