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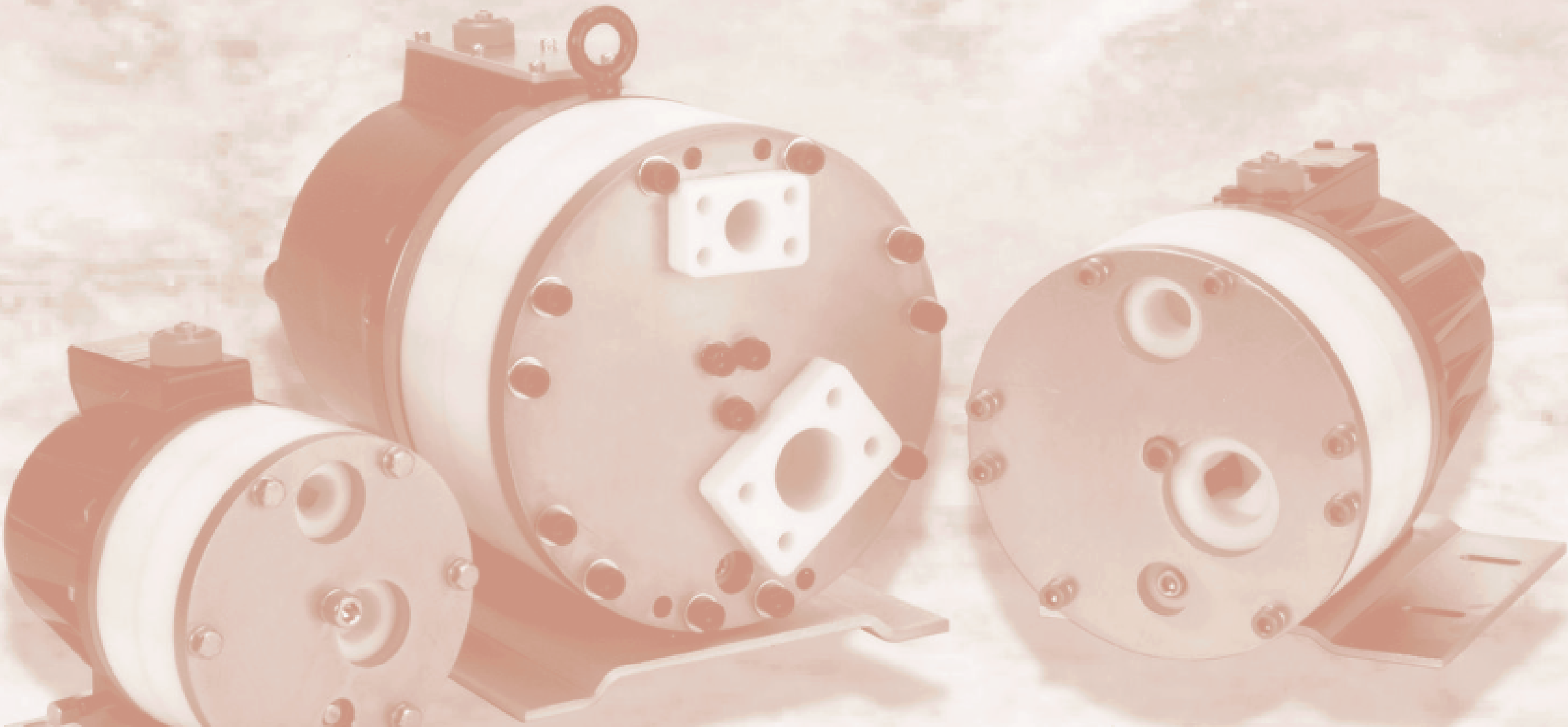
Pumping Abrasive Slurries

Do you know what to look for in pump design?



