

# Shear and Rheology Reduction for Flocculated Thickened Tailings

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## Abstract

*Test work has been conducted to determine the effect of shear on the rheology of flocculated thickened tailings of Minera Escondida with the objective of investigating the relationship between energy input and rheology reduction. This paper presents the test work results with the purpose of initiating discussion regarding the importance of conditioning flocculated high density thickened tailings to minimise rheology for pumping and pipeline transportation.*

*A shear device was installed to determine the effect of shear on thickener underflow rheology. The device shears the tailings breaking down the floc-aggregate structure and thereby reducing the mixture rheology.*

*Comparison between unsheared, sheared and fully sheared samples was performed. The results show that a significant rheology reduction can be achieved by shearing the tailings. A correlation between shear device energy input and rheology reduction has been obtained.*

## 1 Introduction

The rheological properties of flocculated thickened and paste tailings can be altered by breaking the floc-aggregate structures by shearing the mixture.

The paper presents the results of test work conducted to investigate the performance of a shear device developed to reduce the rheology of flocculated thickened tailings slurries. The samples used correspond to Los Colorados and Laguna Seca tailings streams in Minera Escondida.

## 2 Shear device

The shear device, shown in Figure 1, is essentially pipe housing with an inlet and outlet in which different shear rotors can be placed. The flow direction through the device can be reversed. Figure 2 shows the test shear device installation.

Three shear rotor configurations were investigated; bob, impeller and vane as shown in Figure 3. The degree of shearing action within the device is varied by changing the rotational of the rotor using an electric motor controlled by a variable speed drive.

The shear device was connected to a thickener underflow pipe (after a peristaltic pump discharge). The shear effect of the pump was considered to be negligible due to the gentle pumping nature of the peristaltic pump.

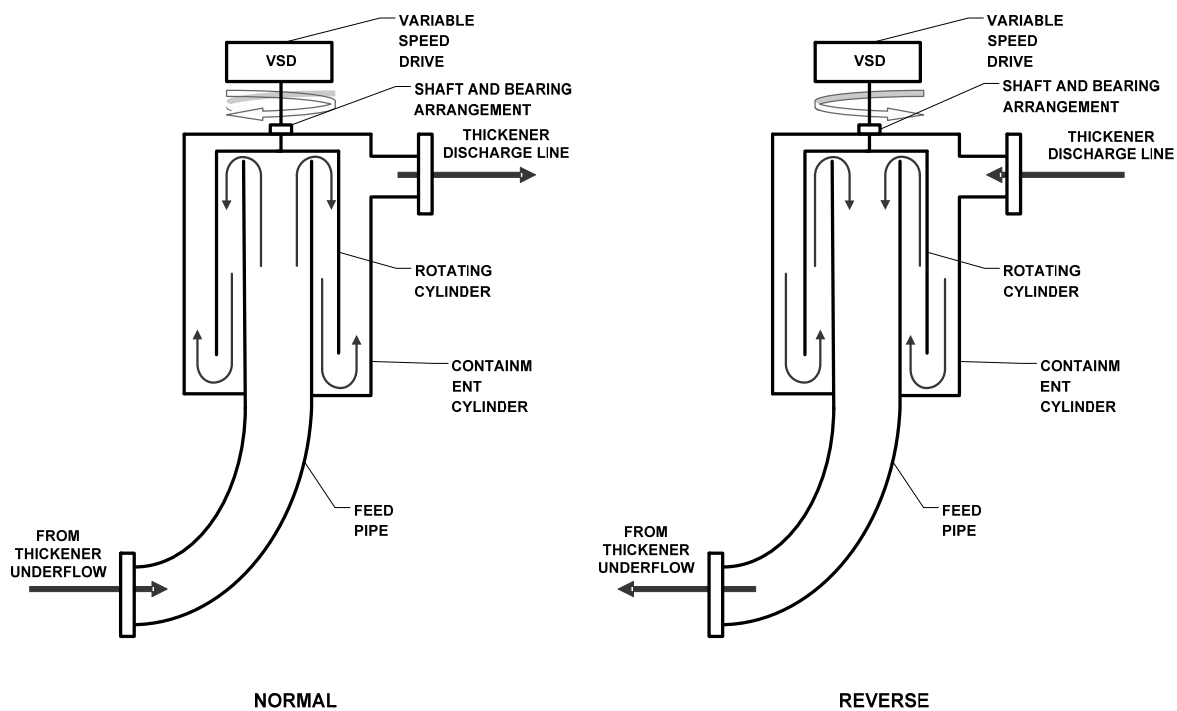
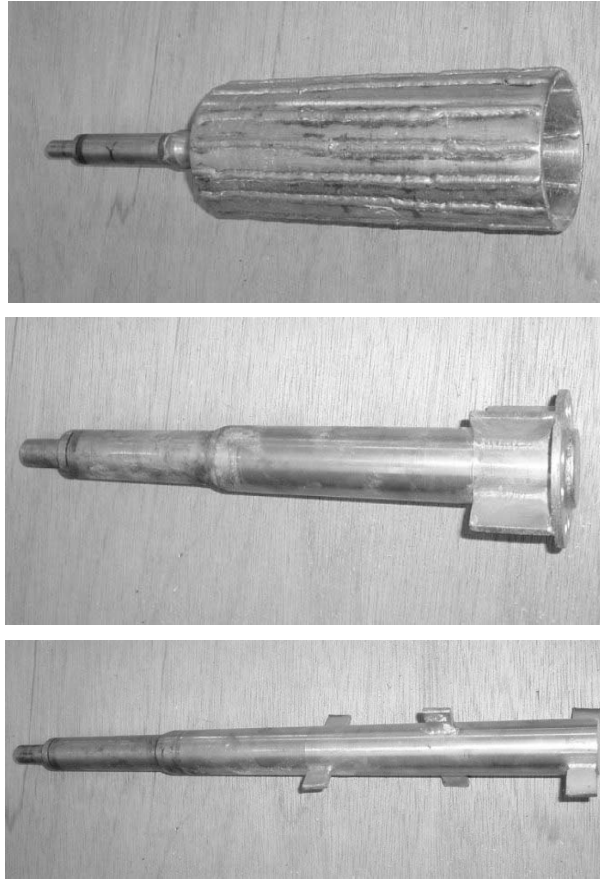


