DEM Simulations of the DI Toner Assembly

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Summary. This paper describes the modelling of the toner behaviour in the development nip of the Océ Direct Imaging print process. The discrete element method is used as the simulation tool for a quantitative description of the system. The interaction rules and the associated parameters are determined for the toner particles and the surfaces of the development rollers. The model is validated with print quality results. It is shown that it is possible to achieve quantitative agreement between DEM simulations and experimental print quality results.

Key words: DEM, electromagnetism, toner.

1 Introduction

The Océ Color Technology is called Direct Imaging (DI). The heart of the image development process is formed by a Direct Imaging Unit. The print quality of the DI technology is primarily determined by the toner flow in the region between a DI-drum and an imaging roller; see Fig. 1. The collection of toner between the DI-drum and the imaging roller is called the DI toner assembly. The simulation of toner deposition conducted here is based on the discrete element method, first proposed by Cundall [2] in 1971. In the discrete element method (DEM) all toner particles as well as the rollers, are considered discrete elements. Each element interacts with its neighbouring elements and its surroundings. These interactions are modelled on a microscopic scale: the motion of each particle is tracked numerically. Every time step the forces that act on a particle are summed and from this the speed and the displacement of the particle is calculated by integration of Newton’s second law of motion. The macroscopic behaviour of the toner flow and print output is then simulated using DEM.
2 Force Models

In this section, we set up models for forces between toner particles. The nature of these forces are due to collisions, friction, adhesion, and electromagnetic actions.

2.1 Geometry

In DEM simulations all discrete elements have to be provided with a geometry to indicate the shape of the real object. A toner particle is described by $n$ clustered spheres. More realistic toner geometries can thus be achieved by increasing the number of clustered spheres that form one toner particle.

2.2 Collisions

DEM simulations involve modelling each collision between particles and between particles and the boundary objects. During a collision, having a certain contact time, particles deform, energy is dissipated in the form of heat, and particles restore to their original shape. A collision is modelled by penetration of the objects during collision. The penetration is described as a certain overlap $\xi$ between two objects and models the temporary deformation of the objects during collision. A range of contact force models are available which approximate the collision dynamics to various extents, and are of the general form

$$F_n = -k\xi^\alpha - \gamma \frac{d}{dt}(\xi^\beta),$$

where $F_n$ is the normal force between the colliding particles during the collision. The linear spring-dashpot model ($\alpha = \beta = 1$) approximates the collision dynamics to a good extent.

Collisions between particles are in general not head-on, and the particles have angular velocity. Therefore, shear also has to be taken into account.