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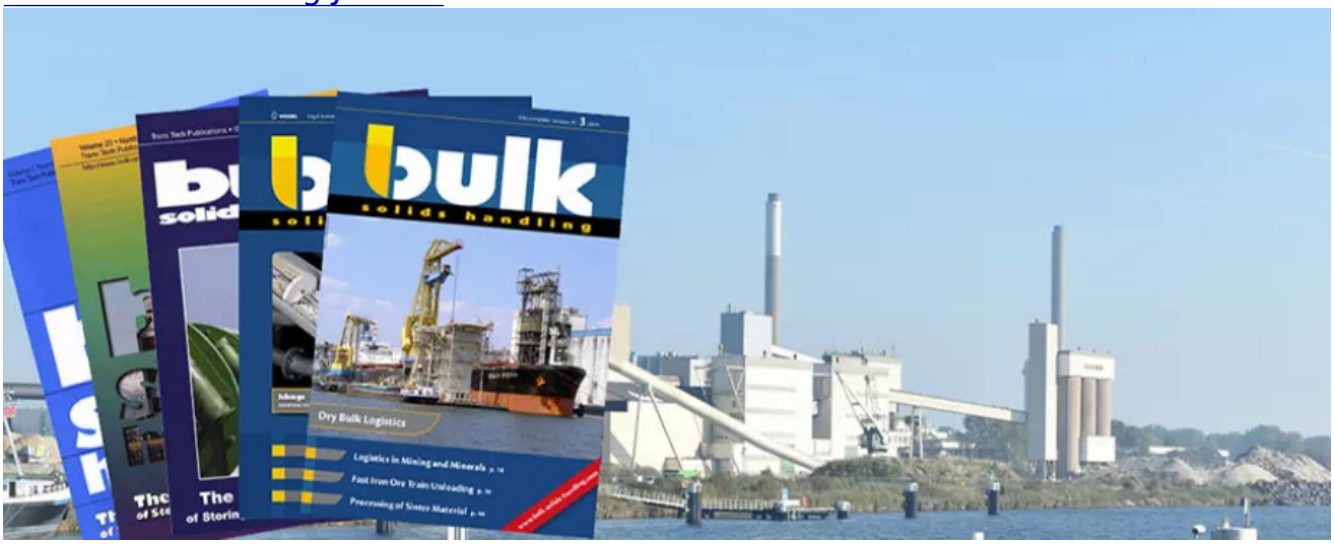

Forschungsbeitrag

On Rapid Flow of Bulk Solids

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A survey is first given on the literature of flow theories of bulk solids as well as the present state of the art on constitutive equations for rapid flow of bulk solids and powders. Then a collision-slip process is defined as the main mechanism responsible in rapid flow theories and a set of pertinent equations are derived for the normal and shear stresses in plane shear rapid flows of bulk solids. An analysis is then presented on the rapid Couette flow of bulk solids and the results available in the literature. It appears that rapidly flowing bulk solids do behave similarly to non-Newtonian micro fluids and do give rise to normal stress effects as well as non-Newtonian free surface profiles in Couette flows reminiscent of Weissenbergs`s effects for classical non-Newtonian Couette flows.

There has recently appeared a great industrial interest in rapid transport of bulk solid materials such as granular materials and powders. Traditionally, bins and hoppers were of wide use in various industrial operations dealing with bulk solids. However, recently, with the advent of utilization of coal as a effective energy source to replace oil there has appeared a great need to understand the rapid transport properties and rheology of powders blown through complex pipe networks and loops. This interest has been contagious and has created a need to understand the rapid flow and transport of powder-like materials in other industrial firms dealing with bulk solids, such as concrete, metal, granular agricultural and pharmaceutical materials, powders, propellant grains, sands,

fluidized beds, bulk reactor fuels, solid wastes and many more. Thus, it will become highly desirable to have a set of constitutive equations for powders suitable for their rapid flows in which the main mechanism for transport is continuous particle collisions. Therefore, the purpose of the present research work is, first, to present a mathematical model or a set of constitutive equations for the rapid flow of powders and, second, to analyze the rapid Couette flows of such powders both theoretically and experimentally. Rapid flow refers to those flows which are maintained by continuous particle collisions in an inertia dominated setting with the effects of inter particle as well as boundaries friction and slip taken into consideration.

First a set of constitutive equations will be derived for the stresses and the couple stesses which predict normal stress effects reminiscent of non-Newtonian fluid behavior. Our preliminary calculations as presented here, indicate that these constitutive equations resemble in fact non-Newtonian microfluid behaviors in the sense that the stresses depend on the square of both the velocity gradients and particle microrotation gradients.