High Concentration Tailings Transportation System Optimisation

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Abstract

The ever increasing move towards high concentration tailings disposal systems over the last decade has mainly been driven by the need to achieve water savings. While the technology for implementing high concentration tailings systems is largely mature, there is a tendency to design for systems for the maximum concentration tailings that can be produced. This often results in uneconomic system designs. This paper presents the findings of a study conducted to determine the optimum concentration for a high concentration tailings transportation system. The study considers the effects of pipeline length, elevation change, tonnage and energy cost. It is recognised that a comprehensive life cycle costing including all the tailings disposal elements must be performed before selecting the optimum tailings concentration.

1. Introduction

The rapid development and implementation of high concentration tailings, generally termed thickened or paste tailings, disposal systems over the last decade has been driven by a number of factors:

Demand factors

- The urgent need to reduce water consumption is the primary driver for mines located in arid areas (Chilean and Peruvian Andies, Southern Africa and Australia).
- The well published failures of some conventional tailings storage facilities (TSFs) has led to the conviction that safer and more environmentally friendly TSF designs can be achieved with high concentration tailings systems.

Technological development

- Significant advances in thickener design and flocculant development have occurred over the last ten years. It is now possible to produce high concentration tailings at reasonable cost.
- There has been considerable progress in the understanding and the development of technology required for implementing high concentration tailings disposal systems (Jewell et al., 2002).

While the technology required for the implementation of a high concentration tailings system is largely mature, there is a tendency to design surface tailings disposal systems for the maximum concentration tailings that can be produced by thickeners. This often results in uneconomic system designs.

This paper explores the optimum concentration for a tailings transportation system.

2. Model Basis

2.1. Battery Limits

The objective of this paper is to illustrate the effect of various parameters on the cost of transporting tailings from the plant area to the TSF. Consequently, the study battery limits are from the thickener underflow discharge flange to the deposition point on the TSF.

The study excludes thickener facilities, the TSF, return water pumping system, control equipment and the cost of mine water supply. These factors must be included in a comprehensive model before definitive findings can be made for a particular mine.

2.2. Pumps

The model considers piston diaphragm positive displacement and hard metal centrifugal slurry pumps.

The combined volumetric and mechanical efficiency of positive displacement pumps is taken as 85%.

The efficiency of centrifugal pumps is a function of the pump size as determined from manufacturers published performance curves. The pump performance is derated to account for the effect of solids and the slurry rheology (i.e. decreasing performance with increasing concentration).

2.3. Pipeline

Carbon steel pipe to ANSI B36.10 dimensions is used for the model.

The Slatter (1999) model for turbulent flow of non-Newtonian slurries is used to calculate the turbulent flow pipeline pressure gradients.

The velocity at which deposition occurs in turbulent flow is determined considering the effect of slurry rheology (i.e. the deposition velocity decreases with increasing slurry density and rheology).

To avoid problems associated with laminar flow settling, the minimum pressure gradient for laminar flow operation is considered to be 1 kPa/m (Cooke, 2002).

2.4. Costing

The costing is based on factored historical costs for tailings pumping systems. The costing accuracy is considered to be “order of magnitude”.

Capital costs are determined for each option and allocated to Year 1 for the cash flow estimate.

Operating costs (maintenance and energy) are escalated for each year based on an average inflation rate. Labour costs are not included in the study.

The net present cost (NPC) for the life of the system is determined from the discounted estimated cash flow.

3. Case Study

3.1. Slurry Properties

The slurry properties are based on a typical gold plant total tailings. The slurry rheology is characterised as a Bingham Plastic. The variation of plastic viscosity and yield stress with slurry concentration is illustrated in Figure 1.

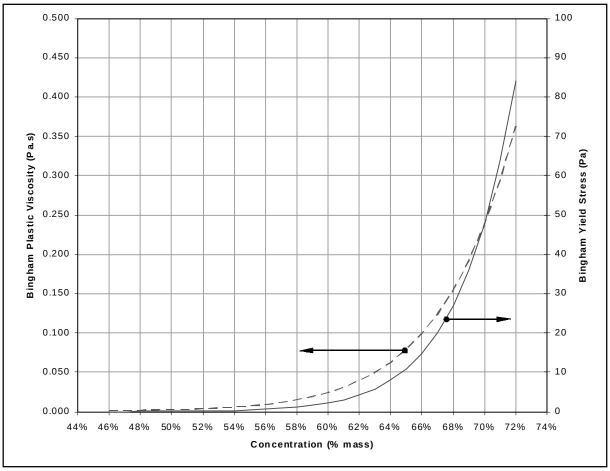


Figure 1: Tailings Slurry Rheology.

