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Axial thrust in vertical turbines

Reliability and availability are crucial for the mining industry, where pump systems are located at isolated and high altitude locations with limited access to machinery and workforce. Petar Ostojic from Neptuno Pumps discusses how incorporating engineered axial thrust bearing assemblies can improve vertical turbine pumps reliability while reducing their life cycle cost.

Vertical turbine pumps (VTP) are currently among the most used equipment in the mining industry worldwide. Their multiple benefits, such as high efficiency performance, reliability, modular design and minimum space requirements, make them one of the favourite pumps when designing a new industrial process or project. Historically, these pumps have been widely used for fluid intake or transfer applications, generally requiring Total Dynamic Head (TDH) of up to 300 m so they can be immediately connected to a booster pumping station—generally equipped with a tank and a set of horizontal pumps—that will finally provide the required high pressure.

Nowadays, as mine sites get bigger and metal ore grades decreases, the mining industry requires total dynamic heads so large that pumping must be done in multiple pump stations installed in series. This increases a project’s CAPEX and sometimes this alternative may not even be feasible, as in cases where geographical or regulatory conditions do not allow the installation of several pump stations. That is why some manufacturers are pushing the limits of this pump model, designing engineered vertical turbine pumps within a limited range of specific speeds ($30 < n_q < 50$), for
High head per stage, reaching Total Dynamic Heads (TDH) of up to 700 (m) or 2,297 feet.

High head vertical turbine pumps

As said before, due to high geographical altitudes and long distances, mining companies are requiring pumps that can offer higher heads. Neptuno Pumps has taking the lead in the design and manufacturing of a complete line of high-head Vertical Turbine Pumps, known as the Neptuno Pumps VTPX, as shown in Figure 1, which resulted finalist in the category Innovation of the Year – Products at the 2015 Pump Industry Awards.

One key parameter for the right selection of this type of pump is thrust. This load is generated due to unbalanced internal pressure, weight and fluid direction change, which acts parallel to the pump shaft and is divided in two directions, downthrust and upthrust. Since downthrust is the predominant hydraulic force in the case of vertical turbine pumps, reaching up to 90 kN per pump stage, some rigorous design aspects must be considered in order to guarantee a reliable, continuous and stable operation without sacrificing neither energy efficiency nor pump availability.

Furthermore, the definition of these criteria in an early design state of any project is of the utmost importance because it will be critical in defining which type of vertical motor will be selected for each application, whether using a vertical hollow shaft motor (VHS) or a vertical solid shaft motors (VSS).

VHS vs VSS

For many years pump users have debated between which are the advantages or limitations of using a vertical hollow shaft (VHS) or vertical solid shaft (VSS) motors. The most common differences are that vertical hollow shaft motors have no external shaft extension and that the couple to the pump shaft is located at the top of the motor. On the other hand, vertical solid shaft motors are connected to the pump through a rigid or flexible coupling and they are coupled to the pump shaft at the lower end of the motor.

Over the years, many pump users have preferred vertical hollow shaft motors because they have fewer parts and less chance of vibration issues, being easier to inspect without disassembly of the motor. However this ‘high thrust’ motors can withstand forces of just 50 kN becoming a limitation for some vertical turbine pump applications that require higher pressures, not taking advantage of the full potential that this type of pump can offer.

Vertical solid shaft motors, on the other hand, have their own set of benefits, being up to 20% cheaper than VHS drivers, offering a more accessible adjustment and fewer problems with eccentricity. However in order to exploit its economic and technical benefits to the fullest, the incorporation of an engineered axial thrust bearing assembly is required, especially when operating with powers over 700 HP, such as in the case of the mining industry located at the Andes Mountains in Latin America.

In thrust we trust

Axial thrust bearing assemblies are commonly used in vertical turbine pumps, especially when using vertical solid shafts that cannot withstand high loads of axial thrusts. A standard motor, with a power ranging from 1000 to 3000 HP, can usually withstand from 25 to 50 kN. However, when facing high-head applications, an engineered vertical turbine pump, even with thrust-balanced impellers, can reach loads of up to 200 kN, leaving most standard vertical solid shaft motors out of the game.

