Lecture from SKIPER College

3D Characterization, Analysis, and Simulation of Multiphase Particulate Systems Using X-ray Computed Tomography

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Presided by Prof. Qi Tao

Time：9:00-10:30 (am)　Sunday, March 6, 2011

Place：Room 308, IPE mansion

Brief Introduction

Dr. Miller is the Chair and Ivor D. Thomas Professor of Metallurgical Engineering at the University of Utah. Professor Miller's research covers the areas of mineral processing and coal preparation, specializing in particulate systems, aqueous solution chemistry, colloid and surface chemistry, and environmental processing technology. Additional research is being conducted in hydrometallurgy, flotation chemistry, and particle technology. Current work includes the development of x-ray CT technology for 3-D analysis of complex particulate systems including liberation/exposure analysis, and on-line coal washability analysis. Also in progress is a program to develop flotation technology for the trona industry, a program for the preparation of magnetic activated carbon, and a program for improved design/operation of heap leach operations. Since joining the faculty in 1968, Dr. Miller has obtained 25 patents, the licensing income of which has generated over $750,000 for the University of Utah. In the last ten years grant monies to support Dr. Miller's research programs has totaled over 10 million dollars. He has authored/co-authored more than 400 publications.

Abstract

Further advancement of mineral processing technology can be facilitated by a more detailed understanding of multiphase particulate systems. Characterization, analysis, and simulation of these complex systems in 3D provide a fundamental basis for the development of improved mineral processing technology. In this regard, developments in X-ray computed tomography (CT) afford the opportunity for multiscale imaging of multiphase particulate systems in 3D and such developments include X-ray milli-, micro-, and nano-CT systems with voxel size resolution extending from the mm range down to 50 nm.

During the past 10 years point-projection X-ray micro CT systems have been used for 3D visualization and quantitative analysis of multiphase particulate systems. Analysis of packed particle beds containing as many as 30,000 particles can be accomplished in less than 3 hours with special software to establish the 3D spatial characteristics of each multiphase particle in the population and the spatial organization of the packed particle bed. Now, due to advances in X-ray optics, the resolution afforded with point-projection micro CT systems has been improved by at least an order of magnitude using a lens-based X-ray micro CT system. The development of software tools for the 3D characterization, analysis, and simulation of packed particle beds using high resolution X-ray micro tomography (HRXMT) has been applied in areas of importance to mineral processing technology including comminution (particle damage and preferential grain boundary fracture), exposure/liberation analysis (liberation-limited grade/recovery curves and coal washability), and filtration/heap leaching (pore network structure of packed particle beds and simulated flow using the LB method of computational fluid dynamics). Considerable research progress has been made as described in the following publications.

References

1. J.D. Miller, C.L. Lin and A.B. Cortes, "A Review of X-Ray Computed Tomography and Its Applications in Mineral Processing", *Mineral Processing and Extractive Metallurgy Review*, 7 (1990) 1-18.
2. C. L. Lin, J. D. Miller and C. Garcia, “Saturated flow characteristics in column leaching as described by LB simulation”, *Mineral Engineering*, Vol, 18 (2005) 1045-1051.
3. C.L. Lin and J.D. Miller, “3D characterization and analysis of particle shape using X-ray microtomograph (XMT)”, *Powder Technology*, 154 (2005) 61-69.
4. X. Li, C.L. Lin, J.D. Miller and W.P. Johnson, “Pore-scale Observation of Microsphere Deposition at Grain-to-Grain Contacts over Assemblage-scale Porous Media Domains Using X-ray Microtomography”, *Environ. Sci. Technol*., 40 (2006) 3762-3768.

5. X. Li, C.L. Lin, J.D. Miller and W.P. Johnson, “Role of Grain-to-Grain Contacts on Profiles of Retained Colloids in Porous Media in the Presence of an Energy Barrier to Deposition”, *Environ. Sci. Technol*., 40, (2006) 3769-3774.
6. A. R. Videla, C.L. Lin and J.D. Miller, “Watershed Functions Applied to a 3D Image Segmentation Problem for the Analysis of Packed Particle Beds”, *Part. Part. Syst. Charact*. 23 (2006) 237-245.
7. A.R. Videla, C.L. Lin and J.D. Miller, “3D Characterization of Individual Multiphase Particles in Packed Particle Beds by X-ray Microtomography (XMT)”, *International Journal of Mineral Processing*, 84 (2007) 321-326.
8. M.C. Sukop, H. Huang, C.L. Lin, M.D. Deo, K. Oh, and J.D. Miller, “Distribution of Multiphase Fluids in Porous Media: Comparison between Lattice Boltzmann Modeling and Micro-x-ray Tomography,” *Physical Review E*, 77(2) (2008) 026710-1-026710-7.
9. A.R. Videla, C.L. Lin, and J.D. Miller, “Simulation of Saturated Fluid Flow in Packed Particle Beds – The Lattice-Boltzmann Method for the Calculation of Permeability from XMT Images,” *Journal of the Chinese Institute of Chemical Engineers*, 39 (2008) 117-128.
10. M.I. Al-Wakeel, C.L. Lin, and J.D. Miller, “Significance of Liberation Characteristics in the Fatty Acid Flotation of Florida Phosphate Rock,” *Minerals Engineering*, 22(3) (2009) 244-253.
11. D. Garcia, C.L. Lin, and J.D. Miller, “Quantitative Analysis of Grain Boundary Fracture in the Breakage of Single Multiphase Particles using X-ray Microtomography Procedures,” *Minerals Engineering*, 22(3) (2009) 236-243.
12. J.D. Miller and C.L. Lin, “High Resolution X-ray Micro CT (HRXMCT) – Advances in 3D Particle Characterization for Mineral Processing Operations,” in *Recent Advances in Mineral Processing Plant Design*, D. Malhotra, P.R. Taylor, E. Spiller, and M. LeVier, eds., SME, Littleton, Colorado (2010) 48-59.
13. J.D. Miller, C.L. Lin, L. Hupka, and M.I. Al-Wakeel, “Liberation-Limited Grade/Recovery Curves from X-ray Micro CT Analysis of Feed Material for the Evaluation of Separation Efficiency,” *International Journal of Mineral Processing*, 93 (2009) 48-53.