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WATER POWERED PISTON SLURRY PUMP

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The paper presents experimental device of piston slurry pump driven by pressure water. In the introduction, the properties, advantages and disadvantages of the piston pump compared to other types of slurry pumps are mentioned. Test circuit with experimental piston pump was built in DPT Design Centrum laboratory. Experimental piston pump has capacity 1 l/s, and maximum pressure is 10 bar. Many tests with different pump settings were performed. Two cylinder diameters (DN100 and DN50) were tested under different positions of cylinder inclination (included horizontal and vertical position). Various types of slurry (homogeneous and heterogeneous) with various particle sizes were tested. Sedimentation of particles in cylinder during the pumping cycle (filling, pressuring and discharging) was observed. Summary of the test results and their impact for practical usage of the piston pump is presented.

KEY WORDS: hydraulic transport, piston pump, slurry pump, high pressure, sedimentation, choke station

1. INTRODUCTION

For pumping suspensions and highly viscous abrasive materials, centrifugal pumps (both low and high pressures), piston diaphragm pumps (high pressures, fine grain suspensions) and piston pumps driven by oil hydraulics (high pressures, coarse-grained suspensions) are used today. In addition to these types, it is advantageous to use a piston pump driven by a pure pressure medium (most often water) to pump these media. This pump is similar to a piston pump driven by oil hydraulics, but has only one cylinder, common to pumped medium and clean pressure medium. These two media are separated by a piston. This concept reduces pressure gradient to the fasting seal (a tenth to a bar unit) and this is big advantage. The main advantages are the longer life of the piston seal, the higher life of the cylinders and the possibility of using other cylindrical materials or the inner surface of the cylinders (plastic). When centrifugal pump is used to pump clean pressurized medium then there are no pulsations in the system. Experimental device of piston pump with transparent cylinders was built to monitor suspension flow in horizontal, vertical and obliquely oriented cylinders and develop pump components. This article describes the model of this piston pump and the results of tests for various suspensions using piston pump. When this type of piston pump is designed, it is very important to choose the correct piston speed and cylinder orientation (horizontal, vertical, inclined). For each pumped medium, another piston speed and cylinder orientation may be more suitable. Correctly selected piston speed and cylinder orientation can have a significant effect on pump cost, pump life of the pump components and reliability of pump operation.

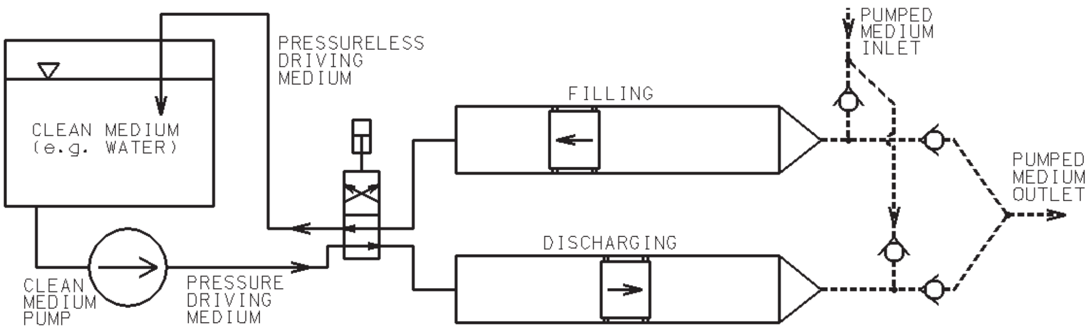

Fig. 1: Principal diagram of a piston pump driven by a pressure medium

The piston pump driven by pure pressure medium (most commonly water) has the following advantages and disadvantages over centrifugal pumps for pumping the suspension:

Advantages:

- Higher efficiency (energy saving) - especially at higher transport pressures
- Possibility of pumping a high viscosity suspension
- Better suction capacity - centrifugal pumps for pumping suspensions usually have high NPSHr
- Higher profitability - the cleaner-driven piston pump has a higher purchase price but lower operating costs (cost of electricity and spare parts)

Disadvantages:

- Higher purchase costs
- More complicated
- Greater installation dimensions

The piston pump driven by pure pressure medium (most commonly water) has the following advantages and disadvantages over piston membrane pumps:

Advantages:

- Much lower number of cycles
- Lower pressure pulsation in the discharge pipe
- It is not necessary to install the pulsation dampers on the suction and discharge of the pump

