300g Discrete Element Method Application for Verification of Kinetic Theory of Granular Flow in a High Shear Mixer

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Recently, multiple authors have worked to develop relevant models describing the kinematics of granular ow in mixers and uidized beds [1, 2]. An improved understanding of the rate processes associated with granulation can prove to be an invaluable tool in predicting the evolution of particle size distributions. The kinetic theory of granular ow (KTGF) is a tool developed from the kinetic theory of gas to describe the kinematics found in granular media. This theory is a statistical mechanical method of describing the mean and uctuating velocity of particles found in continuous granular media. Processes exemplifying the kinetic theory produce Maxwellian speed distributions with Gaussian distributions for velocity uctuations in each direction. Past research has shown the the KTGF can be used to describe the particle motion in a uidized bed. This is due to the inherently random motion caused by the uid mechanics in a uidized bed. It was thought kinetic theory would not suf ce when describing the kinematics in a high shear mixer, due to the shear motion in the mixer. However, recent nding by Nilpawar et al. [3] have shown experimentally that the collision frequency caused by random motion dominates over shear induced collisions. This current work attempts to validate these ndings by determining whether the distributions in a high shear mixer are indeed Maxwellian for speed and Gaussian for the velocity uctuations in each direction. This analysis is performed using discrete element modeling (DEM), a tool commonly used to simulate complex granular ow [4]. This soft-sphere discrete element model calculates the contact forces based on the method pioneered by Cundall and Strack, which expresses forces with the use of a spring, dash-pot, and slider [5]. Furthermore, motion inside the mixer is simpli ed through the use of periodic boundaries and a novel boxing scheme. This work demonstrates that under idealized conditions (coef cient of restitution=1 and no friction), the KTGF is a more than adequate means of describing particle ow, but as the process becomes less ideal, the KTGF proves to be a less successful in tting the data. If the kinetic theory is indeed valid in describing high shear kinematics, kernels based on the kinetic theory such as the equi-partition of kinetic energy (EKE) kernel can be used to model the process. Furthermore, the rate constant found in the EKE kernel is dependent on the granular temperature, particle density and collision ef ciency.

References

[1] H. Tan, M. Goldschmidt, R. Boere jn, M. Hounslow, A Salman, and J. Kuipers. Building population balances for uidized bed granulation: lessons from kinetic theory of granular ow. Powder Technology, 142(30):103ñ109, 2004.

[2] M. Goldshmidt. Hydrodynamic Modelling of Fluidized Bed Granulation. PhD thesis, Twente University, 2001.

[3] A. Nilpawar, G. Reynolds, A. Salman, and M. Hounslow. Kinematics in high shear granulation. In Proceedings: The 8th International Symposium on Agglomeration, 447 Sri Ayudhaya rd. Bangkok, Thailand, 2005. The Industrial Pharmacists Group.

[4] T. Tsuji, T. Kawaguchi, and T. Tanaka. Discrete particle simulation of two-dimensional uidized bed. Powder Technology, 77:79ñ87, 1993.

[5] P. A. Cundall and O. D. L. Strack. Geotechnique, 29:47, 1979.