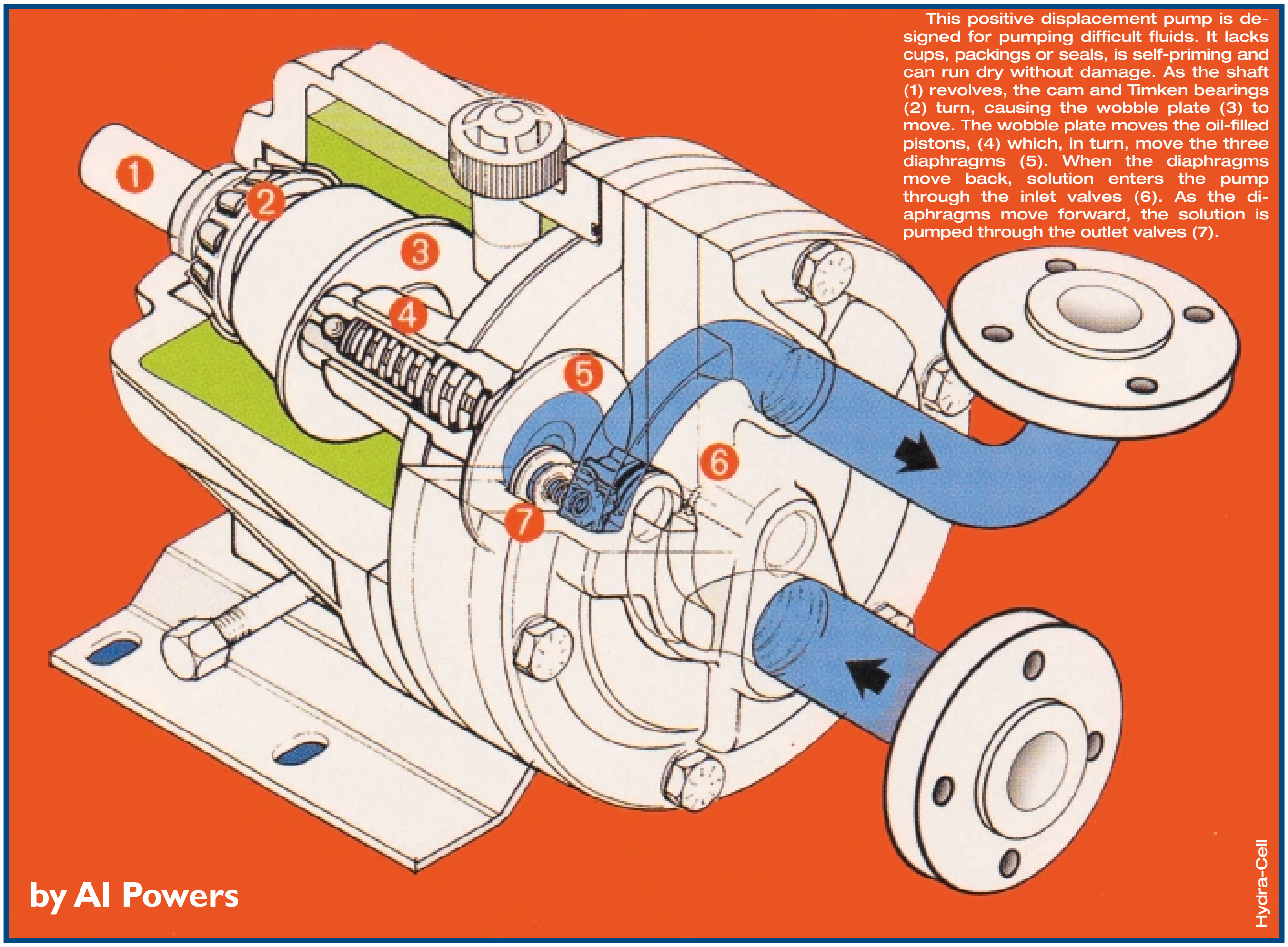
Stainless Steel

How to select the proper alloy for your piping system.

Doppler Dilemma

When to use, when not to use.

Pumping Abrasive Slurries:
What to Look for in Pump Design



This positive displacement pump is designed for pumping difficult fluids. It lacks cups, packings or seals, is self-priming and can run dry without damage. As the shaft (1) revolves, the cam and Timken bearings (2) turn, causing the wobble plate (3) to move. The wobble plate moves the oil-filled pistons, (4) which, in turn, move the three diaphragms (5). When the diaphragms move back, solution enters the pump through the inlet valves (6). As the diaphragms move forward, the solution is pumped through the outlet valves (7).

by Al Powers

Properly designed pumps can both survive and thrive in abrasive applications. It's all about paying attention to the details.

A plethora of pumps are available for the routine pumping of non-abrasive and non-corrosive materials. Pumps designed for these types of standard applications are generally straightforward and simple to build, and function well when applied to their intended use. But when abrasive and corrosive materials are added to the pumping equation, the challenge of designing a reliable and durable pump escalates – significantly.