Figure 1 Shear device



Figure 2 Shear device installation



**Figure 3** Shear rotor configurations

### 3 Experimental investigation

Copper tailings samples were prepared using a pilot scale thickener. Several flocculant types and dosages were used to produce a range of underflow concentrations.

The following test work was conducted.

#### 3.1 Tailings properties

Tests were conducted to determine the material properties of the copper tailings samples, as indicated below. Previous tests indicated that the tailings contain clay minerals as: muscovite, illite, kaolinite, pyrophyllite, alunite, pyrite, siderite, plagioclase, microcline and chlorite.

##### 3.1.1 Solids specific gravity

The average specific gravity of the tailings is 2.68, with measured values ranging from 2.53 to 2.71.

##### 3.1.2 Particle size analysis

Figure 4 shows measured particle size distributions for two samples of the copper tailings.

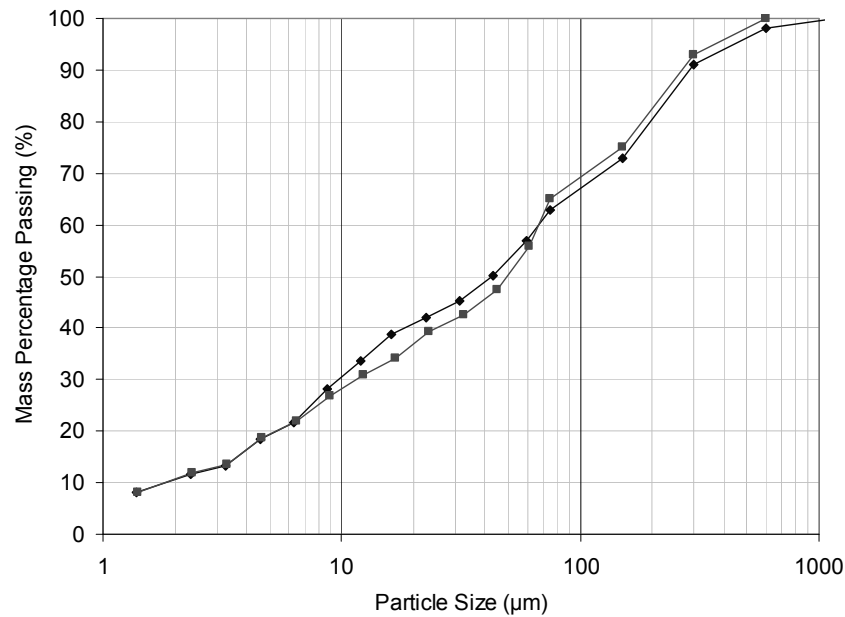
##### 3.1.3 Slurry pH

The pH of the slurry was measured using a calibrated hand held pH meter. The average pH reading was 9.76.

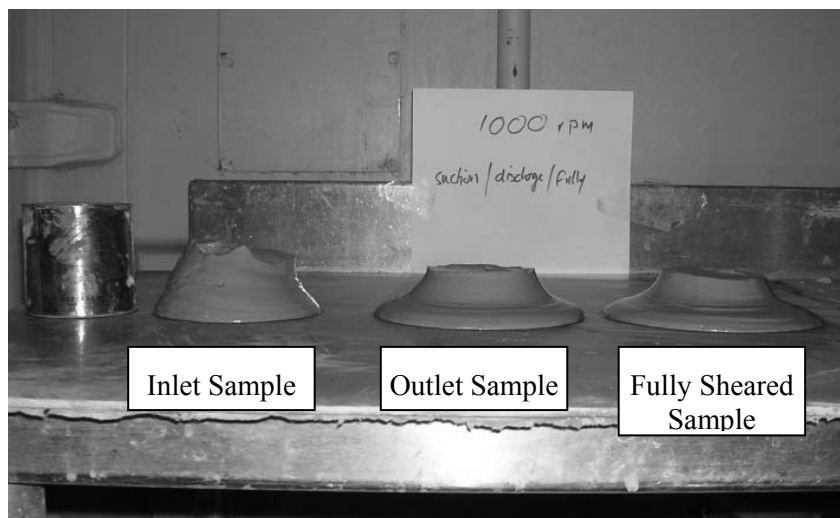
#### 3.2 Slump tests

Slump tests provide an indication of the consistency or ‘stiffness’ of the thickened tailings and accordingly provide a good quality control measure.

Small scale slump cylinder tests (76 mm high and 76 mm diameter) were conducted for all tests as shown in Figure 5.



