The use of hydrotransportation systems in the mining environment

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Synopsis

Increasing importance is now rightly being placed on the 'side effects' of mining operations with regards health, safety and the environment, with the environmental aspect being considered more than at any other time in history. Operators must, however, deliver an economically sound system in order for their processes to continue being viable.

With regards new environmental concerns, as well as the primary function of extraction, the 'incidentals' such as dust and noise must be considered when designing and implementing either shaft or opencast mining projects. Coupled with this, more attention is also being given to the life cycle implications of works, including their eventual decommissioning.

This paper describes technology that has been designed to produce safe, environmentally acceptable results without compromising the efficient operation of primary mining function. In fact, it is likely that the system discussed can be used to enhance productivity along with the secondary benefits delivered.

Over the past number of years, systems have been developed, tested and proven to hydraulically transport solid material over long distances without passing that material through any significant moving parts (e.g. pumps). This technology has recently been further developed in order to transport this material under atmospheric conditions while minimizing the volume of carrier fluid required.

This paper will discuss the development, operating methodology and efficiency of the technology, while demonstrating the health, safety and environmental benefits that such a system can bring.

Introduction

A number of arisings for solid material are generated as part of mining operations in a wide range of industries. This solids material can range from run-of-mine material down to drilling sludge. The treatment and transportation of this material will vary according to its value and properties such as particle size. For run-of-mine and other valuable large size fraction and high throughput material, the handling will usually be undertaken by mechanical systems such as conveyors, trucks, bucket hoists or railway. By-products such as slimes and sludges may well be left alone.

This paper describes an alternative method for handling various materials, including those described briefly above.

Hydrotransportation

Hydrotransportation in various forms has been an accepted technology in industries for a number of years now, with a specific conference having been run since 1970[1], with the 17th conference being organized jointly with SAIMM in 2007. Previously to this, hydrotransportation was used as part of the construction of the Suez Canal in the 1860s, with conduits being used to dispose of a sand-water mixture[2].

Hydrotransportation can loosely be defined as the transportation of solids in a liquid carrier stream. Generally, the carriage will be in a closed conduit or pipe, but equally could be in an open conduit. The technology described here deals with transportation in a closed pipe at either positive or negative pressure. Closed pipe transportation benefits operations by virtue that the solids are sealed within a continuous operating system, thus minimizing secondary considerations such as dust and noise from the working environment.

One of the requirements for successful hydrotransportation is the introduction into the conduit of the solids to be transported. Most commonly, this is achieved with the use of a slurry pump, having its suction connected to a slurry system, usually mixed. The mixing is important to ensure that the solids are mobile enough to be introduced into the pump. Other means of introducing the solids include jet pumps or venturis, which use liquid at pressure to create a vacuum, which draws the solids in under vacuum and discharges them under pressure.

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A third way by which solids can be introduced into the conduit is the indirect use of either vacuum or positive pressure from a pump that does not itself come into contact with the solids under transport. This type of system has the benefit of the venturi in that the solids are not in contact with any moving parts, while it has the benefit of the slurry pump that a pump is used more or less directly, thereby gaining increases in efficiency.

HydroTrans system

The HydroTrans system has been developed over the last three or so years to become an efficient means of transporting solids in a closed pipe environment.

While not pressure-retaining itself, the HydroTrans works by creating a rotational stream of liquid within a pressurized environment containing the solids to be transported. The HydroTrans is normally installed in the base of a vessel containing the solids so that the solids surround the head. Above the head is installed a discharge pipe, which is the only route out of the pressure vessel during pressurized operation. The solids therefore flow through this pipe as a slurry, having been agitated by the liquid pumped into the HydroTrans head. Figure 1 shows a typical installation of the head, including the positioning of the discharge pipe.

The pressurized rotational liquid is generated by using a standard centrifugal pump or similar device. This device creates both the flow needed to transport the solids as a slurry through the pipe and the head needed to overcome the back pressure caused by frictional and static losses in the pipe. As the pump used to generate these forces can be designed for clean liquid, the efficiency of the system is greater than if a slurry pump were to be used (due to the need for solids tolerance within the pump) or if using a venturi (due to the requirement to use pressure to create velocity which in turn creates suction).

