

## Effect of Particle Size and Concentration on Flow Behavior of Complex Slurries

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### ABSTRACT

The flow pattern of complex slurries depends on the contents of fine, especially colloidal particles. The paper describes experimental investigation of the complex hydro-mixtures focused on evaluation of the effect of particle size and concentration on slurry flow behavior in the laminar and turbulent regime. Sand slurries conveyed in water as well as in low and medium concentrated Kaolin slurries and fly and bottom ash slurries were experimentally investigated with respect to the solid phase concentration and composition and their flow behavior was evaluated.

**KEY WORDS:** complex slurry; sand; Kaolin; fluidic ash; effect of particle size distribution; effect of shearing.

### NOMENCLATURE

$B$	material parameter
$c_v$	slurry volumetric concentration, -
$d, d_{50}$	particle and mean particle diameter, respectively, m
$D$	pipe diameter, m
$Fr$	slurry Froude number
$Fr_w$	mean particle Froude number
$i$	hydraulic gradient, m/m
$K$	fluid consistency, Pa s <sup>n</sup>
$n$	flow behaviour index, -
$V_s$	average slurry velocity, m/s
$V_{TR}$	laminar/turbulent transition point, m/s
$w$	particle fall velocity, m/s
$\alpha$	material parameter
$\rho$	density of liquid, kg/m <sup>3</sup>
$\rho_p$	density of solids, kg/m <sup>3</sup>
$\rho_s$	density of slurry, kg/m <sup>3</sup>
$\varphi$	Durand function
$\tau_y$	yield stress, Pa

### Subscripts

$w$	water
$p$	particle, solids
$s$	slurry

### INTRODUCTION

Horizontal transport from collector to storage tank or feeder of vertical transport line should play a significant role in the deep sea mining technology. The raw slurry transported from collector to vertical hydraulic pipeline transport system will consist of poly-metallic nodules as well as from clay particles, which will be collected together with the nodules. The flow behavior of complex slurry in horizontal pipe is therefore important for the safe and economical design of the transport technology. However, most knowledge on dense slurry pipeline flow has been concerned with the slurries consisting of either coarse particles with settling tendencies or very fine particles creating homogeneous, often non-Newtonian slurry. The flow behavior of the slurry containing both coarser and very fine particles has not been hitherto sufficiently clarified.

Flow behavior of complex slurry depends on particle size distribution (i.e. contents of fine, medium and coarse particles), density, shape, and concentration. It is strongly affected by the density and rheological properties of the carrier liquid, too. The behavior of the system is determined by a mutual effect of the attractive and repulsive forces between the solid particles. Presence of fine, especially colloidal solid particles in a Newtonian liquid evokes a complex rheological behavior of the slurry. During the slurry flow shear-induced translational and rotational motions of the particles cause hydrodynamic interactions which lead to the particle collisions and formation of temporary multiples. It leads to an increase in the rate of viscous energy dissipation and the bulk viscosity of the slurry. In the systems containing colloidal particles inter-particle interactions of non-hydrodynamic origin are the most significant. They originate from the random Brownian motion of particles and colloidal forces due to the van der Waals attractive forces and the electrostatic repulsive forces and usually evoke non-Newtonian behavior of the slurry. Even in the medium or low concentrated fine-grained suspensions both types of the interactions can exist. Their effect on the slurry rheology is a function of the physical and electrochemical characteristics of the particles, the carrier liquid and depends on the type of the flow (Nguyen and Boger, 1984; Vlasak, Chara and Stern, 1999 a).

The flow pattern of fine-grained and complex slurries depends strongly on contents of very fine, especially colloidal particles. If their content increases the slurry flow behavior changes from Newtonian to non-