PERFORMANCE CURVE MAINTENANCE

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EFFICIENCY IN THE 90'S

The general behavior of business in the 70's along with the state of the economy in the 80's has led us to the way in which we will do business in the 90's. We have cut our work force yet the workload has not been reduced. As a result, most of us have become involved in some sort of a process in which we are learning to do our jobs better and more efficient. In sum, we are reducing our workload by improving the way we do business.

In the field, we should institute this process with our equipment. By operating our equipment correctly we can reduce down time and as a result, make our jobs more efficient.

The equipment that will be referenced in this paper will be the end suction centrifugal. We will not refer to the mechanical maintenance of the pump, but how to maintain the pump according to the performance curve. An understanding of the relationship between the performance curve and the life of the pump is vital if your workload is going to be reduced.

THE PERFORMANCE CURVE

The performance curve is a graphical expression of the operating characteristics of a given centrifugal pump. The operating characteristics of a pump are derived from the impeller design, impeller style/type, the casting style in which the case and impeller is made, the speed and diameter of the impeller. The performance curve takes all these variables into consideration.

The curve itself is comprised of an 'X' and 'Y' axis. The X axis will depict the volume, generally expressed in gallons per minute. The Y axis will depict the discharge pressure capabilities, generally expressed in feet of head. There will also be several lines representing various impeller diameters. These lines will slope downward from left to right, originating at the Y axis. (see fig. 1) Typical curves will also have lines representing the efficiency of the pump at various spots on the curve. The efficiencies of a pump are also affected by the design of the impeller, the speed, and the diameter of the impeller. One will also see lines representing break horse power on performance curves as well as lines indicating the net positive suction head required (NPSHR).

All of these variables become very important as we begin to look at the curve as a tool that we can use to maintain our pumps for a more efficient and longer service life.

THREE COMPONENTS

In order to understand where a pump needs to operate, in reference to the performance curve, and where not to operate it is important to separate the curve into three regions: the left, the center and the right portion of the curve. All of these regions will have a common reference point. This point, on every curve and on each rated impeller diameter will be the best efficiency point (BEP). The BEP on each curve is that point in which the pump is operating at ease. The horse power requirements are at an optimal level, the pump has neither a radial load nor a thrust load that it isn't capable of withstanding, the required NPSH is typically not a concern, and there will normally not be a heat build up problem caused by minimal fluid circulation through the pump case. All of this results in longer pump life.

Unfortunately, not all pumps can be sized to perform at the best efficiency point. Sometimes pumps must be sized to the left portion of the curve as a result of NPSH requirements. Pumps also run on the right portion of the curve for various reasons. However, a longer pump life can be achieved by knowing how to put pumps back at BEP.

LEFT ON THE CURVE

The left portion of the curve will be defined as that portion which is to the left of BEP by 40% of rated flow on a given impeller diameter. (This number is not published as factual for all given performance curves, it is used strictly as a guide point for this paper and as a general rule.)

There are many adverse reasons for not running to the left on the curve and one very good reason for being there. The NPSH requirements increase as the conditions move from left to right on the curve. As a result, if NPSH available is relatively low, the conditions of flow can be sized to the left portion of the curve. However, it is important to know what to expect when running left on the curve. This is also known as throttling the pump.

Recirculation

When a pump is operating left on the curve, or being throttled, it is not passing through it's cavity enough liquid to maintain the ambient temperature of the given condition. Or, the difference between input horse power and water horse power is transferred to the liquid in the form of heat. This can also be expressed as heat build up caused by internal friction between the fluid and the pump parts.

As the warmer or hotter fluids enter the stuffing box, where there is even less circulation, the heat is magnified. Once the temperature rises within the stuffing box the potential for mechanical seal failure due to the excessive heat increases greatly.

As the mechanical seal wears prematurely and as a result fails, the bearing end of the pump has a very good chance of filling up with the pumpage and contaminating the bearings. The chain reaction is pump failure through the bearing housing. There is a potential cost of at least 60% of a new pump price due to bearing failure. This does not include cost of lost process time.