3.2. Base Case

Table 1 details the investigation base case parameters.

Tonnage	500 t/h
Solids density	2.90 t/m^3
Pipeline length	5 000 m
Pipeline elevation change	zero
Design life	10 years
Operating hours per year	8 000 h
Steel grade	API 5LX42
Pipeline wear allowance	0.25 mm/y
Energy cost	US$ 0.05 /kWh
Inflation rate	8%
Cash flow discount rate	10%

Table 1: Base Case Parameters.

3.3. Pipe Diameter Selection

Figure 2 shows the variation of pressure gradient with concentration for a range of pipe diameters at a constant mass flow rate of 500 t/h. The following limitations are considered when selecting the pipe diameter:

- For turbulent flow (i.e. to the left of the laminar-turbulent flow transition line), the operating velocity must be high enough to prevent deposition of solids on the pipe invert (i.e. above the curve labelled “fully suspended flow transition”).
- For reliable laminar flow operation, the pressure gradient must be greater than 1 kPa/m.

Referring to Figure 2, Table 2 details the selected pipe diameters (marked as solid dots on the graph) for the concentration range considered.

Concentration	Pipe Diameter and Selection Basis
46 to 53%m	300 mm fully suspended turbulent flow
54 to 63%m	350 mm fully suspended turbulent flow
64 to 65%m	300 mm fully suspended turbulent flow
66 to 67%m	250 mm fully suspended turbulent flow
68 to 69%m	200 mm fully suspended turbulent flow
70%m	250 mm laminar flow, press. gradient > 1 kPa/m
71%m	300 mm laminar flow, press. gradient > 1 kPa/m
72%m	350 mm laminar flow, press. gradient > 1 kPa/m

Table 2: Pipe Diameter Selection (500 t/h).

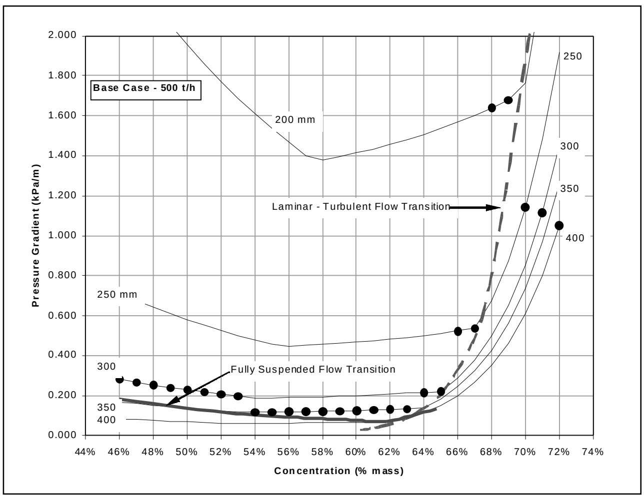


Figure 2: Pressure Gradient versus Concentration.

3.4. Optimum Operating Concentration

Figure 3 shows the variation of NPC with concentration for positive displacement and centrifugal pump systems.

The minimum NPC for the centrifugal pump system is relatively independent of concentration in the range 54%m to 63%m with the minimum value at 58%m. The minimum NPC for the positive displacement pump system occurs at a concentration of 62%m.

For concentrations less than 66%m, the NPC of the centrifugal pump system is significantly lower than the positive displacement pump system. For concentrations greater than 67%m, the positive displacement system has a lower NPC cost (the concentration corresponds to the point where multiple pump stations are required for the centrifugal pump system).