The industrial applications that require pumping of abrasive materials are as varied as the products we see and use every day. The following two application examples provide a snap shot of the challenges facing today's pump designers.

Challenging Applications

Ceramics manufacturing

From the point of mining, to the application of glazes, pumping clay-based slurries is integral to the process of ceramics manufacturing. During the mining process, clay is removed from the mines, dissolved in water and run through a number of filtration processes. This is done to remove rocks and relatively fine sand. Finally, the clay solution is pumped through a filter press that allows water to pass through the filter, while trapping the semi-refined clay in a cake. This cake is then further blended to form various grades of product that range from fine porcelain, to stoneware, to bricks.

Each of these clays has unique levels of particle hardness, particle size distribution and chemical composition. After bisque firing, most ceramic products are glazed and fired again to produce specific colors, patterns and other desired appearance features. The color in glazes is generally the result of metallic oxides that are very abrasive in nature. This entire manufacturing cycle is filled with both opportunities and challenges for pumping thick abrasive mixtures.

Spray drying

Another application that, in some cases, overlaps with ceramic manufacturing, is that of spray drying of materials. Materials under high pressure are sprayed into a heated drying chamber and allowed to dry from a solution of water to a dry powder at the bottom of the chamber.

Homogenous blending of various clays is accomplished by dissolving clay cakes of different types, mixing them in solution and then spray drying. Carbide powders, specialized glass powders and other products of a similar nature are often spray dried during some stage of blending and manufacturing. All of these products are inherently abrasive and difficult to handle, and, in many cases, represent great challenges in designing pumps and systems that are commercially viable.

Pump Types

Positive displacement pumps offer some key advantages for these types of abrasive slurry pumping applications, and a few critical challenges. Positive displacement pumps, that feature sliding seals, can be designed to minimize the impact of abrasion on the seals. However, in applications where the product being pumped becomes increasingly abrasive, their life expectancy is often unsatisfactory.

Diaphragm pumps of various types can, and do, eliminate sliding seals on piston rods. Oil backed diaphragm pumps that can generate high pressure and offer excellent abrasion resistance in the diaphragms provide significant advantages for this type of application. The elastomeric diaphragms used in these pumps provide a means of bypassing the abrasion limits of sliding seal pumps.

Check valves are another critical element in both types of positive displacement pumps. During operation, they open and close literally millions of times, and are exposed to both erosive wear and wear from compaction of abrasive particles between the valve and seat.

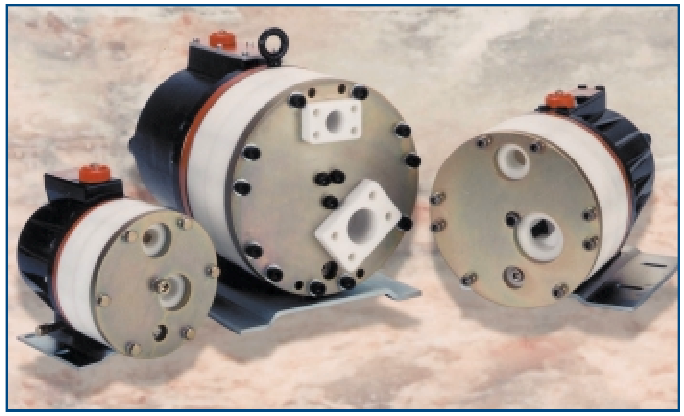
Minimizing Wear

There are two basic ways to approach minimizing wear in these pump components. First, they can be fabricated from extremely hard, wear-resistant materials. This approach has strong merit, where the hardness of the particles in the solution being pumped is significantly lower than the hardness of the seat and valve materials that can be used. Relatively hard and fracture resistant materials are available for this purpose. For instance, tungsten carbide and toughened ceramics work well for these situations. Note that, in applications such as those previously mentioned, it is not uncommon for the pumped particle hardness to approach or exceed the hardness of practical seat and valve materials.

A second way to approach this problem involves the use of at least one very soft material, typically run against a hard wear-resistant material. For example, in a properly designed system, running a ceramic valve against an elastomeric valve seat can provide an exceptional wear pair.

