Dewatering natural fiber suspensions via compression

June 17 2016

The removal of water from dense suspensions is a longstanding and perplexing industrial challenge—one that's particularly important when it comes to papermaking and wastewater treatment.

But now, the work of a group of researchers from the University of British Columbia and the University of Cambridge is providing insight into both process and product development for natural fiber suspensions.

As the group reports in *Physics of Fluids*, they discovered that the microstructure of suspensions has a significant effect on the macroscopic behavior of the suspension under compression. In other words, the way a suspension responds to large compressive stress is sensitively dependent upon the precise constitutive behavior—the rheology and permeability—of the suspension.

The theoretical model involved in this work describes the dynamics of a mixture or suspension using two-phase theory.

"This formulation describes the coupled dynamics of a fluid phase and a solid (fiber) phase on a continuum scale, much larger than the size of an individual fiber," explained Duncan Hewitt, Research Fellow, Gonville and Caius College, Department of Applied Mathematics and Theoretical Physics, University of Cambridge.

The group's model describes the evolution of the solid fraction, which is "the relative fraction of fiber to fluid within a particular location," he added. "This formulation is relatively well established—the most complicated part of the modeling is the rheological description of the solid phase (manner in which the solid phase transmits and responds to stress)."

To put their model to the test, the group recreated a well-known experiment—outlined by Darcy—to determine the constitutive behavior of the fibrous suspensions by mimicking a traditional French coffee-making press.

"Using these devices, we were able to measure all of the empirical relationships required for the two-phase model," Hewitt said. "Then we tested the model under industrially relevant, but not widely studied, conditions of rapid compression using a French press geometry."

The group discovered that the behavior of nylon fibers under rapid unidirectional compression is in agreement with their model.

"Fibers build up near the compressing piston, which causes the required load to increase," said Hewitt. "But for cellulose fibers, the local solid fraction is more uniform. The fibers spread more evenly—rather than clogging up near the permeable piston, which our model predicts."

In terms of applications, "there is a burgeoning economy, commonly termed the 'bio-economy,' based upon developing remarkable new products from cellulose or the constituents of plant biomass," Hewitt explained. "And bio-based materials made from cellulose, such as nano- or micro-crystalline cellulose, are at the forefront of replacing numerous oil-based plastics with natural ones."

Fibrous suspensions are extremely versatile and can also be used for many other applications—including rheology modification, cosmetics, and nutraceuticals. "At the heart of this growing industry, as well as traditional papermaking, is the removal of water," he noted. "Our work helps with the design, scale-up, and operation of one of the most critically important units of operation within this process. It's also relevant for mining and wastewater treatment, for which the dewatering of suspensions and sludges is a key process."

Next up? The group is continuing their work with an industrial sponsor "to help develop simulation tools useful for design of industrial machinery," said Hewitt. "The most pressing physical question we'll explore is the manner in which such suspensions transmit shear—as opposed to compressional—stress."

More information: Dewatering of Fibre Suspensions by Pressure Filtration, *Physics of Fluids*, DOI: 10.1063/1.49582

Provided by American Institute of Physics