- Better suction capacity - piston membrane pumps usually have a high NPSHr
- Possibility of pumping a suspension with grains larger than 10 mm
- Comparable acquisition costs

Disadvantages:

- A little more complicated
- Greater build dimensions

The piston pump driven by pure pressure medium (most commonly water) has the following advantages and disadvantages compared to oil hydraulic driven piston pumps:

Advantages:

- Reduced maintenance costs (costs of the piston seal, cylinder) - especially with vertically oriented cylinders
- Environmentally friendly pressure medium (water)
- Healthy pressure medium (drinking water) - suitable for food industry
- Possibility to use high pressure medium (water) to flush the suspension pipeline - cost savings for the high-pressure flushing pump
- Possibility of using for clean liquids pumping when the driven medium is a slurry - replacing of choke station
- The pressure medium can be any which pressure energy would otherwise be degraded on the curtains, throttle valves, or similar.

Disadvantages:

- When installing outside the tempered hall, the risk of freezing of the water

2. WORKING CYCLE OF PISTON PUMP DRIVEN BY PRESSURIZED MEDIUM

Working cycle of the piston pump has 4 phases, Janalík 2010. The first one is the filling of the suspension cylinder, the second one is the pressure of the cylinder filled with suspension, the third one is the discharge of the cylinder into the pump discharge pipe and the last one is the depressurisation of the cylinder without suspension. From the point of view of the piston pump dynamics, the second phase is very important, when the slurry is insufficiently pre-pressurized before the cylinder is emptying, there is a significant decrease in the flow rate of the suspension from the piston pump and thus the pressure pulsations occur. However, with respect to sedimentation in the cylinder, it is necessary for the second phase to take as short a time as possible. This implies that the flow of clean medium to the cylinder in the second phase must be as high as possible. This can be achieved by a centrifugal pump that behaves almost as a source of constant pressure, by means of a accumulator installed in the clean medium supply to the cylinders or by means of a separate pressurizing pump.

In terms of cylinder life and piston seal life, the vertical orientation of the cylinders is very advantageous. Horizontal cylinder orientation may result in erosion cylinder and increased wear of the piston seal due to the seating of the particles on the bottom of the cylinder and their subsequent mechanical displacement by the piston. This problem with the vertical orientation of the cylinders is completely avoided. In the vertical orientation of cylinders, heterogeneous suspensions containing fast settling particles may show a significant increase in the concentration at the bottom of the cylinders and consequently also at local elevated concentrations in the discharge line from the pump. Therefore, it is important to choose a suitable piston speed and assess whether the vertical orientation is appropriate. With a suitable choice of cylinder inclination, an almost constant concentration of the suspension in the pump outlet will also be achieved throughout the cylinder emptying time.

