Conclusions

The characteristics of turbulent flows of air in the presence of solid particles in pipes (channels) and under conditions of flow past bodies have been treated. The basic results given in the book include:

1. The suggested classification of turbulent heterogeneous flows by the volume concentration and inertia (Stokes number) of particles in averaged, large-scale, and small-scale fluctuation motion.
2. The solution of a large complex of metrological problems associated with the diagnostics of the structure of particle-laden turbulent flows of gas.
3. Detailed analysis of the characteristics of motion of particles and of their inverse effect on the parameters of carrier gas under conditions of flow in vertical pipes and of flow past bodies.
4. The description (based on unified methodology within a single mathematical model) of the processes of additional dissipation and additional generation of turbulence in heterogeneous flows with relatively low- inertia and large particles, respectively.

Note at the same time that many of the important problems and aspects of the theory of turbulent flows of gas with solid particles have been hardly dealt with in the book. These are the characteristic features of highly dust-laden flows, the regularities of formation of profiles of concentration of the dispersed phase, heterogeneous flows in horizontal channels, the characteristic features of high-velocity flows with solid particles, the sedimentation of particles on channel walls, and many others.

One can use the suggested classification of turbulent heterogeneous flows to estimate in advance (prior to investigations) the presence and intensity of determining interphase interactions and exchange processes. The thus developed classification may be recommended for use in theoretical and experimental investigations of multiphase flows of various types.

The investigations referred to in the book are not characterized by a clearly defined application pattern; therefore, the results of these investigations will find application in the most diverse spheres of human activities. We will take a brief look at possible spheres of practical utilization of these results.

The developed procedure of measurements in heterogeneous flows opens up extensive possibilities for improvements in the diagnostics of multiphase flows. The diagnostics of heterogeneous flows pursue two objectives, namely, those of (1) determining the characteristics of flow for the purpose of maintaining optimal process conditions and (2) obtaining data to be employed in the calculations of concrete processes.

Examples of devices in which the thus developed diagnostic procedures may be employed to advantage include devices for sand- and shot-blasting of various surfaces, pneumatic conveyers of loose materials, classifiers of polydisperse materials by the particle size, various dust collectors, devices for thermal preparation of coal in schemes for energy-technology utilization of fuel, combustors of heat engines, devices for heat treatment of loose materials, heat exchangers with two-phase working media, and so on and so forth.

Such procedures may be further recommended for use in performing measurements in flows of gas suspensions resulting from natural processes (fogs, sandstorms, forest fires, volcanic eruptions, etc.) and from human activities (production of dust and harmful exhausts by moving vehicles and atmospheric pollution by industrial emissions).

Priority problems associated with the diagnostics of turbulent heterogeneous flows today include:

1. The investigation of the characteristics of highly dust-laden flows which involve collisional interaction of particles.
2. The measurements of the fields of correlation of fluctuations of velocities of the carrier and dispersed phases, correlations of fluctuations of concentration and velocity of particles, and so on.
3. The investigation of the impact made by particles on the fine structure of turbulence of carrier flow, in particular, on the spectrum of turbulent fluctuations of velocity and on the microscales of turbulence.
4. The investigation of the statistical parameters of flows with substantially polydisperse particles, as well as with bidisperse, hollow, porous particles, etc.
5. The development of methods of local measurement of the temperature of continuum flow, as well as of fluctuations of this temperature in the presence of particles.

In view of the rate of development of the methods of experimental investigation of heterogeneous flows, as well as of ever growing interest of numerous research teams in studying such flows, one can hope that the problems listed above will be solved in the nearest future.

The investigation results make it possible to predict the effect of particles on the turbulent energy of carrier flow. The understanding of the physics of interaction between particles and surrounding gas further enables one to control the integral characteristics of flow, such as friction and heat transfer.

The control of the properties of continuum flows in flow trains of power plants by introducing particles of certain physical properties into the flow at certain concentration of particles may be very effective. However, one must bear in mind that the presence of particles in flows almost always entails the possibility of sedimentation of particles on the walls, erosion, and other negative effects.

The investigation results described in the book make it possible to raise the intensity of processes occurring in heat exchangers, which utilize gas suspensions, by optimal selection of the basic structural (pipe diameter, etc.) and process (gas velocity) parameters, as well as of the properties (thermal and dynamic inertia) of the employed particles.

Examples of practical uses of "gas–solid particles" heterogeneous flows may be further provided by pulverized-coal ducts and pneumatic conveyers of loose materials; in the nearest future, such devices may possibly present an alternative to automobile and railroad transport. The consumption of energy for the pipeline conveyance of various materials are directly associated with the pressure loss due to a number of reasons such as the roughness of pipe walls, the conveyer length, the pipe diameter, the density, viscosity, and velocity of gas, the type of material being conveyed, the density, size, and velocity of particles, and so on. Investigations revealed that, in addition to the above-identified parameters taken into account in designing pneumatic-conveyance systems, one must further take into account the Stokes number of particles of the material being conveyed in large-scale fluctuation motion. The correct choice of this characteristic of heterogeneous flow will make it possible to significantly lower the level of turbulent fluctuations of velocity of the carrier gas phase and, consequently, reduce the hydraulic resistance and loss of pressure due to conveyance.

The process of dissolution of solid particles is a typical mass-exchange process extensively employed in the chemical industry. The inclusion of the modification of turbulence by particles will make it possible to optimize column-type units for dissolving particles in a fluidized bed; this will raise significantly the efficiency of this process.

The foregoing may be extended to various devices capable of heat treatment of loose materials (heating, drying, cooling, sintering, etc.) and employed in the food, medical, and other industries.

Note that the model of additional generation and dissipation of turbulent energy of gas flow by particles, described in this book, may be used in calculating and designing various turbulence stimulators and damping grids extensively employed in power generation and in aviation and space engineering.

I hope that this monograph will generate interest among students, postgraduates, and researchers involved in investigations of hydrodynamics and heat transfer in solid particle-carrying heterogeneous flows and will give impetus to further development of the theory of multiphase flows.

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Preface

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