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Population balancing methods to describe the increase and decrease of particle size

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ABSTRACT

In this article, we first find out in a specialized way how the size of particles increases and decreases, then we define each of these two categories and explain the equilibrium equations of the population of particles in different sections and show the changes in the size of particles with the passage of time. , about the electric double layer, we discuss various processes of particles such as creation, accumulation, death, disintegration, aggregation, nucleation, breakdown, how the particles shrink and grow, and the equilibrium equations of particles in gas, liquid and solid environments. we show Particle population balances are discussed in Sect. Checking the balance of the population of particles is an optimal task in the industry and the production of chemical fertilizers, etc.

1. Introduction

The balance of the population of particles is an equation in which the amount of particle density is mentioned and it may show this amount in the equilibrium state in a special state. These equations are often prepared for particles in a continuous (continuous) phase environment. The equation of the population of particles is governed by a wide range of methods, so that in a special case, the shape of a number of particles in the system appears and others disappear. When the particles are in a continuous state and then a process is created and they create a reliable process with time that affects the rate of formation and disappearance of certain types of particles.

When the particles cross the boundaries of the system, they cause changes in the total number of particles in the system.

"birth" processes, the process of the birth of particles, other methods that show this particular state.
"Death" processes are the process of disintegration of particles.

They have separate transitions, therefore Navier-Stokes equations with average Reynolds number (RANS) for gas phase and liquid phase are written as follows.

The beginning of new particles can be created by the processes of breakage or breaking (Splitting), aggregation processes, nucleation processes, etc.

The processes of breaking and gathering cause death processes for a type of particle that is broken (into other particles) or whose existence does not increase with the continuation of the process. Since convection processes are similar to Breath and Death processes, phenomenologists are satisfied with population balance models. These models depend on the individual behavior of particles.

Among engineers, the concept of population balance is important for chemical, urban, mechanical, and material engineers. Chemical engineers use population balance with the greatest diversity.

Population balance applications cover a wide range of phase systems, such as solid-liquid spectra with a minor emphasis on decrystallization systems, and gas-liquid, gas-solid, and liquid-liquid spectra. -Liquid or solid-liquid leaching.

Prepared reactants such as (dimicrobial process, fluid bed), dicatalytic reaction (phase reactor), transfer across the interface and the reaction of equilibrium equations are the governing ones.

Particle breakage is a complex phenomenon. which is

used in the processes of flour or dusting to reduce the size of particles and to increase the specific surface area of various types of industry, including ceramics, composites, foods, minerals, paints, medicine, etc.
The operation can be done under dry and wet conditions in any of the non-continuous conditions (Bathe) and continuous open circuit (closed-circuit), open-circuit and continuous non-rotating models.

The basis of population balance formulation assumes that there is a dense number of particles in the state of particle space, which is the number of particles in each region of space with a specific density on the desired region.

Articles have been written about the engineering sciences of particle heat and particle size and forces involved, along with the drag coefficient of bubble particles[11-17]. Reza Kakulvand has investigated solutions for balancing particle populations and discovered a relationship for particles, especially gas-liquid towers.[18-20]. The rate of heat transfer in pipes has been investigated by researchers in various studies.[21-25]. Research has been conducted by researchers in the field of equations governing particles and a review of the equations and best solutions for particle and heat transfer governing particles.[26-33]

2. Theoretical:

How particles grow and shrink

To understand this article, we must first explain some specific issues:

Electric Double Layer:
It is a layer that attracts opposite ions due to the charged surface of the particle and forms a layer of opposite electric charges on the surface of the particle.

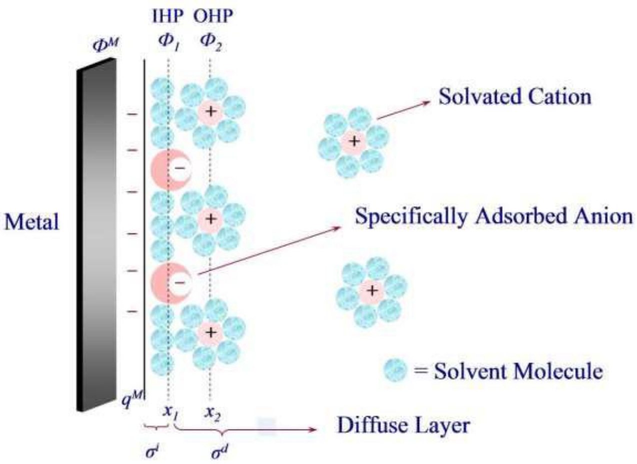

Figure 1: Electric Double Layer

IEP (Iso Electric Point) is a point where the electric charge of the surface is neutral, as a result, the electric double layer on the surface of the particle is destroyed, and the van der Waals force of attraction exists in the particles, which causes the accumulation and clumping of particles. Zeta potential at the specific pH of the particle is zero compared to the general range of acidic and neutral pH at the surface of the particles.