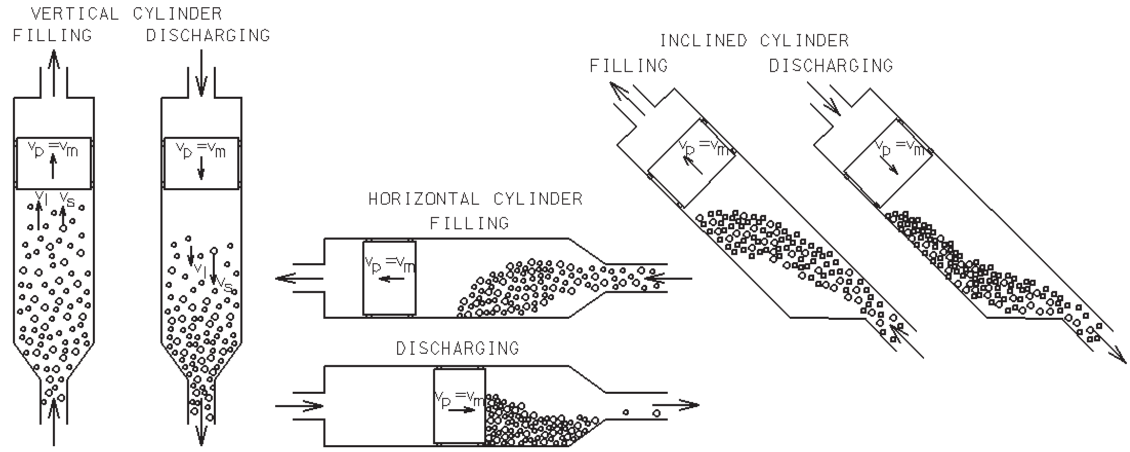

Fig. 2: Flow of suspension in a cylinder during filling and discharging

3. PARAMETERS OF EXPERIMENTAL DEVICE OF PISTON PUMP DRIVEN BY PRESSURIZED MEDIUM

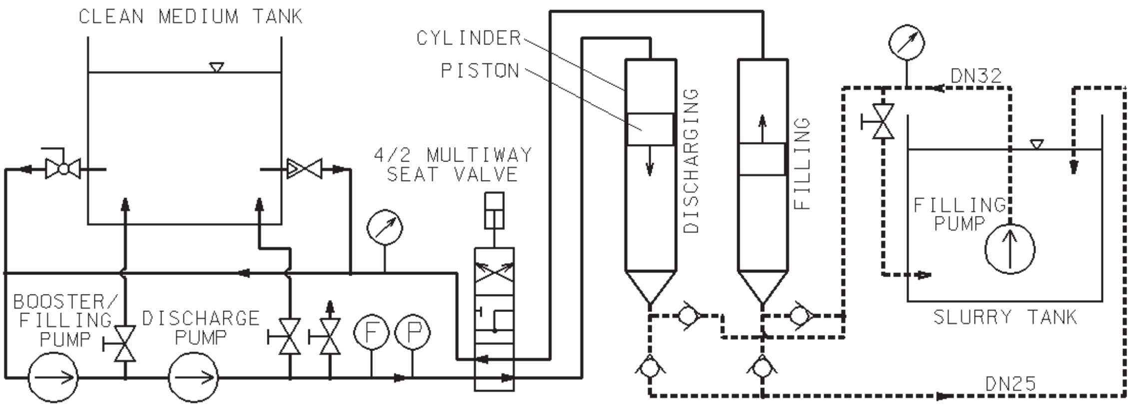

Fig. 3 Diagram of experimental device of piston pump driven by a pressure medium

Test piston pump has the following parameters:

- Maximum suspension flow: 1 l/s
- Maximum suspension pressure: 10 bar

- Maximum suspension granularity: 6 mm
- Relative weight of suspension: up to 80 %
- Number of pistons: 2
- Piston material: transparent PVC-U
- Piston diameter: 110 x 5,3 (inner dia. 99,4 mm) or 63 x 4,7 (inner dia. 53,6 mm)
- Piston stroke: 1400 mm (110 x 5,3), 1900 mm (63 x 4,7)
- Suction flange size: DN 32
- Discharge flange size: DN 25

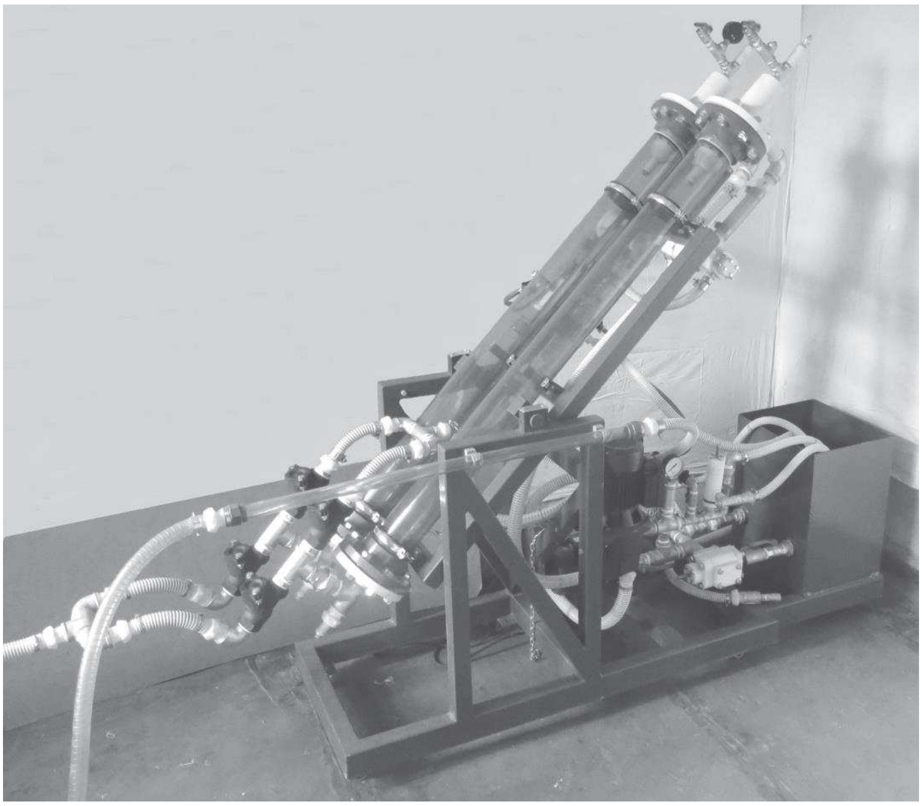

Fig. 4: Experimental device of piston pump (inclined cylinders DN100)