**Figure 4 Particle size distribution**



**Figure 5 Typical slump test result**

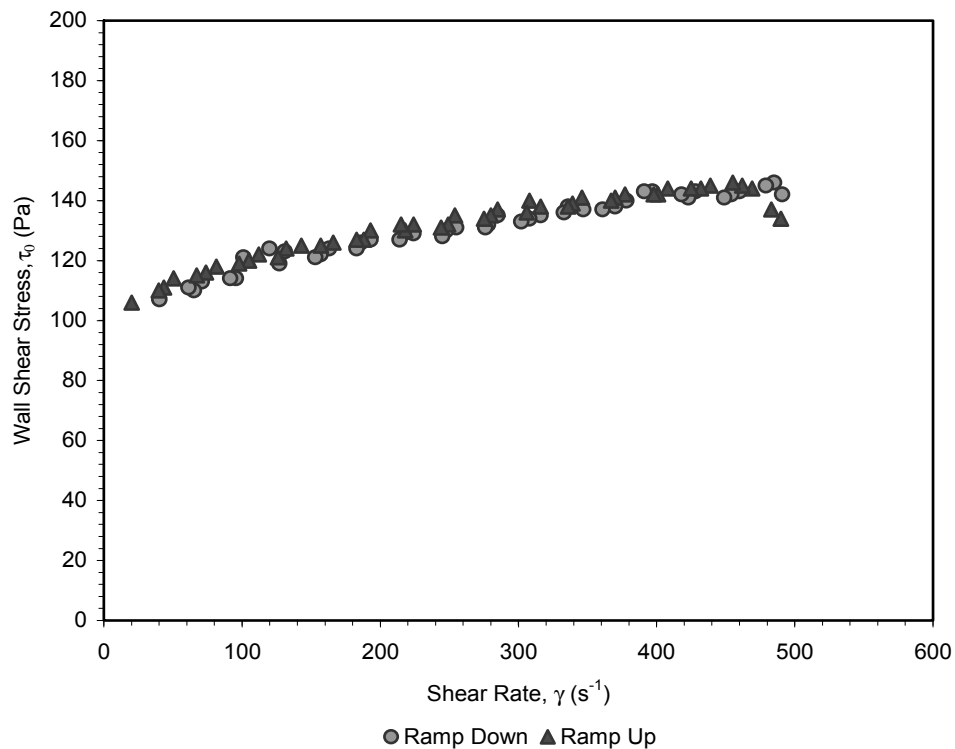
### 3.3 Viscometer tests

A rotational viscometer was used to determine the yield stress, rheogram and shear energy for the rheological characterisation of the tailings.

Flow curves or rheograms obtained using the rotational viscometer in a bob and cup configuration established whether the tailings samples were fully sheared. This was determined by obtaining a ‘ramp-up’ rheogram to  $500 \text{ s}^{-1}$ , and then ramping down to  $0 \text{ s}^{-1}$ . If the sample is fully sheared, the curves are co-incident as shown in Figure 6.

It is not possible to determine flow curves for un-sheared or partially sheared thickened tailings as rheological properties are changed during the test due to the shear between the cup and rotating bob.

Accordingly, for these slurries the vane yield stress was measured using the method proposed by Boger and Nguyen (1985).



**Figure 6** Typical fully sheared rheogram

### 3.4 Shear device tests

The general procedure for the shear device test work was as follows:

- Mount the shearing device.