There are, of course, trade-offs involved. Elastomeric seats must be well contained to prevent extrusion. They must be designed to keep the seat and valve contact stress well within the operational range of the selected elastomer, and there are typically more chemical compatibility issues related to elastomers than there are to hard wear parts. With careful design, though, these compromises can be managed to result in a product that has superior overall performance within significant operating ranges.

The mechanism that allows an elastomeric/hard pair to work well is fairly simple to understand, if wear is examined at an individual abrasive particle/seat/valve interaction level. In hard seat/on hard valve closure, particles are trapped between the two components. The percentage of area that is actually in contact between the two parts is very low, as only a few of the largest particles will be involved in supporting the valve off of the seat. As a consequence, the contact stress between the particles and the valve components often exceeds the yield strength of all three elements involved. Typically, the particle is crushed to some degree, and microscopic amounts of material are gouged out of the valve and seat during each valve closure.



Some pumps are specifically designed for abrasive applications.

Why do elastomeric/hard seat wear pairs work so well? It is apparent from examination of the events that occur during valve closure. Hard particles trapped between the hard valve and soft seat are *elastically* pressed into the seat by relatively small loads, loads too small to bring on localized yielding and material removal from the hard element of the valve. Correct selection of elastomers can result in wear pairs that can run millions of cycles, while limiting wear to both elements of the valve system.

There are urethane elastomers that feature inherently high levels of abrasion resistance, tear resistance and extrusion resistance. When combined with Transformation Toughened Zirconia (TTZ) valves, they provide an excellent blend of properties, and an excellent wear pair to utilize the best aspects of this approach, while minimizing potential problem areas. Even with its high extrusion and tear resistance, urethane seats require high strength metal retainers to limit extrusion and gross deformation as pressures are increased.

Careful design of the seat containment can extend the upper pressure range of urethane seats well beyond that of a simply supported seat. There are, of course, limitations to this technology.

Very large particles can overpower the ability of the elastomer to absorb the particle without damage to the elastomer seat. There are also upper limits to the basic contact stress that the elastomer can sustain without extrusion or other forms of pressure related damage. However, the range of pressures, flows and particle sizes that can successfully be pumped makes this approach viable in many abrasive slurry pumping applications, including those mentioned above. Where pressure exceeds the capability of the elastomers, the "extremely hard on extremely hard" approach can be used. Repair costs typically rise with this approach, but economic trade-offs can be determined in individual applications, by running tests of the various approaches to the problem.

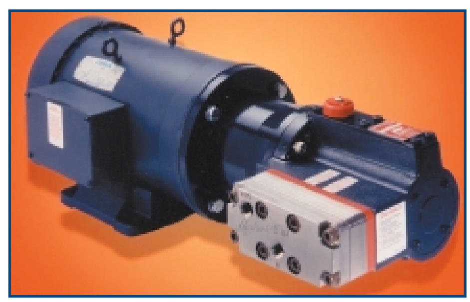
Another valve-life consideration in these types of systems is the absolute need to prevent relative motion between adjacent parts in pumps that are not intended to move. Many valve designs generally hold the valve components stationary, but on a microscopic level, relative motion does occur. When pumping fine abrasive particles, any relative motion can result in wear that will cause component failure far sooner than will occur in properly designed systems. Too frequently, valve system failures can be traced to inadequate design in this area. Taking care to properly preload components, in an effort to prevent relative motion, is a must to prevent problems in this area.

Conclusion

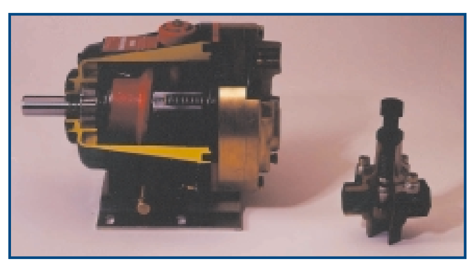
Properly designed pumps for abrasive applications can and will survive (and indeed thrive), while providing high levels of productivity in difficult environments. Avoiding the details will almost invariably lead to disappointment, and unsatisfactory commercial results. FC

About the Author

Al Powers holds 11 patents relating to fluid handling. He has been involved in the fluid handling industry and pump design since 1978. He graduated in 1976 with B.S.M.E. from Michigan Tech University. Currently, he is the vice president of engineering for Wanner Engineering.