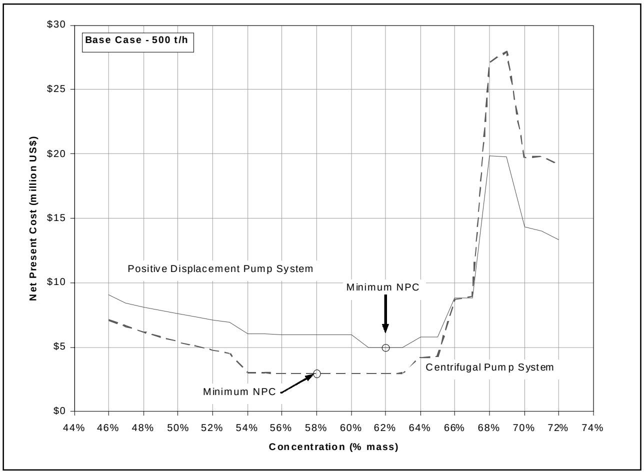
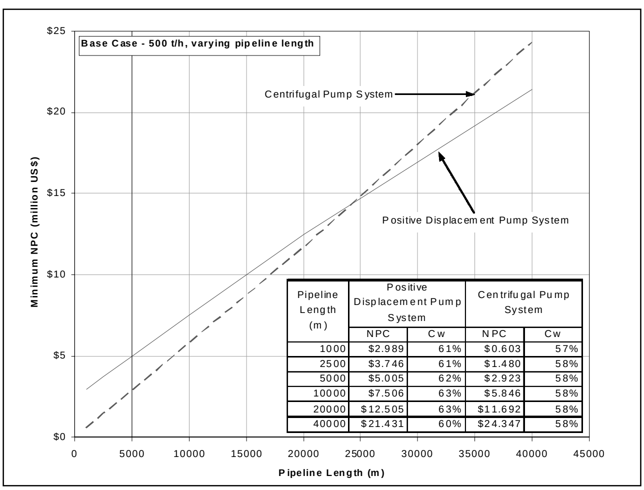


Figure 3: NPC versus Concentration (500 t/h).

4. Sensitivity Analysis

4.1. Pipeline Length

Figure 4 shows the variation of minimum NPC with pipeline length. The NPC of the positive displacement pumping system is less sensitive to pipeline length and, in this case, is lower than the centrifugal pump system for a pipeline length of more than 25 km.



Pipeline Length (m)	Positive Displacement Pump System		Centrifugal Pump System	
	NPC	Cw	NPC	Cw
1000	$2.989	61%	$0.603	57%
2500	$3.746	61%	$1.480	58%
5000	$5.005	62%	$2.923	58%
10000	$7.506	63%	$5.846	58%
20000	$12.505	63%	$11.692	58%
40000	$21.431	60%	$24.347	58%

Figure 4: Minimum NPC versus Pipeline Length.

4.2. Elevation Change

The effect of elevation difference on minimum NPC is illustrated in Figure 5. There is little difference between the two pumping systems for negative elevation differences greater than -100 m as in these cases, the gravity head is sufficient to overcome the pipeline friction losses.

For positive elevation differences, the NPC of the positive displacement pumping system is less sensitive to elevation and, in this case, is lower than the centrifugal pump system for elevation differences greater than 150 m.

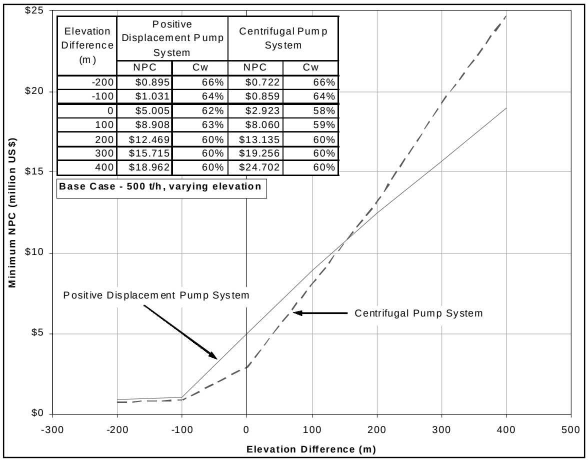


Figure 5: Minimum NPC versus Elevation Change.

4.3. Mass Flow Rate

Figure 6 shows the variation of minimum NPC with mass flow rate. The NPC of the centrifugal pumping system is less sensitive to tonnage and the cost difference between the two systems increases with increasing mass flow rate.

