ABSTRACT

Park, Junyoung, Ph.D., Purdue University, December, 2003. Modeling the Dynamics of Fabric in a Rotating Horizontal Drum. Major Professor: Dr. Carl Wassgren, School of Mechanical Engineering.

The dynamics of fabric is of interest in a number of applications including those that manufacture or handle textiles, garments, and composite materials. There has also been considerable interest recently from the computer graphics industry where virtual environments, models and actors are widely used in clothing design, movies, and video games. Of particular interest in this thesis is the dynamics of fabric in rotating horizontal drums such as those found in clothes washers and dryers.

In order to provide a tool for designing more efficient methods of mixing fabric, several simplified discrete element computational models were developed for modeling fabric dynamics in a rotating horizontal drum. The geometry is essentially a horizontal ball mill, but with the media consisting of fabric rather than rigid particles. Because modeling the interactions between actual pieces of fabric is quite complex, three simplified models are proposed. The first model treats a fabric element as being balled up so that it can be represented geometrically as a circular "bundle." The second model treats a fabric element as being twisted so that it can be represented geometrically as a series of connected circular particles referred to here as a "fiber." The fiber model is further classified as being either a rigid fiber or a completely flexible fiber. The rigid fiber model is not considered to be an accurate representation of fabric behavior, but is included nevertheless in order to demonstrate the effects of fiber aspect ratio. The completely flexible fiber model incorporates large aspect ratio effects in addition to fabric flexibility.

The models are used to perform a large number of parametric studies investigating the effects of bundle/fabric density, baffles, drum fill percentage, normal contact force models, coefficient of restitution, friction coefficient, bundle diameter, fiber thickness and length, and drum rotation speed and rotation profile. Measurements of the forces, power, and torque are reported to provide insight on fabric dynamics.

The simulation results indicate that fill percentage, rotation speed, rotation profile, and friction coefficient play significant roles in the bundle/fiber dynamics. Smaller fill percentages result in greater power dissipation per fabric element due to increased relative movement between elements. Rotation speeds just below the centrifuging speed and rotation profiles with large accelerations also result in large specific powers. Friction coefficients that are sufficiently small result in rocking of the fabric load and very small normal to tangential power ratios. The existence of baffles plays a significant role only at low fill percentages. Bundle diameter, fiber length and width, bundle/fiber density, and coefficient of restitution have a relatively weak influence on the fabric dynamics. Hence, in order to maximize the specific power dissipated in contacts (*i.e.* the mechanical action acting on the fabric and, hence, the degree of cleaning) the fill percentage should be decreased, the drum rotation speed should be just below the speed at which centrifuging occurs, the drum should have baffles.

The geometric computational models have only a small effect on the fabric dynamics and measured powers. The differences that do result appear to be more a function of the tangential force rather than geometric interactions. In addition, the normal force contact models used in the computations have little effect on the simulation results.