Inherently abrasive and difficult to handle pumping materials represent great challenges for industrial pump manufacturers. Positive displacement pumps offer some advantages for these types of applications, and many manufacturers offer a variety of construction materials to suit given application requirements.



The need to prevent relative motion between adjacent pump parts is one key valve-life consideration. When pumping fine abrasive particles, any motion can result in fear that it will cause component failure prematurely, when compared to properly designed systems. Taking care to properly preload components is necessary to prevent problems in this area.

How to Properly Size a Motor to Save Energy and Extend Pump Life

By Jim Handzel

Variable output from a particular rotary driven positive displacement pump can be achieved by mechanical reduction (fixed or variable), or by using vector drive motors (with inverter and encoder); simple adjustable speed drive motors (with inverter only) or brushless DC motors. Running a pump only as fast as required to meet process demand will extend its life and save energy. If process demand is constant, fixed mechanical reduction is most economical. If, however, process demand fluctuates by more than 10 to 20 percent, it will pay off over time to control the pump with a variable speed electric drive. Maintenance costs will be reduced due to less wear and tear on pump components and bypass valves. Typically, a bypass valve will dump fluid not required for process flow directly back to the supply tank. This wastes energy, and may require additional energy to cool the supply tank.

When using a variable speed electric drive at lower than rated motor speed, shaft torque must be specified, in addition to motor HP. Example: Consider a Hydra-Cell Model D-10 Pump with E-cam (consult performance chart on page 41) being used for an application requiring 925 psi, and four to 6.5 GPM. The following equation applies for rotary driven positive displacement pumps:

BHP = [frictional HP] + [fluid HP] =

$$\frac{k_f \times RPM}{63,000} + \frac{GPM \times psi}{1,714 \times \eta_p}$$

Where: BHP = Total Brake Horsepower required

k_f = pump torque factor (15 in.-lbs. for Hydra-Cell Model D-10 Pump)

η_p = pump efficiency (85 percent for Hydra-Cell Model D-10 Pump)

Calculating BHP only, and not considering motor torque, would yield:

$$BHP = \frac{15 \times 1,400}{63,000} + \frac{6.5 \times 925}{1,714 \times 0.85}$$

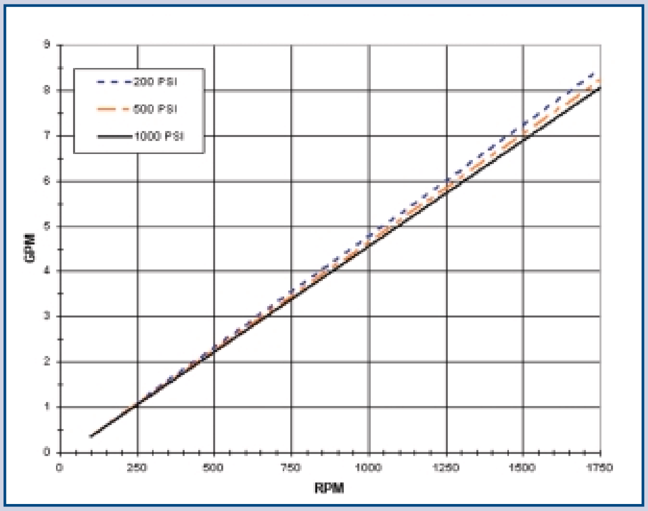
A five HP, 1,750 RPM motor cannot be specified, however, because 4.45 HP must be available from the shaft at 1,400 RPM. Shaft torque required to do this is equal to:

$$T_s = \frac{BPH \times 63,000}{RPM} \qquad \frac{4.45 \times 63,000}{1,400}$$

A motor rated at five HP @ 1,750 RPM will only deliver shaft torque equal to:

$$T_s = \frac{5.0 \times 63,000}{1,750} = 180 in.-lbs.$$

If periods of continuous duty are required at 6.5 GPM and 925 psi, a 7.5HP, 1,750 RPM motor should be specified (Ts = 270 in.-lbs.) to avoid overheating.



Performance chart for Hydra-Cell Model D-10 Pump with E-cam.

About the Author

Jim Handzel is named on three U.S. Patents for pump design and related fluid handling accessories, and is also named on several foreign patents. He graduated from the University of Minnesota in 1989, with a B.S. degree in mechanical engineering. Handzel worked for eight years with Graco as a senior project engineer. Currently, he is senior design engineer with Wanner Engineering.

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