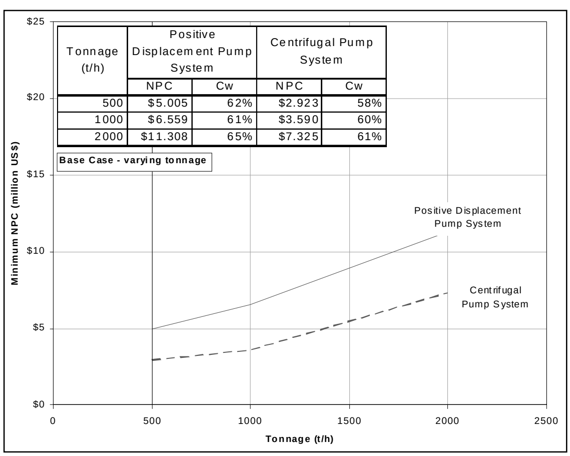


Figure 6: Minimum NPC versus Mass Flow Rate.

4.4. Energy Cost

Figure 7 shows that the minimum NPC of the centrifugal pump system is more sensitive to energy cost than the positive displacement pumping system.

Figure 8 illustrates that this sensitivity of the centrifugal pumping system to energy cost is significantly increased for pipelines with a positive elevation difference.

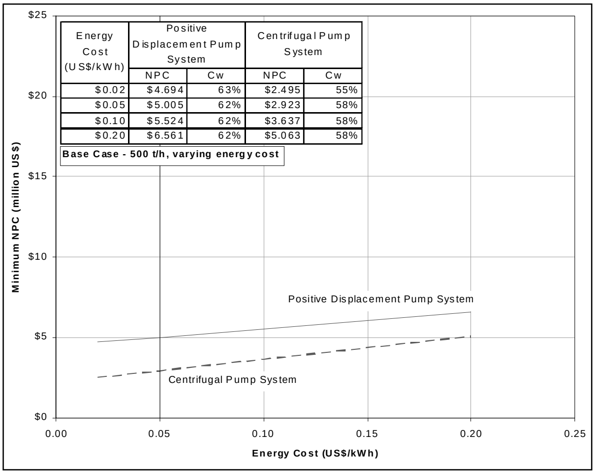


Figure 7: Minimum NPC versus Energy Cost.

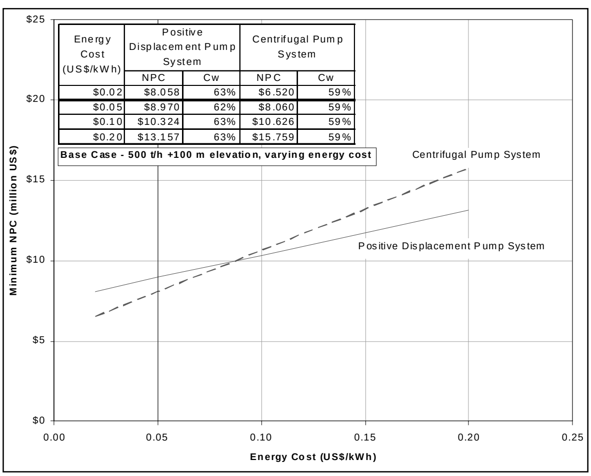


Figure 8: Minimum NPC versus Energy Cost.

5. Conclusions

The capital and operating costs of tailings pumping systems are extremely sensitive to concentration for thickened and paste tailings slurries. Before selecting the operating concentration a detailed life cycle costing study must be undertaken to determine the optimum concentration for the life of mine. The study should include all the elements of the tailings disposal system – thickener plant, transportation, deposition, return water pumping, water supply and rehabilitation.

This paper presents findings from a study investigating only transportation associated costs. The findings indicate that centrifugal pump systems can be more economic for many situations. Positive displacement pumps will generally be more economic for very high concentration, long distance, positive elevation difference and low tonnage systems.

References

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Slatter, P.T. (1999) The role of rheology in the pipelining of mineral slurries, *Min. Pro. Ext. Met. Rev.*, Vol 20, pp. 281-300.