- Ensure the pilot thickener is operating at a relatively constant density (from operator).
- Set the rotor rotational speed.
- Collect samples from the shear device inlet and outlet. Measure the flow rate through the device and the rotor torque (from the variable speed drive controller).
- Measure the vane yield stress for the inlet and outlet samples. Conduct slump tests for these samples.
- Shear the outlet sample further using a hand held drill and agitator until the ramp up and down flow curves are coincident. Measure the vane yield stress and conduct a slump test.
- Measure the slurry density and pH. Collect a sample for particle size analysis.

## 4 Measured data analysis

### 4.1 Vane yield stress

Figure 7 presents vane yield stresses recorded for various shear device configurations and rotor speeds.

The shear efficiency is based on the unsheared vane yield stress (inlet sample), partially sheared vane yield stress (outlet sample), and the fully sheared vane yield stress (sample fully sheared with an agitator).

The percentage reduction in vane yield stress is defined as:

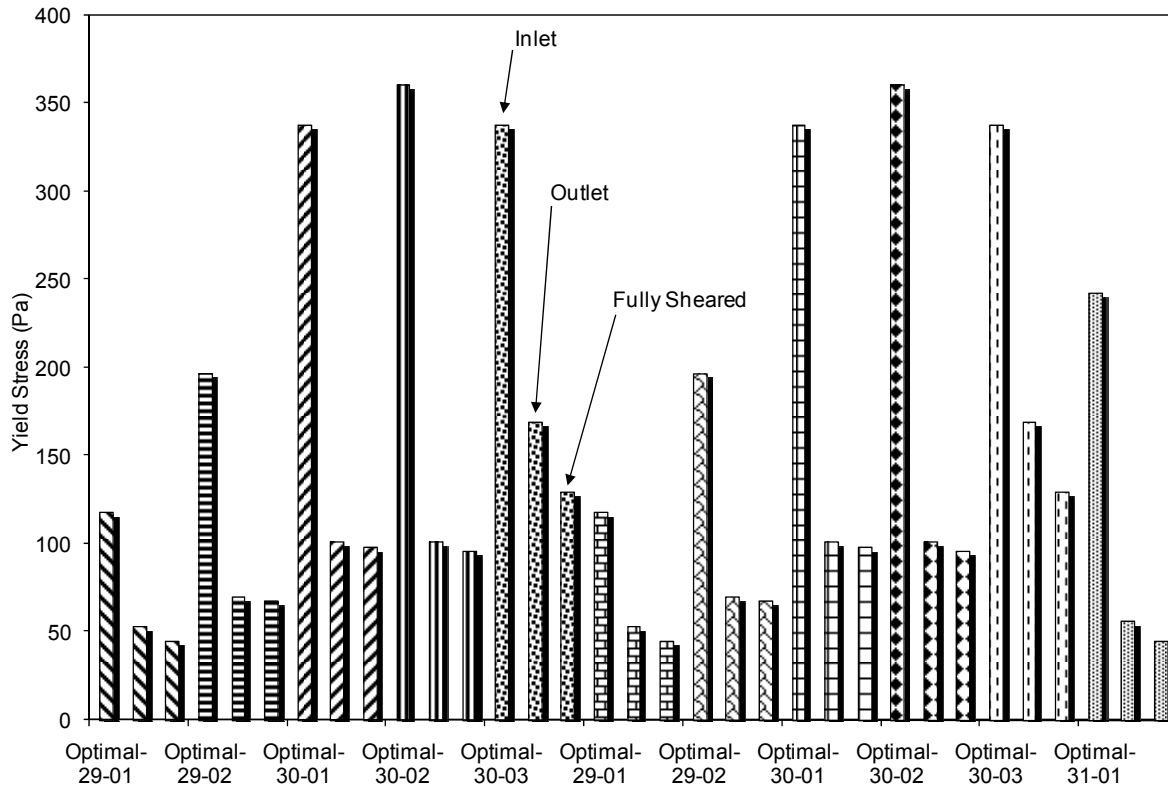
$$\% \text{ Yield stress reduction} = \frac{(\tau_{yIn} - \tau_{yOut})}{(\tau_{yIn} - \tau_{yFS})} \quad (1)$$