Once in the pipeline, the solids are kept in suspension due to the velocity of the system and other physical properties affecting the settling velocity of the material being transported. Again, as a clean fluid pump is being used, the parameters of the transportation can be varied to suit the application. For instance, the distance over which the solids can be transported is limited only by the pressure rating of the vessel and drive pump required to overcome the line losses.

As the solids are discharged from the vessel, they are replaced by a proportion of the carrier fluid pumped into the vessel. As a guide, sand is discharged as a slurry at 40% concentration. This means that for every 1 m^3 of carrier fluid, 0.6 m^3 will be used for transportation and 0.4 m^3 will replace the volume of sand in the pressure vessel. To contain 0.4 m^3 of sand, the pressure vessel will require a volume of 0.66 m^3, due to the voidage of the sand (approximately 40%).

The solids can be loaded into the vessel by a variety of methods. The simplest method is to load the solids in through a hopper mounted on top of the vessel and allow them to fall under gravity into the vessel, displacing the fluid inside. This operation is batch-wise and requires a small amount of infrastructure such as a local conveyor to load the hopper. The second method by which the solids can be loaded is by using two pressure vessels and a hopper stacked in a vertical arrangement. The middle vessel cycles between atmospheric pressure and discharge pressure, with the lower vessel constantly at discharge pressure and the hopper obviously constantly at atmospheric pressure. This arrangement, whilst occupying more space and still requiring a loading mechanism, allows for the continuous discharge of material and is thus potentially best suited to high

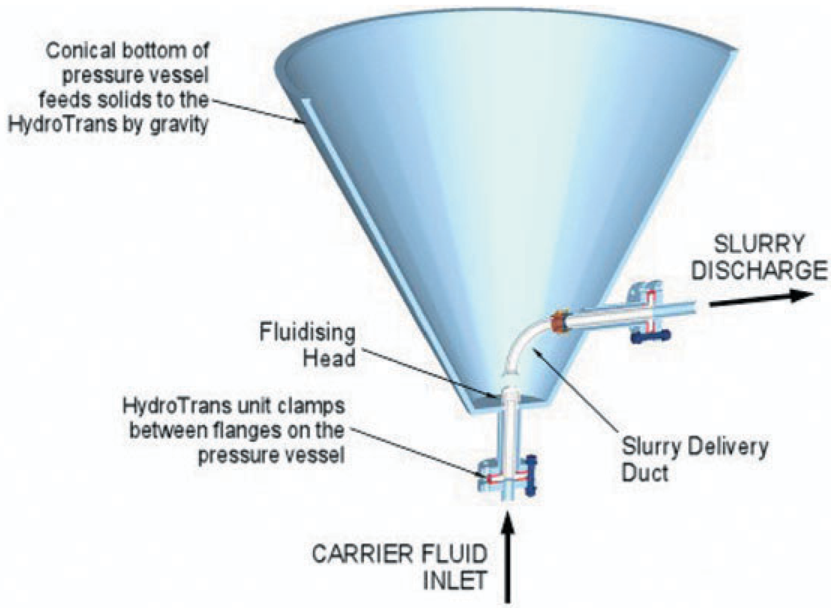

Figure 1—HydroTrans installation on a pressure vessel

throughput production facilities. The third method is to cycle the pressure vessel between vacuum and positive pressure, alternately sucking in and discharging material. It is this last technology that is described here.

AtmoTrans technology

A system has been developed that is capable of recovering solids from an atmospheric situation and transporting them over considerable distances without passing them through any moving parts such as pumps. The system employs hydrotransportation (as described above) at both negative and positive pressure to achieve this.

Recovery—negative pressure

The recovery of solids from atmospheric conditions is carried out by creating a vacuum within the pressure vessel described above. This vacuum is created by using a standard liquid pump connected to the top of the vessel, as shown in Figure 2. As the vessel is under negative pressure, so the line connecting the vessel to the retrieval mechanism is also under vacuum, thus drawing settled solids up the line.

The discharge of the pump is fed back to the area of the solids via three routes. The first, but not necessarily major route is to generate a swirling flow similar to that described under HydroTrans system. This flow causes the settled solids to be mobilized in the region of the suction head, enabling the transport of the slurry into the vessel. The second route for the discharge from the pump is back to a covering layer of liquid over the solids. This flow is used to optimize the swirl flow and prevent over-fluidization of the material, leading to loss of fines pick-up. The third flow shown in Figure 2 is a flow split to the base of the suction head. This flow is used for controlling the concentration of the slurry retrieved by the system giving the option of a lower concentration if system hydraulics dictate or purging the retrieval line of solids at the end of a recovery batch.

