Corrosive handling

Moving abrasive and corrosive liquids

It is difficult to find a reliable and cost effective pump for applications having both corrosive and abrasive media. The equipment is expensive to buy and maintain, and safety for those using the equipment is a headache, given their hazardous applications. One solution is a pump using standard parts, while various linings allowing for quick delivery at reasonable costs.

Pumping a liquid that is only corrosive is relatively simple. Find the correct materials of construction for the pump and piping and the system will generally be reliability. Because of the hazardous nature of these applications, magnetic or seal-less centrifugal pumps are used extensively to eliminate seal leakage and give zero emissions from the pump. An alternative is a double or tandem mechanical seal with a barrier fluid. All such designs tend to be subject to failure during system upsets.

When moving an abrasive liquid, the problem is more difficult because the material rarely acts like a simple Newtonian fluid. The specific gravity tends to be high, and it is more difficult to find the correct materials for construction. The velocity of the fluid in the system becomes a large factor in the system reliability; any increase in liquid velocity through the pump greatly accelerates component wear. If the pump does not operate at the correct point on the curve, recirculation within it causes excessive wear of both casing and impeller (Figure 1).

Specially designed slurry pumps made of hard metals, such as a 28% chrome or Ni Hard material, are generally used for these applications.

More difficult together

The combination of both corrosive and abrasive makes these applications far more complex. The corrosive/abrasive liquid requires a high alloy material or a plastic, and also requires a very hard or very resilient material to survive the abrasives. If a seal-less pump is used there are high velocities and close tolerances around the sleeve bearings, as well as other issues that increase abrasive wear. Generally, hard abrasive resistant materials, such as 28% chrome, are not available in pumps designed for corrosives. If a pump can be found, using a hard metal, such as Ni Hard or high chrome, will help with the abrasive, but the hard metals do not tend to be highly corrosion resistant.

Replaceable rubber-lined centrifugal pumps are used, but have the same recirculation and velocity issues as all centrifugal pumps. Ceramic epoxy coatings for the wetted parts of the pump are another alternative and have limited success because of variations of coating methods and special machining of the pump and its components, as well as the high velocity and recirculation within the pump.

Positive displacement pumps require close clearances or interference fits to move liquid efficiently. The capacity and pressure will quickly degrade as the internal clearances become larger. Progressive cavity pumps (Figure 2) have limited life because

Figure 1. This shows a centrifugal pump curve. If the pump does not operate at the correct point on the curve, recirculation within it causes excessive wear of both casing and impeller.
of internal slip at higher pressure, causing both stator and rotor wear.

Standard double diaphragm pumps, or air operated diaphragm pumps (AODs), tend to operate too fast with undersized valves to give long life.

Gear pumps have metal parts working together and the corrosive/abrasive mixer is in between the parts. This causes excessive wear on the gears. Hose pumps have limited mechanical and chemical hose life.

In all the positive displacement pump types, there is some level of slip within the unit. This is inherent in the design, and there is, therefore, an internal recirculation liquid through the clearances. As the recirculation increases with wear, the volume of slip increase exponentially, accelerating the wear, decreasing the flow and pump life exponentially.

Velocity and circulation

Let us examine the velocity and recirculation issue more closely. In all types of pumps, velocity is one of the key components. Most standard centrifugal pumps are designed with a specific speed below 8000. This represents a radial design impeller and turns the liquid within the impeller basically 90° as it moves through it.

The rotation accelerates the liquid to a defined velocity based on its diameter and speed. As the slurry moves from the impeller through the volute, the liquid velocity is reduced and the pressure increases, which is what we see on a gauge. In general, a specific velocity is required to create a specific head, so the velocity is a function of the required head. In a simpler form, the higher the head required, the higher the internal velocity required and the higher the wear rate.