These bearing assemblies are usually installed on top of the pump discharge head, over a separate fabricated driver stand and immediately before the flexible coupling. This component withstands both the total hydraulic axial thrust and the total rotor weight. However, as shown in Figure 2, most vertical turbine pump’s axial thrust bearing assemblies, for applications above 1000 HP, are water-cooled, requiring a continuous flow of fresh water, with flows of up to 1 gpm and pressures of 35 psi, which is quite difficult to get in a mining operation located in the isolated mountains at 4,500 metres above sea level. Others are designed to use water directly from the pump’s discharge head, however, when using vertical turbine pumps with high total dynamic heads, pressures are extremely high, reaching up to 850 psi, thus requiring different methods for...
of the oil inside the bearing assembly was analysed in order to confirm that a good temperature distribution is obtained that would allow a long life cycle of the bearing. At the same time a complete structural analysis of the bearing assembly ad fan is done in order to select the right geometries and materials.

This highly engineered air-cooled bearing assembly, shown in Figure 4, can withstand up to 270 kN of axial thrust, enabling the use of lower-cost, standard vertical solid shaft motors without requiring a special independent fresh water refrigeration system, allowing to be used even for heavy-duty applications that transport highly corrosive fluids, such as in the case of solvent extraction/electro-winning (SX/EW) plants.

Success story
Compañía Minera Lomas Bayas is located in the Atacama Desert, 120 km east of the city of Antofagasta in northern Chile. As one of the world’s lowest-grade copper operations, with average grades of 0.27% soluble copper, this open pit copper mine is heavily intensive in the use of hydrometallurgy processes, such as solvent extraction/electro-winning (SX/EW), which allows them to, efficiently and economically, process lower-grade ores with lower water consumption (for more information on the SX/EW process please read our

Figure 4. Neptuno Pumps Axial Thrust Air-Cooled (ATAC) Bearing Assembly.
In the SX/EW process the ore is leached with sulphuric acid, and then the copper is extracted from the acid leach with a solvent which flows to the leach pad where it is collected and directed to flow into the leach ponds, where pumps transfer it to the SX plant and the copper is subsequently electrolytically refined. This means that there is a limited supply of fresh water and at the same time it is not possible to use the same pumped fluid to cool down their vertical turbine pumps’ bearing assemblies.

The company was operating two pump stations, as shown in Figure 5, each consisting of four vertical turbine pumps, with all wetted parts manufactured in Super Duplex 2507 stainless steel (UNS S32750). Station 1 was equipped with four, two-stage pumps powered by 600 HP vertical solid shaft motors, while Station 2 had four, five-stage pumps with 1500 HP VSS motors.

When operating, these motors presented an axial displacement of three millimetres when starting which immediately damaged the mechanical seals. Impellers on both pump stations were unbalanced and bushings where out of dimension by 250%. These substandard mechanical conditions had the pumps operating with high vibration values of up to ten millimetres per second, a critical condition that damaged the pumps and, as said before, was practically destroying its mechanical seals, requiring a continuous replacement of this component almost each week. This translated in a mean time between failures (MTBF) of just three months or 2160 hours. Under these operational conditions, and at an average price of US$140,000 for the repair and maintenance of each of these pumps, the company was paying US$4,480,000 a year.

The solution consisted in repairing the entire pump under new dimensions and tolerances which would guarantee a reliable performance, by manufacturing new bushings and wear rings, rebalancing the impellers under the ISO 1940/1 norm, welding and re-machining the discharge heads and columns. It also required the manufacturing of a new longer discharge shaft in order to install the new ATAC bearing assembly.

This engineered solution, as shown in Figure 6, has allowed the company to operate continuously 7,200 hours with vibrations of just 1.5 (mm/s). Under these performance conditions there is no need of taking the pumps out before 10,000 hours of continuous operation for preventive maintenance. This solution, consisting of repairing the old pump plus incorporating the Neptuno Pumps ATAC bearing assembly represented a cost for the customer of US$200,000 per pump, representing a total investment for both pump stations of US$1,600,000, offering a payback period for this project of just 4.2 months.

**Conclusion**

As described above, vertical turbine pumps are gaining terrain over other pump models in the mining industry due to its versatility, reliability and highly efficient operation. However, the conception that these pumps can offer low to medium total dynamic head operations has limited its full performance potential. By using an Axial Thrust Air-Cooled Bearing Assembly, vertical turbine pumps can be taken to the next level, reaching total dynamic heads of up to 700 m, using lower-cost and standard vertical solid shaft motors, reducing the number of required pumps for some projects, as well as the payback periods to as little as one year, while cutting the total cost of ownership up to 50%.

VTPX and ATAC are trade marks.

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