Blue Mining: Vertical Transport System Development
If you want to go fast,
go alone.
If you want to go far,
go together.
Outline

• Fundamental Research into Vertical Slurry Transport

• Hydraulic Design of the Vertical Transport System

• Development of the Deep Sea Special Motor.
Hydraulic Design of the Vertical Transport System

Deep Sea flexible hoses

Vessel, processing & logistics

PROVEN RESERVES

Vertical Transport System

Crawler, excavation tool & preprocessing
Fundamental Research into Vertical Slurry Transport
Modelling Approach

\[
\frac{\partial \rho_m}{\partial t} + \frac{\partial \rho_m \cdot v_m}{\partial z} = 0
\]

\[
\frac{\partial \rho_m \cdot v_m}{\partial t} + \frac{\partial \rho_m \cdot v_m^2}{\partial z} = \frac{\partial p}{\partial z} - \frac{4 \cdot \tau_m}{D} - \rho_m \cdot g - \frac{\partial \rho_m \cdot v_{slip}^2}{\partial z}
\]

\[
\frac{\partial c_v}{\partial t} + \frac{\partial c_v \cdot v_s}{\partial z} = \frac{\partial}{\partial z} \cdot \epsilon_z \cdot \frac{\partial c_v}{\partial z}
\]
Validation Tests

High Sphericity
- Well rounded
- Rounded
- Sub rounded
- Sub angular
- Angular
- Very angular

Low Sphericity

Graph showing comparison of measured vs modelled velocities for different diameters (D = 99.4 mm, D = 136.4 mm).
Plug Formation and Friction

Riser differential pressures of multiple batches at startup

$\Delta p$ [Pa]

$t$ [s]

$h_1 = 0.5 \text{ m and } h_2 = 0.5 \text{ m}$

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Submerged weight

$h_1 = 0.75 \text{ m and } h_2 = 0.25 \text{ m}$

$h_1 = 0.5 \text{ m and } h_2 = 0.5 \text{ m}$

$h_1 = 0.25 \text{ m and } h_2 = 0.75 \text{ m}$

Submerged weight
Density Waves

Density waves during fluidization

Density waves during transport?
Medium Scale Test Program

From 10 meter scale to 100 meter scale to 1000 meter scale
Hydraulic Design of the Vertical transport system
Hydraulic Design Approach

- Low specific energy consumption
- Centrifugal pumps running close to their best efficiency point (BEP)
- Pump impeller tip speeds below a certain threshold
- Acceptable pump ball passages
- Acceptable under- and over pressures in the system during pump failures
- Low weight of the booster stations (including pump and drive)
- Low weight of the riser system
Hydraulic Design Approach

- Mixture density
- Riser diameter
- Booster stations positioning
- Number of booster stations
- Centrifugal pump type and size
- Drive/motor for the pumps (power and rotational speed)
## Hydraulic Design

- **System parameter**: riser inner diameter (constant)  
  - Specification: 14” (356 mm)

- **Centrifugal pumps**:  
  - Specification: 12 (6x2) HRHD 78-13-30, 3 bl.

- **Electrical drives for 12 pumps (6x2)**:  
  - Specification: 506 kW @ 931 rpm

- **Slurry density (design)**:  
  - Specification: 1200 kg/m³

- **Slurry velocity**:  
  - Specification: 4 m/s

- **Max under-/over pressure**:  
  - Specification: -6 / 39.1 bar
Development of Deep Sea Special Motor
Development of Deep Sea Special Motor

Design Requirements

- Water filled (no enclosed air pockets).
- Water cooled (ambient salt water).
- Water lubricated (no additional lubrication).
- Compact with built on pump
- Minimal maintenance during operational period.
- No environmental impact (not even in fault conditions).
- High efficiency
- Built with proven components in a unique innovative combination.
Development of Deep Sea Special Motor

From the drawing board

First Concept

Deep Sea Special Motor at Motor test facility
Testing the Deep Sea Special Motor
Testing the Deep Sea Special Motor
Testing the Deep Sea Special Motor
Testing the Deep Sea Special Motor
The research leading to these results has received funding from the European Union.

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End of Presentation
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