Reducing the speed of the pump is the standard solution to increase life. However, the primary abrasive/corrosive issue concerns the velocity of the liquid inside the pump. As stated above, the impeller creates a certain liquid velocity to fit the required design head. If the impeller is small, turning fast, or a large impeller rotating slowly, makes little difference. A 30 cm (12 in) impeller turning 1750 rpm has a velocity at the outside diameter of 1746 m/minute (5500 ft/minute) and creates the same velocity as a 53 cm (21 in) impeller turning at 1000 rpm. The larger impeller will also have a greater minimum flow, as well as greater shaft deflection and bearing load problems. The velocity as the liquid leaves the impeller is approximately the same. A larger pump will have greater recirculation issues because the impeller is larger and has been designed to pump a greater volume of fluid.

Positive displacement pumps have much the same issue. In applications having a significant discharge pressure, the abrasives will open the pump clearances and the corrosion will increase the degradation of the material. The result is high recirculation within the pump and short life.

Many PD pump manufactures will de-rate their pumps to a maximum pressure of only 60% of design pressure on a clean liquid, or will reduce the speed of the pump. In both cases this will increase the required unit size, the initial cost and the maintenance cost. It also decreases the efficiency of the pump.

As demonstrated by the pump curve (Figure 1), as the pump moves to greater head, the flow is reduced and the corrosive/abrasive liquid begins to re-circulate within the pump. The high velocity and recirculation tend to rapidly increase wear. If the liquid is also corrosive, any oxides that form on the surface of the metal are wiped away by the abrasive, exposing new metal which, in turn, forms a new oxide coating. This is then wiped away. The combination of the two exponentially increases the wear on the pump.

Successful design

What are the criteria for a successful corrosive/abrasive pump? These are:

- Low internal velocity (but not allowing the slurry to settle)
- High corrosion resistance

Figure 2. Progressive cavity pumps, like this example shown here, have limited life because of internal slip at higher pressure, which eventually causes both stator and rotor wear.

Figure 3. Rubber and ETFE linings on the wetted parts can be used to offer both corrosion and abrasive resistance.
• Good abrasive characteristics
• Reasonable initial cost
• Standard parts having good availability
• Zero leakage (or no seal to fail).

A combination of these variables would create a successful pump application.

By using a reciprocating pump with a low stroke rate and a varying acceleration head, a change of the fluid velocity with each stroke of the pump is created. This change will tend to keep solids in suspension at low velocities of less than 0.61 m/s (2 ft/s). Rubber and ETFE linings on the wetted parts can be used to offer both corrosion and abrasion resistance. Because the pump is lined, there is no oxide coating for the abrasive particles to wear away. The linings can be a variety of materials, Neoprene, Nordel (EPDM), Nitrile (Buna N), Viton (FKM) or ETFE, allowing the pump to be tailored to the media requirements (Figure 3 ETFE lining).

By using an elastomeric diaphragm as the driver element, the pump becomes seal-less with zero emissions. Again, the diaphragm material can be tailored to specific applications. Using standard bolt on check valves allows a variety of valve to be offered, including a 90° ball check, inline ball check and full port flap. The design is easily varied to accommodate particle size and type. This combination of materials and design characteristics allows for standardized parts, which reduces costs and increases availability.

Air is an excellent driver for the diaphragm and liquid because it equalizes the pressure on both side of it, greatly extending its life. Air will easily compensate for the changing solids volume and the weight of most slurries. It will offer varying flow, which can easily compensate for changes in density and viscosity of the corrosive/abrasive liquid, without overloads or catastrophic failures matching the pump to system requirements.

In conclusion

What has been described is a single diaphragm air driven pump (Figure 4). RamParts has been manufacturing this style of equipment for more than 30 years with high reliability on the most difficult applications. The pump is made using standard parts, while various linings allowing for quick delivery at reasonable costs. This design has also been able to reliably move the most abrasive and corrosive slurries.

With the introduction several years ago of ETFE linings, we have been expanding our applications to include the most corrosive and abrasive slurries in mining, food, paper chemical and petrochemical process. We are pumping copper and silver slurries containing hydrochloric, sulphuric, arsenic, hydrofluoric acid, plus titanium dioxide – both in its manufacture and uses. These include green liquor in paper mills, waste pickle liquor in steel mills, as well as many more. All of these are pumped with efficiency, high reliability and low life cycle cost.

Figure 4. A single diaphragm air driven pump by RamParts. The company has been manufacturing this style of equipment for over 30 years, with high reliability on the most difficult applications.