4. PUMPING OF CLEAN MEDIUM (WATER) WITH PRESSURIZED SLURRY

In addition to pumping the slurry where the pressurized medium is clean liquid, this piston pump can also work the other way around, i.e. the pressure medium is slurry and the pumped medium is water. The use of this pump is, for the hydraulic transport of ores and dredges from highly laid down mines, especially in South America, where the excess pressure energy of the slurry is useless on the choke station, Derammelaere et al. (2002).

This system can be successfully replaced by a piston pump that either draws water from the tailing dump or sea into the mine, or draws clean water to a water turbine where it produces electrical energy, Rayo (2007). Thanks to this replacement of the choke station, the piston pump uses the excess energy of the slurry and, on the other hand, reduces the operating costs (the orifice suffer from considerable wear and need to change them often). To test this option, it was necessary to change the connection of a experimental device.

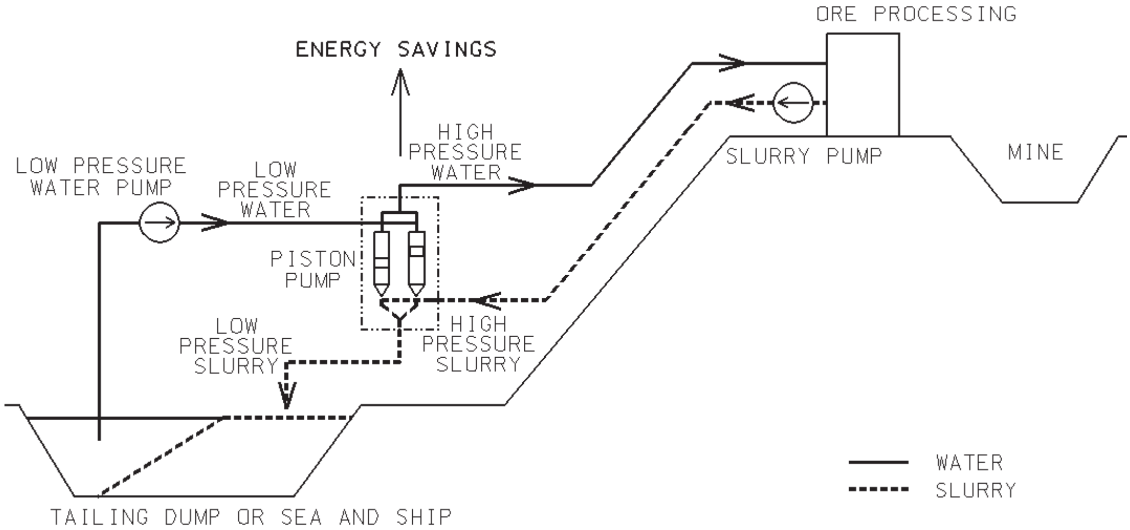

Fig. 5: Possible usage of a piston pump driven by a pressure slurry

5. TESTS OF DIFFERENT MEDIUM PUMPING

5.1. COLORED WATER

The goal was to verify the tightness of the piston in the cylinder. Very good tightness was demonstrated. Even after several hours of operation, the penetration of the dye with the suspension circuit into the clear liquid circuit was not apparent.

5.2. SUSPENSION OF WATER WITH PLASTIC CHIPS

Plastic chips parameters:

- Type of plastic: POM
- Shape of grain: angular
- Size of grain: 3 - 6 mm
- Density: 1400 kg/m^3
- Sedimentation velocity of one particle in water: 150 mm/s

