Correlating Yield Stress with Pumpability of Mining Tailings

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Introduction
Tailings are the materials left over after the process of separating the valuable fraction from the uneconomic fraction (gangue) of an ore. Tailings are distinct from overburden, which is the waste rock or materials overlying an ore or mineral body that are displaced during mining without being processed [1].

The extraction of minerals from ore can be done two ways: placer mining, which uses water and gravity to extract the valuable minerals, or hard rock mining, which uses pulverization of rock, then chemicals. In the latter, the extraction of minerals from ore requires that the ore be ground into fine particles, so tailings are typically small and range from the size of a grain of sand to a few micrometres [2]. Mine tailings are usually produced from the mill in slurry form (a mixture of fine mineral particles and water) [2]. The composition of tailings is directly dependent on the composition of the ore and the process of mineral extraction used on the ore [1].

Usually, the major quantity of a tailings product consists of rock, mainly ground to a fine size ranging from coarse sands down to powder consistency. Many Tailings may also contain small quantities of different metals that are found in the host ore as well as added components used in the extraction process.

Usually tailings are stored in tailing ponds. Tailing ponds are areas where the waterborne refuse material is pumped into a pond to allow the sedimentation of solid particles from the water. In 2000 it was estimated that about 3,500 active tailing ponds existed worldwide [3].

Tailings ponds are instrumental in storing the waste coming from separating minerals from rocks, or the slurry produced from tar sands mining. Often, tailings are mixed with other materials like bentonite to slow down the release of impacted water to the environment [1]. However, no matter which composition the tailing has, it needs to be pumped from the mine to the pond. In order to understand if a (modified) tailing can be pumped with the existing pumping equipment, not just the viscosity needs to be determined but also the yield stress $\tau_0$. The yield stress describes the amount of energy needed to overcome elastic behaviour for a given fluid and enter sustainable flow.

As can be seen later this yield stress value is strongly dependent on solid content of the slurry. The yield stress value can be extracted easily from a simple measurement on the HAAKE Viscotester iQ rheometer.
As soft solids and slurries like tailings are often difficult to work with when using conventional parallel plate or coaxial cylinder geometries on rotational rheometers due to possible wall slip and excessive sample disruption during sample loading into narrow gaps, vane geometries are recommended here.

When a vane rotor is fully immersed in the sample, the yield stress itself can then be calculated according to Boger [4]:

\[ \tau_0 = \frac{M_{\text{max}}}{K} \]  

With \( M \) being the Torque and \( K \) the vane parameter that depends on the height (\( H \)) and the diameter (\( D \)) of the paddle according to:

\[ K = \frac{\pi \cdot D^3}{2 \cdot H} \left( \frac{H}{D} + \frac{1}{3} \right) \]

Thus, in order to determine the yield stress the Torque (or corresponding shear stress) needs to be tracked as a function of time. The maximum value can then be calculated into the yield stress.

**Experimental Results and Discussion**

We recommend to rheologically test tailings with vane rotors to prevent wall slip. Fig. 1 shows the HAAKE Viscotester iQ rheometer for vane configuration as well as an open stand to allow testing samples in large containers.

For this study, sand mine tailings have been tested at different solid mass fractions so that a yield stress vs. mass fraction map could be derived later.

Fig. 2 shows as an example the yield stress determination according to the Boger model. The test was conducted with a 0.4 solid mass fraction tailing.

With this easy and fast method a range of sand mine tailings with different solids mass fractions ranging from 0.2 to 0.5 have been tested. The result can be seen in Fig. 3 as a plot of the respective yield stress values versus the solid content.

With the data derived from a short series of tests shown in Fig. 3, the pumpability of a specific tailing can then be easily predicted by calculating the needed pumping pressure in bar via the cross-section of the pipe and the yield stress.

**Conclusion**

The vane rotor method on the HAAKE Viscotester iQ rheometer is a quick, simple and accurate approach to measure the yield stress of mining tailings. Those values can then be easily correlated with the pumpability of a specific tailing formulation with given solids mass fraction.

**Literature**


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**Fig. 2: Flow Curve of a tailing with 0.4 solids mass fraction at room temperature (RT) with automatic yield stress extraction according to Boger.**
Fig. 3: Yield Stress as a function of solids mass fraction for sand mine tailings at RT.