QUASI-SMOLUCHOWSKI EQUATION AND DEPOSITION OF MACRO-NANO PARTICLES ONTO A SURFACE

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INTRODUCTION

Smoluchowski Equation (S.E.)

The Smoluchowski equation is a population balance equation, describing temporal evolution of particulates’ concentrations, applicable to the study of particulate dynamics and morphology such as formation of particles, bubbles, sprays, clouds and galaxies, processes of polymerization, flocculation, fragmentation, charge transfer and evolution of microbial population.

The S.E. is a set of non-linear coupled partial differential equations, by which microscopic description of particulate interactions explains how macroscopic parameters evolve in space and time. The microscopic interactions are subsumed into the agglomeration rate kernel \( \alpha \). In this study the macroscopic parameter is \( N(x) \), the number concentration of clusters of size \( x \) at time \( t \). Discrete and continuous forms of the S.E. are:

\[
\begin{align*}
\text{S.E}_{\text{Discrete}}: & \quad \frac{dN(x)}{dt} = \sum_{y \neq x} \alpha(x-y, \cdot) N(y) - \sum_{y \neq x} \beta(x-y, \cdot) N(x) \\
\text{S.E}_{\text{Continuous}}: & \quad \frac{dN(x)}{dt} = \int \left( \alpha(x-y, \cdot) N(y) - \beta(x-y, \cdot) N(x) \right) dy
\end{align*}
\]

Quasi-Smoluchowski Equation (Q.S.E.)

A set of extra equations to the conventional S.E. accounts for poly-disperse particles entering to the physical system of particle-surface. These particles enter to the system to either deposit on a free surface or form aggregates to the existing clusters deposited before.

In the S.E., collision kernels are derived based on theories describing the microscopic phenomena such as Brownian diffusion and then the macroscopic parameters are obtained by the solution to the S.E. system.

As opposed to what is conventional in the S.E., here we observe the macroscopic parameters to obtain the kernels. Discrete and continuous forms of the S.E. are shown in Eq. 2 where the macroscopic parameters (number concentrations \( N_k \), \( N(x) \) and \( N_N \) ) can be functions of space and time \( (x,t) \).

Theoretical comparisons and classifications of different flows are possible by solving the QSE describing macroscopic transport phenomena to a surface under flow, such as:

- Formation/adhesion of biofilms, organisms or bacteria on different materials and surfaces
- Volcanic ash deposited on the ground
- Particle impaction process in particle impactors
- Mass and charge transfers
- Surface characterization

CONCLUSIONS

We theorized and derived governing equations (QSE) of cluster growth and deposition on a surface versus time. One application of the governing equations could be in classification of different physical phenomena according to the probability kernels by which the observed data will be best described. For a synthetic deposition as a test example, we extracted the probability kernels which were in agreement with the given probabilities by which the data were produced.

RESULTS

Probability kernels calculated and governing equations derived are given in Fig. 4 and Eq. 3 respectively.