With the three lines controlled by valves and the pump discharging the same volume as that retrieved, the system operates as a closed loop during the retrieval phase, meaning that no external sources of water are required to assist with the lift of the solids.

Retrieval capabilities

The technology has recently been thoroughly tested for its application in the nuclear industry, retrieving radioactive waste from settling tanks and cooling ponds. As part of the test work the system has been used to retrieve waste through 30 m pipework, including a lift of greater than 5 m above the level of over-standing liquid. This means that the system has been proven to be capable of quite arduous duties. In addition, the retrieval head design has been optimized so that it is able to be deployed into restricted spaces while still functioning efficiently.

The $1^1/_2$ "nominal bore (42 mm ID) system under test has been shown to be suitable for the retrieval and transportation of a wide range of solids used in the nuclear industry. A summary of these materials is given in Table I. As this table shows, the system is able to transport solids with a variety of properties. As an example, the $1^1/_2$" line was shown to discharge 9.5 tons per hour aloxite at controlled velocities of 2.3 m/s. This capability makes the system ideal for use on production facilities.

Technology benefits

As the technology utilizes closed pipes for the transfer of material, it removes the problem with noise, dust and loss of containment associated with open conduit dry transportation (e.g. conveyor belt). This becomes of particular benefit when

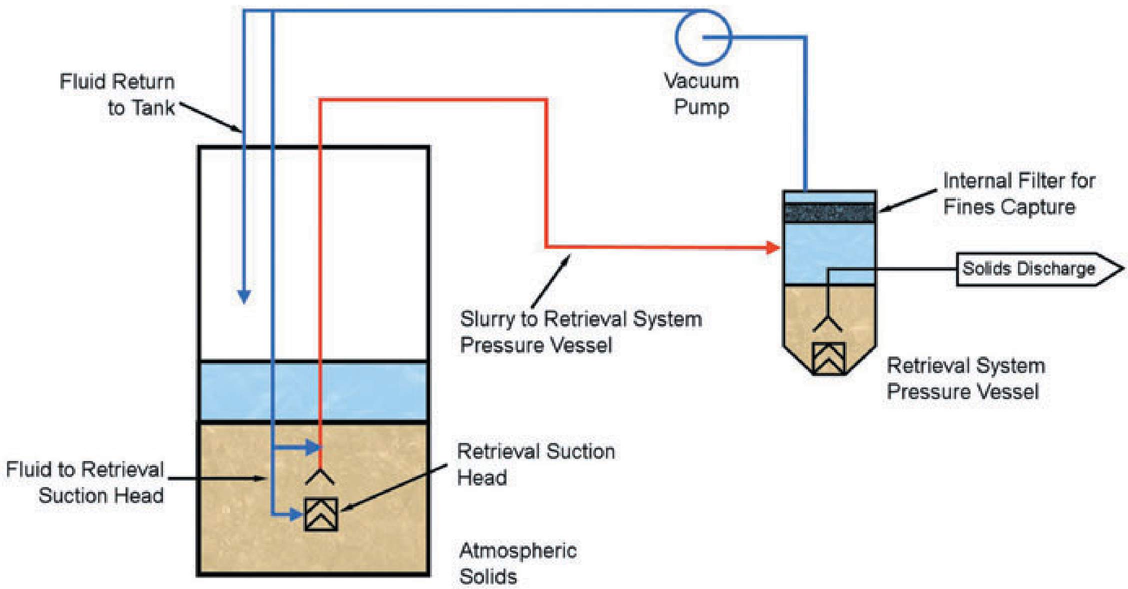

Figure 2—AtmoTrans retrieval operation

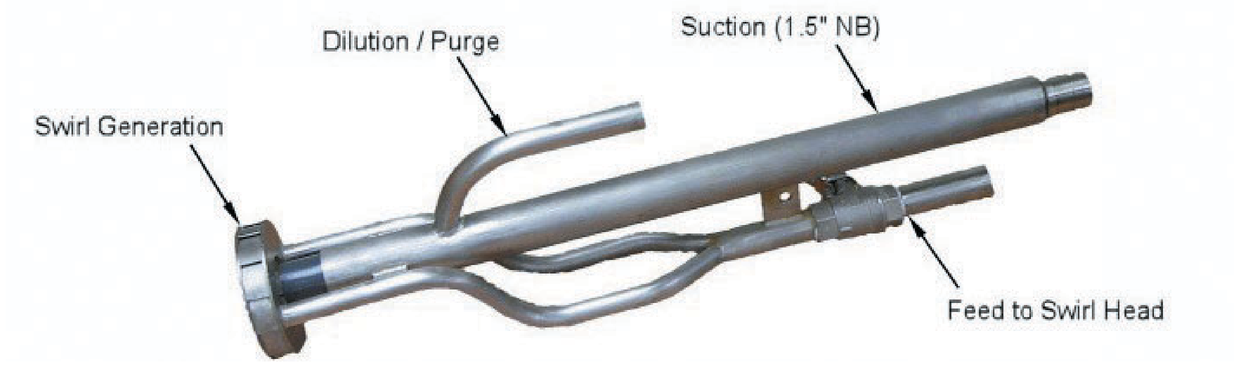

Figure 3—AtmoTrans retrieval head

Table I

Materials tested with AtmoTrans system

Material	SG	Volume conc.	Mass conc.
Aloxite (aluminium oxide)	3.90	39%	71%
Sand	2.65	40%	64%
Sludge (AETP simulant)	2.00	35%	52%
Resin (Lewatit DN KR)	1.21	43%	48%

a change in elevation is required. A typical non-profiled conveyor belt is capable of a 17 degree incline, while this increases to 35 degrees[3] with a profiled belt. As the material inside the closed conduit is being suspended by a liquid travelling at a velocity set above the settling velocity of the solid, a hydrotransport line can operate in a vertical orientation, normally requiring a bucket lift or similar.

A hydrotransportation system generally also requires less infrastructure than alternative methods due to the compact nature of the system. For instance, a 6” NB pipe is capable of transporting almost 125 tons per hour sand (35% vol. 2, m/s), with nothing other than the single pipe installed.