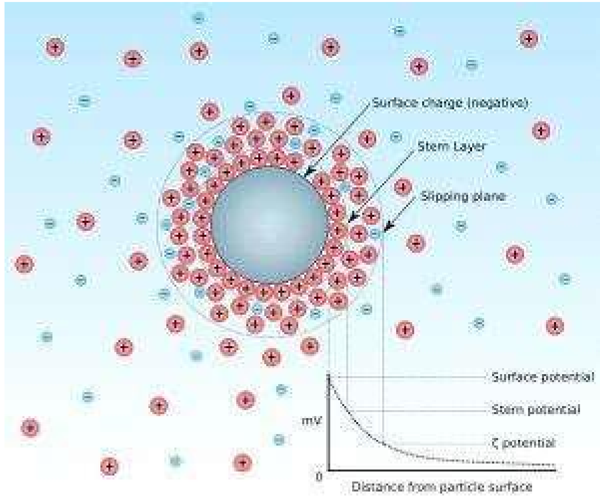

Figure2: *IEP (Iso Electric point)*

These particles accumulate and clump at zero Zeta potential, and the particle size increases, or they move away from this potential and disperse due to the repulsive force between the particles.

1- Equations of mass continuity

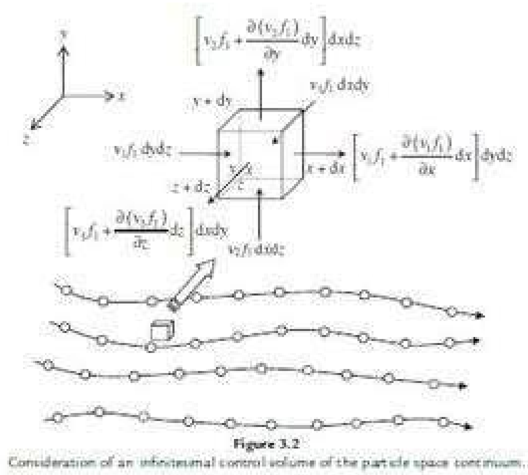

Figure 3; The fundamental equation of population balance

$$\frac{\partial f_1}{\partial t}dxdydz + \left[\frac{\partial(v_1 f_1)}{\partial x} + \frac{\partial(v_2 f_1)}{\partial y} + \frac{\partial(v_3 f_1)}{\partial z}\right]dxdydz = S_f\,dxdydz$$

$$\frac{\partial f}{\partial t} + \nabla_{\mathbf{r}} \cdot (\mathbf{v}_{\mathbf{r}} f) + \nabla_{\mathbf{x}} \cdot (\mathbf{v}_{\mathbf{x}} f) = S_f$$

2. General form of population balance:

What is the population balance approach?

The population balance method, in particular, in addition to considering the balance of motion, mass and energy, is used to consider the balance in the population of particles, these stages of evolution may be different combinations related to the nucleus such as growth, dispersion. Dissolution is accumulation or coalescence, breakage or failure to produce dispersion.

The external coordinate refers to the distances of each particle in the physical space, while the internal coordinate is primarily related to the internal properties of the particles such as size, surface area, density, etc.

The physical processes that are investigated based on this figure are the processes of heat transfer by horizontal flow (advection) and heat transfer by vertical flow, because they arise from the movement of particles in the phase space.

At the same time, this group of physical processes may be effective in creating and ending certain types of particles.

A number of particles of a particular type can also be changed among particles.

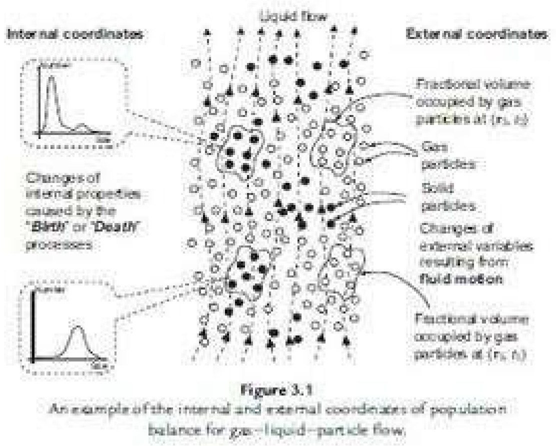

Figure 4; Population balance for gas-liquid-solid flow

The beginning and end processes of creating known particles are known as the processes of death. Phenomenologically, population growth includes the processes of convection, the creation and extinction of the good processes of the population of particles.

Equilibrium fluctuation of the population equilibrium model:

The population balance proposal for the mass solution was first described to ***Smoluchowski*** only to be enlarged.

$$\frac{dN_k}{dt} = \frac{1}{2}\sum_{i=1, i+j=k}^{k-1} \beta_{ij}N_iN_j - \sum_{i=1}^{\infty} \beta_{ik}N_iN_k$$

However, population balance models for example sedimentation/clotting also have a capture efficiency term and a growth term.

$$\frac{dN_k}{dt} = \frac{1}{2}\sum_{i=1, i+j=k}^{k-1} \alpha\beta_{ij}N_iN_j - \sum_{i=1}^{\infty} \alpha\beta_{ik}N_iN_k - S_kN_k$$

$$+ \sum_{l=k+1}^{\infty} \Gamma_{lk}S_lN_l$$

Where

N_i is the number of i.