where:

$\tau_{yIn}$  = unsheared vane yield stress (inlet sample) [Pa].

$\tau_{yOut}$  = device outlet sample yield vane stress [Pa].

$\tau_{yFS}$  = fully sheared sample yield stress [Pa].



**Figure 7 Measured vane yield stresses (inlet, outlet and fully sheared samples)**

### 4.2 Absorbed energy

The energy input to the slurry is calculated from the measured motor torque and motor speed, and normalised to a volume basis using the measured flow rate through the shear device. The expression used to determine the energy absorbed per unit volume is:

$$E = \frac{P}{Q}, \quad (2)$$

where:

E = absorbed energy per unit volume [J/m<sup>3</sup>].

P = power absorbed [W].

Q = flow rate [m<sup>3</sup>/s].

The absorbed power was calculated as:

$$P = \frac{2 \cdot \pi \cdot N \cdot T}{60} \quad (3)$$

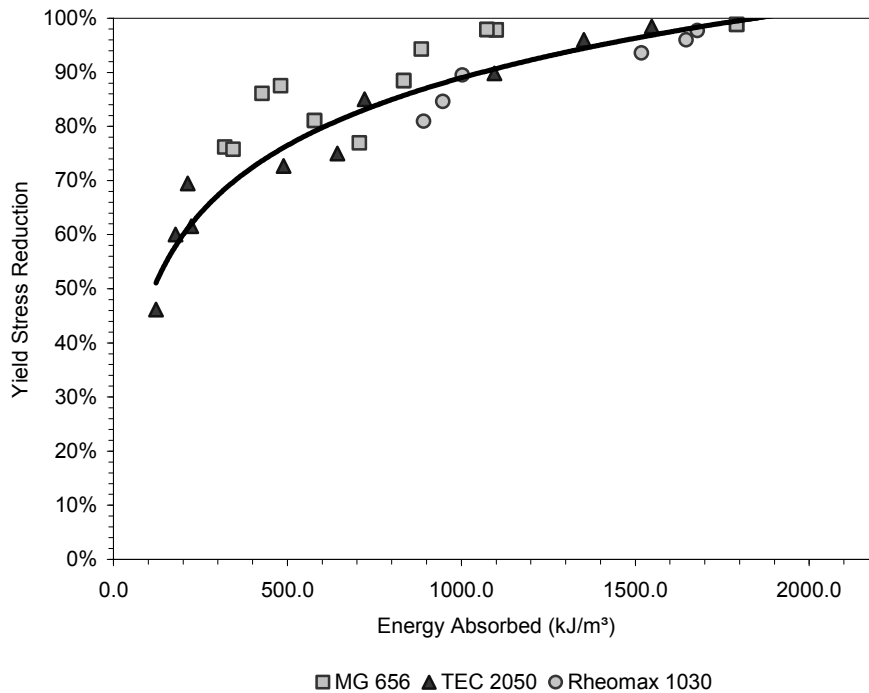
where:

- N = device speed [rpm].
- T = rotor shaft torque [N·m].

