Valve solutions for mine dewatering systems

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A significant amount of energy is required to dewater mining shafts from fissure and service water. One type of Demand Side Management initiative on a mine dewatering system is load shifting. Sustainability necessitates the full automation of the dewatering system to realise the full potential of load management savings. Automation often requires major instrumentation infrastructure changes such as discharge valve actuation and vibration, as well as flow and pressure monitoring of a multistage pump. Discharge valve actuation is critical for pump performance and operation as well as the remote stop and start capabilities. Special attention must be given to selecting the most suitable valve and actuator combination. Incorrect valve selection can result in reduced pump efficiency.

Deep gold mine dewatering system control mainly utilises non-return and discharge valves to ensure correct pump operation. The discharge valve isolates the pump from the dewatering column and plays a critical role during the multistage pump starting and stopping procedures. The pump valve configuration is critical for reducing the possibility of water hammer, stopping reverse flow and facilitating maintenance during the pump lifecycle. Selecting the correct valve size is important to ensure that pump efficiency is not compromised. Correct valve selection will also prolong pump operating life.

Dewatering system operation

Mines have to be constantly dewatered. Large volumes of water, as high as 30 Ml per day, are pumped by multistage pumps to surface holding dams. These pumps have a common manifold and usually have the functionality to discharge into more than one dewatering column. A simplified pump chamber set-up is shown in Figure 1.

When two or more pumps simultaneously discharge water into the same column, the efficiency of the pumps is reduced. This is because of increased pipe friction losses experienced as a result of the increase in water velocity profile caused by the larger water mass flow. The efficiency of each pump is continuously monitored. This is done in order to ensure that the most efficient pumps are used during Eskom peak periods and the less efficient pumps utilised during the Eskom off-peak periods. Pumps are usually operated until a predetermined minimum efficiency value is reached. This value varies between 70% and 75%. Some mining groups adopt a minimum cut-off efficiency policy of 75% as standard practice. When operational schedules permit, these pumps are removed from service and refurbished.

Multistage pump discharge valves

During normal system operation, that includes load shifting, pumps are stopped and started throughout the day. Each pump is fitted with a discharge isolation and non-return valve. The typical flapper type non-return valve used on the discharge of the dewatering pump consists mainly of a valve body and flapper. The differential pressure and flow of water in the correct direction will open the flapper to ensure continuous flow through the valve. When flow is reversed, the flapper will close automatically and prevent any reverse flow from occurring. These valves are selected according to the fluid pressure, flow rate and flow characteristics of the fluid medium being pumped. The main function of the isolation valve is to avoid water hammer and the non-return valve is used to prevent reverse flow. Waterhammer, also sometimes referred to as fluid hammer is a high pressure pulse or wave that is caused when the velocity of a flowing fluid is suddenly decreased or brought to rest. Water hammer occurs whenever a valve is closed. The severity of the hammer phenomenon depends on the fluid velocity and the rate at which the valve is closed.

The resulting pressure surge can cause noise and vibration as well as extensive damage to equipment. Reverse fluid flow can be as destructive as water hammer. If reverse flow occurs, it can cause impeller reversal and result in major damage to the pump [1].

The non-return valve will ensure that no reverse flow occurs. A typical pump discharge isolation and non-return valve is shown in Figure 2.
Due to the high pressure and high flow conditions experienced at the discharge side of the pump, any increase in pipe friction will result in pump efficiency losses. Efficiency losses will occur if a pump operates at a higher than optimum designed discharge pressure [2].

**Energy losses due to friction**

There are numerous factors that can cause energy losses in a multi stage pump chamber. The main factors are:

- Friction or pressure losses
- Balance disk wear leak-off
- Pipe bends, valves and other restrictions

Various components situated in series within a closed system can increase friction losses. These components include valves where friction losses are sometimes neglected. A study was undertaken to determine what effect the discharge isolation valves will have on the pump efficiency. By analysing the total pressure measured at the discharge flange of the pump and comparing this pressure with the static pressure, the friction losses can be obtained. The total and static pressure profiles are shown in Figure 3.

By subtracting the static pressure ($P_s$) from the total pressure ($P_t$) the dynamic pressure ($P_d$) can be determined. It can be seen that the total pressure in chamber A1 is approximately 60 kPa higher than the static pressure. In incompressible fluid dynamics dynamic pressure ($P_d$) is quantified by:

$$q = \frac{1}{2} \rho \nu^2$$

$q = \text{dynamic pressure in pascals}$

$\rho = \text{fluid density in kg/m}^3$ (e.g. density of air)

$\nu = \text{fluid velocity in m/s}$

Calculations showed a theoretical reduction of approximately 10.9 m/s in flow is present due to friction losses. However it must be determined if the pressure losses can be as a result of increased pipe friction due to old installations and increased velocity of the medium being pumped. A comparison was made between two cascading pump chambers with almost identical properties. The result of the pressure losses comparison is shown in Table 1.

<table>
<thead>
<tr>
<th>Chamber A1</th>
<th>Chamber B1</th>
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<tbody>
<tr>
<td>Difference in pressure losses (%)</td>
<td>6.8</td>
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<tr>
<td>Total pressure losses of chamber A1 (%)</td>
<td>5.6</td>
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Table 1: Pump chamber A1 total and static pressure losses.

From Table 1 it can be seen that chamber A1 experienced a 5.6% increase in system friction losses although both chamber piping installations were completed simultaneously. The pipe friction losses were not included for these calculations because they only have a minimal effect on the pressure losses. Restrictions or orifices are used in the centrifugal pump discharge to ensure that the pump operates as close as possible to the optimum design conditions. Other restrictions or components in the water supply line will result in decreased pump efficiency.

The pump chamber average power baseline was determined. It can be seen that load shifting occurs during the Eskom morning and evening peak periods. Atypical working weekday power baseline is shown in Figure 6. When considering the lifecycle of a pump, energy consumption is the largest cost component because these pumps operate more than 2 000 hours a year [3]. Inefficiencies in the pump...
system will have major financial impact throughout the operational life of the pump. It was determined that a restriction of 50 mm caused by a discharge valve being sized too small, resulted in a 5.6 % efficiency loss per pump.

Conclusion

On large dewatering systems selecting the correct pump discharge valve combination will ensure that the pump system is operated as close as possible to the optimum operating point. Using the incorrect valve can result in a reduction in efficiency of the pump and increased energy costs. On mine A it was determined that the incorrect valve application caused a 5% reduction in pump efficiency which in turn resulted in average losses of approximately 150 kW in one pump chamber. This contributed to financial cost increases of approximately R550 000 per annum.

References


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