$\beta_{i,j}$ boiling rate i and j particle size mass enlargement (in) seconds per cubic meter,

S_k is the failure rate of mass k

$\Gamma_{i,k}$ is the fracture distribution function of particle size number k produced from fracture of one particle size Collision rate between particles i and j (Aggregation Kernel) is in m^3S^{-1}.

$$\beta_{ij} = 1.294\sqrt{\frac{\varepsilon}{\nu}}(a_i + a_j)^3$$

Net production of particles: The net production rate of particles $S_{f,i}$ (x, r, Y, t) can be calculated by the algebraic sum of the net production of particles due to breaking S_C (x, r, Y, t) (Breakage/Breakup) S_B (x, r, Y, t) (Aggregation/Coalescence)

$$S_{f_i}(x,r,Y,t) = S_B(x,r,Y,t) + S_C(x,r,Y,t)$$

$$S_{f_i}(x,r,Y,t) = \int_{V_x} \nu(x',r,Y,t)\,b(x',r,Y,t)\,P(x,r|x',r,Y,t)\,f_1(x',r,t)\,dV_x$$

$$- b(x,r,Y,t)f_1(x,r,t) + \int_{V_x} \frac{1}{\delta}a(\tilde{x},r;x',r,Y,t)\,f_2(\tilde{x},r;x',r,t)\,\frac{\partial(\tilde{x},r)}{\partial(x,r)}dV_x$$

$$- \int_{V_x} a(x',r';x,r,Y,t)\,f_2(x',r';x,r,t)\,dV_x$$

The physical importance of the process caused by (Breakage/Breakup) and (Aggregation/Coalescence) is described in the following equation.

(**Breakage/Breakup**) Particles can have two consequences. The first consequence is that the number of particles in a particle component increases due to the breaking of larger particles. The second consequence is that the number of particles with fractional size decreases due to breakage.

(**Aggregation/Coalescence**) of particles also has two consequences: firstly, new particles are formed in the direction of joining smaller particles together, the second consequence is that the number of particles in one component subsequently decreases and some of them are added to other particles.

Droplet Population Balance Equation (DPBE)

In the present case, this equation can be written as

$$\frac{\partial f(V,\boldsymbol{x},t)}{\partial t} + \nabla \cdot (v_d f(V,\boldsymbol{x},t) = S(f(V,\boldsymbol{x},t),V,\boldsymbol{x},t),$$

Where

$$S = -\Gamma(V)f(V,\boldsymbol{x},t) + \int_V^{V_{max}} \Gamma(V',\boldsymbol{x},t)\ \beta(V|V')\ f(V',\boldsymbol{x},t)\ dV'$$
$$-f(V,\boldsymbol{x},t)\int_{V_{min}}^{V_{max}} \omega(V,V')\ f(V',\boldsymbol{x},t)\ dV'$$
$$+\frac{1}{2}\int_{V_{min}}^{V} \omega(V-V',V')f(V-V',\boldsymbol{x},t)f(V',\boldsymbol{x},t)$$

f(V, x, t) is the numerical density function with the particle size V as an independent variable. The vector v is the particle velocity that was introduced in the previous section.

The source term S includes the loss term (before the minus sign) and the gain term (before the plus sign) due to breakage and collision of droplets. Droplet breakup and aggregation are controlled by the breakup and aggregation frequencies, respectively. The breakup frequency Γ (V)represents the fraction of droplets breaking per unit time, while the accumulation frequency . ω (V, V) calculates the probability of a successful collision between a pair of drops. The division of the mother droplet with size V into daughter droplets with a size spectrum is given by the daughter particle β(V |V).

Integrated formula of population balance equation:

Application to particle systems with particle growth

$$\frac{\partial w(x;t)}{\partial t} + \frac{\partial (Gw)}{\partial x} = S_b(w) + S_c(w)$$

$$S_b(w) = -\Gamma(x;\varphi)w(x;t) + \int_x^{\infty} \Gamma(x';\varphi)\beta(x|x')w(x';t)dx'$$

$$S_c(w) = \frac{1}{2}\int_0^x \left(\frac{x}{\eta}\right)^2 \psi(\eta,u,\varphi)w(u;t)w(\eta;t)du$$
$$-w(x;t)\int_0^{\infty} \psi(x,u,\varphi)w(u;t)du$$

3. *Result and discussion*

As you have seen in the text of the article, progress has been made in the general field of population balance, and as far as possible, the concepts of applications and equations of population balance were investigated, the general view that the researcher can get from the subject of particle population balance is that in this matter A lot of research has been done, which has room for growth and development due to the wide range of subjects. Industry, the new technology of producing chemical fertilizers and granulating materials in petrochemicals and many economic works in this field are very valuable processes in production, industry and economy.

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