The percentage yield stress reduction as a function of absorbed energy is presented in Figure 8 for the following test variables:

- Three shear device configurations.
- Shear device speed ranging from 500 RPM to 100 RPM.
- Three flocculant types.
- Slurry density ranging from 1445 kg/m<sup>3</sup> to 1684 kg/m<sup>3</sup>
- Flow rate through the device ranging from 0.03 ℓ/s to 0.22 ℓ/s.

Referring to Figure 8, initially there is a significant reduction in yield stress with absorbed power but this effect diminishes with increasing absorbed power. This trend is independent of the test variables noted above apart from flocculant type which slightly impacts the trend curve.



**Figure 8** Device yield stress reduction as a function of absorbed energy

### 4.3 Absorbed head

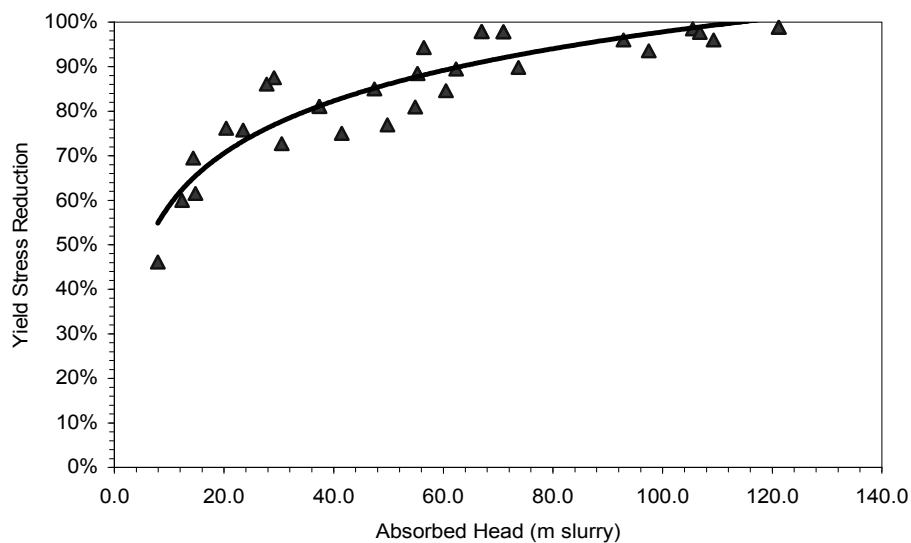
The data is further normalised by dividing the energy absorbed per unit volume by the slurry density to obtain the absorbed head, as follows:

$$H = \frac{E}{\rho_m g}, \quad (4)$$

where:

- H = head absorbed [m].
- $\rho_m$  = tailings slurry density [ $\text{kg}/\text{m}^3$ ].
- g = acceleration due to gravity [ $9.81 \text{ m}/\text{s}^2$ ].

The absorbed head is measured in meters of slurry, in the same manner that head is specified for slurry pump duties. Figure 9 presents the reduction in yield stress as a function of absorbed head.



**Figure 9** Device yield stress reduction as a function of absorbed head

## 5 Conclusions

The main conclusions from tests performed are the following:

- The yield stress of flocculated thickened tailings slurries are significantly reduced by applying shear energy.
- The various shear device rotors performed similarly for a given energy consumption.
- The rheology reduction as a function of energy input per tailings volume is similar for all concentrations and flocculant types tested.
- In the particular case of the tailings tested, an 80% yield stress reduction (80% of the fully sheared state) can be achieved by dissipating approximately 600  $\text{kJ}/\text{m}^3$  or 40 m, and a 90% yield stress reduction (90% of the fully sheared state) can be achieved by dissipating approximately 1 100  $\text{kJ}/\text{m}^3$  or 70 m.

## References

- Boger, D.V. and Nguyen, Q.D. (1985) Direct yield stress measurement with the vane method, *Journal of Rheology*, 29 3, pp. 335–347.