Simulation of Toner Manufacturing Process

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Abstract

Toner manufacturing process involves a series op operations including mixing, extruding, crushing and pulverizing. Simulation of such processes requires modeling of microscopic properties of material as well as macroscopic behavior of billions of particles in full size production equipment. Scale-up from prototype to full scale is difficult unless the details of the process and physical properties of the material are understood in from a single particle to a large collection of particles.

In this paper, we use two models and link them to predict the overall toner production process. We use a DEM model of individual particles while we use a flow model to describe the behavior of . The limitation of such computations is the number of particles. Even a small scale prototype requires analysis of billions of particles which is not practical with everyday computers. Thus, we perform simple experiments to validate the DEM models with smaller number of particles. The purpose of this analysis is to find a direct relationship with measurable physical properties of toners and the motion and particle size history.

Introduction

Toner manufacturing process for chemical toners involves a series of operations in growing particles. During these operations, physical properties of the material changes from nano size particles to a jel and then production of micro size particles:

Step 1: Primary Aggregation: Particle size growth from nano size particles to 1-2 μm.

Step 2: Forming of gel

Step 3: Secondary Aggregation: Breakage of gel into small aggregates: Particle size 3-10 μm.

Step 4: Stabilization of small aggregates

Step 5: Production of spherical particles

Steps 1, 2 and 4 requires control of acidity of the mixture, while steps 3 and 5 require control of temperature. Concentration of acidity, distributions of flow and temperature need to be calculated during the entire process. Forming a jel from particles and then breaking back into particles requires understanding of material behavior at both ends. Scale-up from prototype to full scale is difficult unless the details of the process and physical properties of the material are understood in from a single particle to a large collection of particles. Physical properties of the toner in small scale such as particle shape, size and surface properties have to be linked to large scale properties such as density, average stresses and size distribution of billions of particles.

In this paper, we use two models and link them to predict the overall toner production process. First we utilize a DEM model of individual particles. As an input, we include shape and size distribution and individual physical property of each component of toner. We analyze forces acting on each particle including the interaction with blades or walls to determine their motion and variation of their size.

The limitation of such computations is the number of particles. Even a small scale prototype requires analysis of billions of particles which is not practical with everyday computers. We then construct a continuum model to define motion, stresses and size distribution of particles at each point in a macroscopic sense. The material is then defined as a nonlinear material with specific properties such as concentration, particle size distribution, stress-rate of strain relationship, yield stress, etc. These material properties for the continuum model are then determined starting with the DEM model.

Modeling of the Process

In this paper, we summarize the modeling of each steps of the process.

Modeling Steps

Primary aggregation: Mixture is circulated in a baffled stirred vessel and acidified to increase viscosity. After PH reaches a desired level, acidification stops and mixing continues. In this step, initial particles create primary agglomerates of size 1-2 □m. For this analysis, the growth of the particles by modeled with a flow model as related to the turbulent mixing and concentration of acidity.

Forming of Gel: Mixing continues while acidity is reduced and temperature does not vary. In this step a gel type structure is formed. Secondary Aggregation: Mixing and agitation of the gel results in the breakage of the gel into small aggregates. In this step temperature is increased, viscosity of the gel is reduced while acidity stays constant producing aggregates of 3-10□m.

For modeling the above three steps, a continuum model is utilized. Material acidity, flow and temperature distributions are calculated during the development of process. Model includes both formation and breakage of the gel. (a)

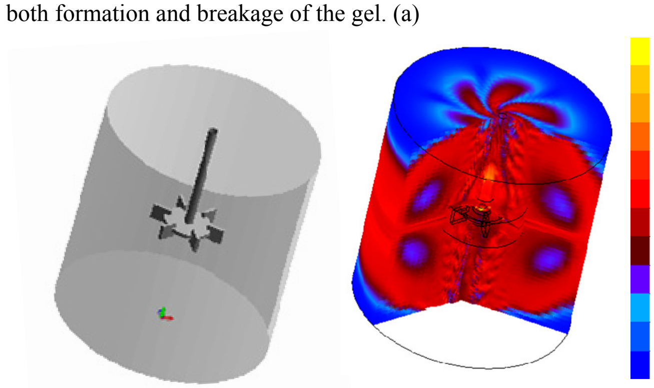

Figure 1. Left: Stirred vessel used for analysis, Right: Gel formation during primary aggregation. Color represents the size of aggregates.

Stabilization of Small Aggregates: Mixing continues at constant temperature while acidity is increased producing the final aggregate size.

Production of Spherical Particles: Finally temperature is increased to produce spherical particles.

For modeling the above two steps: We utilize DEM models modeling the individual behavior of 3-10 μm particles.

Determination of Material Properties for the Flow Model

Flow model includes formation of gel, properties of the gel and breaking of the gel under varying temperature and acidity distributions. Once it is determined, it can be used to simulate large scale operations. We model simple experiments and DEM models to determine such material properties. In summary, the modeling process involves the following steps:

- Determine the microscopic physical properties of the material,
- Perform a simple experiment and model this experiment by using a DEM or combined DEM and continuum model,
- Model the same problem with a continuum model and compare results,
- Determine macroscopic properties of the material and use it for large scale simulation.

DEM Models

DEM models are used for individual behavior of toners. In this problem, the growth of particles and the formation of the finalized shape of the particle are studied for typical particle sizes and shapes. Steps 4 and five require study of the growth and stabilization of chopped particles with varying temperatures and acidity.

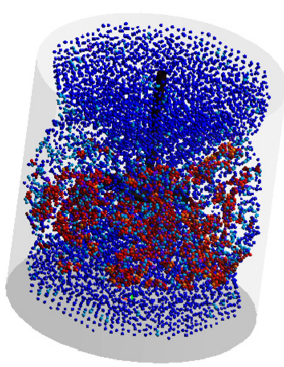

Figure 2. Agglomerate formation during mixing process. Color represents adhesion strength of aggregates.

Concluding Remarks

This paper summarizes the procedure used for simulating the chemical toner manufacturing process. During the process material properties vary considerably from liquid to gel to particles. Two models are necessary to simulate the process. Flow models are used to represent material as a continuum before the particles are formed. DEM models are used to evaluate the properties of such fluids. DEM models are also used to simulate the growth of individual particles. The problem involves multi-physics and chemistry regarding the material properties and the process. All these issues need to be identified and treated for controlling the process.

References

[1] A, Ecer, V. Rubek and K. Arican. Computer Simulation of Mixing of Toners in Electro-photographic Processes (NIP 26, Loisville, KY, 2010) p. 365-367

Authors Biographies

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