Title: Wet Solids Flow Enhancement

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Abstract:

Three main directions are considered in the study of wet granular materials. The first are the characterization or the flow characteristics of wet model systems. The flow characteristics were determined using both the tensile strength and the shear loci of the wet powders. A simplified shears tester was used to determine the shear locus. The shear results were consistent with the uniaxial tensile measurements made using a Parfitt Tensile Strength Tester with an oversized split box.

Second, the flow properties of wet materials differ from those of the free flowing dry solids due to the attractive capillary forces. At low volume fractions of liquid, the capillary bridges connecting the particles are mainly responsible for the cohesive properties of the wet powder. Several factors, such as the liquid content, the particle size and void fraction, surface tension and contact angle determine the properties of the powder. The objective is to modify these attractive forces to improve the solids flow and, possibly, to prepare powders of the desired flow properties. An example would to induce a small cohesiveness in a free flowing powder to reduce the amount of segregation during flow.

While past work has emphasized the modification of the surface tension by the addition of surfactants, the effect of changing the hydrophobicity of the surface on the tensile strength was studied in this part of the project. Octadecyltrichlorosilane (OTS) was used to treat monodisperse glass beads of sizes between 1 micron and 2.24 mm. OTS provides $Si(CH_2)_{17}CH_3$ groups that bind with the surface hydroxyl groups to make it hydrophobic. Contact angle measurements were made to probe the difference between unsilanized and silanized glass particles, and changed from 79 to 102 degrees after silanization. Silanized particles showed no measurable tensile strength. The tensile strength of mixtures of treated and untreated particles showed that the tensile strength varies linearly with the volume fraction of treated particles. Addition of small (1-10 micron) treated particles to a mixture of larger particles had no effect on the strength of the material.

Third, a Bruker (Amx-360) Nuclear Magnetic Resonance Imager was used to study the distribution of water in the wet granular media. The region sampled was a cylinder 25 mm in diameter and 25- 40mm in length. Eight to sixteen slices containing 128x128 to 256x256 pixels were generated for each image. The study was complemented by the imaging of other capillary surfaces, such as sessile droplets in a variety of substrates. Clear images of the water bridges were obtained for large particles (2-3 mm). They showed a relatively uniform distribution of water bridges for the untreated hydrophilic particles, while the silanized hydrophobic particles pushed the water phase to the walls of the container. Because of the presence of the solid surfaces, no imaging was obtained for the mixtures of smaller particles. The solid surfaces provide a sink that dramatically reduces the relaxation time and signal

intensity to an undetectable level. Images of single droplets on a surface show also distinct signal profiles with a gradient of the signal in the neighborhood of free surfaces that was very different from that found near solid surfaces. Finally, the natural oils found in mustard seeds and peppercorns give a strong NMR signal. They were used as markers to observe the discharge of a cohesionless powder in a small scale silo. The resulting images show clearly the effect of the walls in the solid motion in the silo.