Finally, containing the solids within the pipeline removes all but one rotating item from the carrier system. The moving item remaining is simply the pump/s that is used to drive the fluid, rather than the drives, rollers and other rotating equipment required with either belt, bucket or railway transportation.

Applications

Current applications

The most recent reference application for the technology is the use of the system to remove settled material from the floor of a cooling pond in a decommissioning UK nuclear power station.

The pressure vessel has been submerged with the pond and the retrieval head is manually operated with some 30 m of hose between the two. The discharge from the system is carried out using a standard submersible pump in the cooling pond to feed the HydroTrans head, transporting the material approximately 140 m across the site. In this application, it is obviously crucial that the material is contained. For this reason, dual containment is used in the form of a pre-threaded co-axial flexible pipe. This type of transport system also allows the pipeline to follow contours and routes that allow the material to be kept a safe distance from plant operators.

Suggested applications for the mining environment

It is suggested that the technology be employed either as the primary transport mechanism for production material or for the removal of by-product material.

If the system is used as primary transportation, some size reduction of the run-of-mine material may be required, as hydrotransportation pipelines are generally designed such that the internal diameter of the pipe is at least seven times that of the material being transported.

If the system is used for the recovery of by-product material, for instance the emptying of gullies, sumps, etc., no size reduction would be required. In addition, if the system were employed for this purpose, it could be rail-mounted so that the overall recovery operation was mobile, discharging solids only when required.

Future developments

Work is currently being undertaken to explore the use of the system to perform in-pipe treatment. This would involve the use of a fluid other than water for the transportation, allowing a reaction to occur as the discharged material was transported along the pipeline.

Given the residence time and temperatures involved in some deep mining activities, this would mean that the raw material would be at least partially treated during its journey to the surface, thus further reducing the amount of infrastructure required above ground and its inherent environmental impact.

References

1. *First International Conference on Hydrotransport of Solids in Pipes*, Coventry, England. 1970.

2. Abulnaga, B.E. *Slurry Systems Handbook*. McGraw-Hill. 2002.

3. Lodewijks, G. *Modern Belt Conveyor Systems*. http://www.pipeconveyor.com. 2000?. ◆