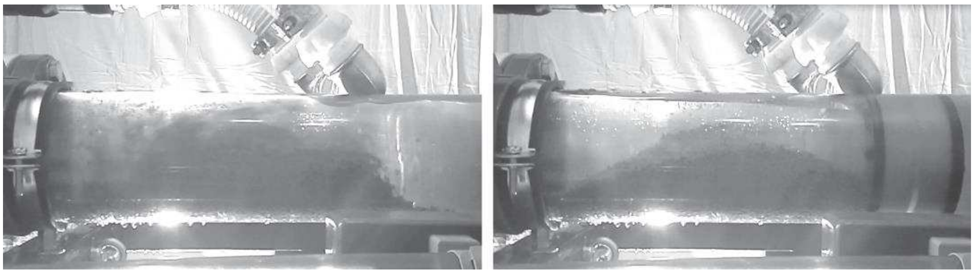

Fig. 6 Pump test suspension of plastic regranulate (POM, grain size 3 to 6 mm) and water, horizontal orientation of cylinders DN100, piston filling speed 140 mm/s, piston speed at 110 mm/s, filling (left)

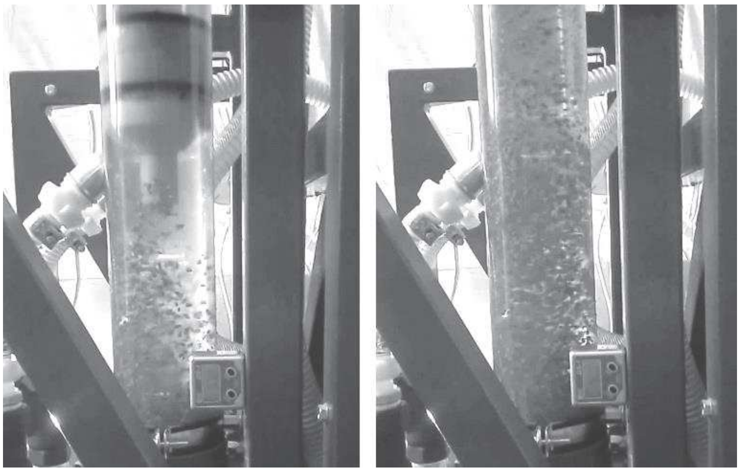

Fig. 7 Pump test of plastic regranulate (POM, grain size 3 to 6 mm) and water, vertical orientation of cylinders DN100, piston filling speed 140 mm/s, piston speed at extrusion 110 mm/s, filling (left) and start of extrusion (right) cylinders

5.3. SUSPENSION OF GLAZED BALLS AND GLYCERINE

Glazed balls parameters:

- Diameter: 3 mm
- Surface: matte
- Density: 1260 kg/m^3
- Sedimentation speed of one ball in 90 % glycerine: 24 mm/s
- Density of 90 % glycerine: 1209 kg/m^3
- Fluidity of 90 % glycerine (Vicat ring, diameter 84/74 mm, height 40 mm): 220 mm

5.4. SUSPENSION OF FLY ASH AND BOTTOM ASH WITH WATER

Practical test of commonly used suspension containing sedimentary particles (bottom ash). Transport pressure was calculated according to Hrbek et al. (1991).

Suspension parameters:

- Mass concentration: 42,4 %
- Density of suspension: 1224 kg/m^3
- Fluidity (Vicat ring, diameter 84/74 mm, height 40 mm): 250 mm
- Weight ratio of fly/bottom ash: 4 : 1
- Density of ash: 1817 kg/m^3
- Maximum size of ash particles: 4 mm

6. CONCLUSION

Test results show that piston speed and the inclination of the cylinders have a significant impact on cylinder behavior. For heterogeneous suspensions with a high settling velocity of particles, the horizontal arrangement of the cylinders is almost unusable due to the rising of the cylinder bottom of the settling particles by the piston, which significantly reduces the life of the cylinders and piston seals. For vertically oriented cylinders, these suspensions increase the suspension concentration shortly after the cylinder has been discharged. For heterogeneous suspensions with a high settling velocity of particles, the oblique orientation of the cylinders appears to be the most appropriate, but only at an optimally set slope. From a practical point of view, therefore, the vertical orientation is the most suitable for heterogeneous suspensions. Testing a experimental piston pump with slurry as a driving medium has shown that this use is possible and can be very good in the future, especially for hydraulic transport of ores and tailings from high-pit mines while pumping process water back into the mine (especially in South America). In the future, it will be necessary to devote deeper into sedimentation of particles in differently oriented cylinders and the inlet and outlet ducts from the cylinders and the influence of shape and diameter of the inlet to the cylinders. This deeper exploration of sedimentation during dynamic flow variations in cylinders will help to design piston pumps with greater reliability, longer cylinder life and piston seals life and better dynamics (minimizing pressure pulsations in pump displacement).

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