TITLE: **ASH & PULVERIZED COAL DEPOSITION IN COMBUSTORS & GASIFIERS** **DATE:** April 1997

PI: Goodarz Ahmadi

STUDENTS: C. He, M. Soltani, S. Guo, J. Cao and H. Zheng, Ph.D. Candidates
J. Gayne M.S. Student

INSTITUTION: Clarkson University
Potsdam, NY 13699
(315) 268-2322

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I. ABSTRACT

OBJECTIVES: The main objective of this project is to provide a fundamental understanding of deposition process of flyash and pulverized coal particles in coal combustors and coal gasifiers. The other objective is to develop a Lagrangian particle trajectory analysis for flyash and coal particles under various conditions. Assessing the significant effects of nonsphericity of coal and ash particles, as well as turbulent dispersion, Brownian diffusion, thermophoretic, electrostatic and surface forces on wall deposition process is included in the project. Developing a semi-analytical model for deposition rate of coal and flyash particles and experimental verification of the simulation and analytical results are important parts of the study.

WORK DONE AND CONCLUSIONS: Numerical simulations of particle deposition process in a circular duct, dispersion of elongated particles in an isotropic turbulent flow field and in a recirculating region, as well as physical models for evaluating particle deposition and removal in turbulent flows were completed. The new model for particle resuspension includes the effects of surface and hydrodynamic forces and torques and covers smooth and rough surfaces. A thermodynamically consistent model for turbulent two phase flows and a kinetic base model for particulate flows were formulated. These models were used and dense and dilute two-phase gas-particle turbulent flow in a vertical duct and granular flow over a chute were analyzed.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAM: Transport and deposition of particles play a critical role in operation, efficiency, safety and maintenance of coal combustors and gasifiers. Turbulent mixing of pulverized coal significantly affects the efficiency of combustion, pyrolysis and gasification processes. Deposition of flyash and other particles on the wall leads to the formation of coal slag. Corrosion by coal slag is a serious problem in coal-gasification and combustion systems. Presence of particulate contaminant in the combustion product is also a major source of air pollution in coal energy systems. No completely satisfactory model describing the motion of a coal or ash particle in the highly transient turbulent flow and thermal conditions in coal combustors and gasifiers exists. More importantly, the controlling mechanisms for deposition of particles on surfaces in a turbulent stream with strong temperature gradients are not fully understood. Without such an adequate understanding, providing mitigation measures against slag formation and/or improving the efficiency of coal combustors are not possible. The general goal of this research is to provide such a fundamental understanding, and to develop an accurate computational model for simulating motions of ash, pulverized coal, and soot particles in complex geometries of

coal combustors and gasifiers. Availability of these tool and knowledge base will be indispensable for the future development of the environmentally acceptable coal energy system.

PLAN FOR THE UPCOMING YEAR: The plan is to complete the computer simulations for the sudden expansion combustor geometry including the effect of theromphoresis. It is also planned to perform numerical simulations of flyash and coal particles in the complex geometry of hot-gas filtration systems. Furthermore, computational modeling of elongated particle transport and deposition is also planned. In addition, a series of experimental study on flyash and coal particle deposition in the aerosol wind tunnel will be performed. Comparison of the data with the theoretical model predictions and model verification is also planned.

HIGHLIGHT ACCOMPLISHMENTS

An efficient computational model for understanding the mechanisms that control transport and deposition of particles is developed. The computational model makes use of an advanced anisotropic turbulence model and is capable of simulating flows conditions in complex passages. The particle equation of motion which includes all the forces relevant to the motion and deposition of particles is used in the simulation studies. In addition to the Stokes drag and turbulence dispersion effects, the model includes the lift force, as well as, the Brownian and thermophoretic effects. The instantaneous turbulence fluctuations are simulated as an anisotropic continuous Gaussian random vector process. The computational model have been tested earlier for several cases and its accuracy was verified. Studies concerning dispersion and deposition from a point source of particles in a turbulent air flow and deposition from uniform concentration in a circular cylindrical duct and in a recirculating flow were performed. In a related work, duct flows of dense and dilute two-phase flows were numerically simulated. Based on the downsweep flow pattern generated by the near wall turbulence eddies, a simplified model for particles deposition rate in the presence of gravity and electrostatic forces was developed. A new flow physical (flow structure based) model for particle resuspension in turbulent gas flows was also developed. Considerable progress was also made for direct numerical simulation of charged particle transport, deposition and removal.

III. ARTICLES AND PRESENTATIONS

F.G. Fan and G. Ahmadi, "On the Sublayer Model for Turbulent Deposition of Aerosol Particles in the Presence of Gravity and Electric Fields," J. Aerosol Science Technology 21, 49-71 (1994).

M. Soltani, G. Ahmadi, R.G. Bayer and M. A. Gaynes, "Particle Detachment Mechanisms from Rough Surfaces Under Base Acceleration," J. Adhesion Science Technology 9, 453-473 (1995).

F.G. Fan and G. Ahmadi, "Dispersion of Ellipsoidal Particles in an Isotropic Pseudo-Turbulent Flow Field," ASME **J.** Fluid Engineering I 1 7, 154-161 (1995).

S. Abu-Zaid and G. Ahmadi, "A Thermodynamically Consistent Rate-Dependent Model for Turbulent Two-Phase Flows," Int. **J.** Nonlinear Mech. 30, pp. 509-529 (1995).

J. Cao and G. Ahmadi, "Gas-Particle Two-Phase Turbulent Flow in a Vertical Duct," Int. J. Multiphase Flows 21, 1203-1228 (1995).

J. Cao, G. Ahmadi and Massoudi, "Gravity Granular Flows Down an Inclined Bumpy Chute," J. Fluid Mechanics 316, 197-221 (1996).