A second option for failure is cavitation caused by the heat build up. This holds especially true for liquids that are being pumped at or close to their vapor pressure. An example would be on a crude oil LACT unit during the summer months. The crude heats up as it passes through the suction line toward the pump and continues to build heat after entry into the pump case. As the crude recirculates and is heated the vapor pressure increases and pockets of gas escape causing cavitation.

A third adverse result of running left on the curve is an inefficient pump. The difference between the efficiencies at BEP and left on the curve can be as high as 25%. Over the life of the project this can mean several dollars.

Radial Load

Closely related to the problem of recirculation, due to the effects of throttling, is radial load. Radial load is a vertical downward thrust on the impeller that also affects the stability of the shaft. This load can cause several adverse reactions to the internal parts of the pump.

First, the downward load attacks the shaft. Since the impeller is over hung on end suction centrifugals there is no support for the shaft except the shaft itself. As the radial load increases so does the deflection of the shaft. Continuous deflection will eventually cause shaft failure. The break typically takes place at the point where the impeller mates up with the shaft. (see fig 2) For ANSI designed pumps this is not normally a problem except for the large impeller diameters at high horse power applications. However, for trash pumps with large impellers, non-ansi pumps designed for high volumes, and non-ansi pumps turning 3600 rpm, this can and will create problems. Keep in mind that pumps, in general, are designed around the best efficiency point. Steering away from this point gives an opportunity for failure no matter the pump design.

A second problem created by radial load will directly affect the impeller. On open and semi-open impellers, radial load causes impeller fatigue under certain conditions. First, the diameters of the impellers are usually in the 12 to 13 inch range; and second, the pump speed is at 3600 rpm. The fatigue takes place at or near the impeller tips where the main body of the impeller stops and the veins continue. This fatigue will eventually cause the tips to break and as a result cause more problems internally.

Impeller tip breakage does not readily take place with ANSI or API designed pumps. If it does a different metallurgy for the impeller may correct the problem. There are also pumps that are designed with 2 different impellers, one for 3600 rpm and one for

1800 rpm. It is imperative that the correct impeller is in the pump. Keep in mind that when running left on the curve premature failure is a strong possibility.

Although the impeller and shaft will see the results of most major radial thrust problems, there is another indicator when the loads are of a lesser magnitude. This indicator is the radial bearing. (see fig 2) Radial bearings, found in most end suction centrifugal pumps, are typically the inboard bearing closest to the impeller. As the name indicates, it is the bearing designed to absorb the radial load. As a result premature wear can be caused by running left on the curve. Normally, the radial bearing will have a premature life when the load is not sufficient enough to cause problems on those items previously mentioned. Reduced bearing life will also be the result of smaller pumps that are throttled, large pumps turning at a lower rpm while running left, and the larger horse power applications with trimmed impellers that are also running left.

Although the loads that attack the radial bearings only may not be as severe as the loads that get shafts and impellers it still has the potential of being a major problem. If the bearing is not detected as being worn in a timely manner the life of the pump is at jeopardy.

At the point of bearing failure, the shaft may not quit turning immediately. As the pump continues to spin the life of the case, the impeller and the stuffing box is reduced. The cost of these three items alone is normally at 60% of a new pump price. This does not include both bearings, all oil retainers, the mechanical seal and the labor to repair, plus your process down time.

As stated previously, sometimes the pumps must run left on the curve but there are ways to protect your pumps against the inevitable.

Solutions to the Left

There are several ways to get the pump running toward BEP depending on whether or not the volume being pumped is a critical point. First lets assume that the volume has no real impact on the conditions at hand.

The performance curve is created as a function of volume and discharge conditions. This relationship is such that one cannot change without the other changing. So in order to move toward BEP one must decrease the discharge pressures and as a result increase the volume being pumped.

Probably the easiest way to perform this task is to reduce those items that are causing friction losses on the discharge side. For example, use 45 degree ells as opposed to 90's, use full opening valves as opposed to those that are restricted, keep your discharge lines free from debris as best you can, and when possible use larger discharge line. Flow meters can also restrict flow if not properly used and installed. When flow meters are required, follow instructions on installation procedures and make sure they have large enough ports to allow passage of the desired volume.

Another option may seem extreme up front, but, over the project life, may cost you less. If all measures have been taken to reduce the friction losses on the discharge side of the pump and there is still a problem, buy a pump that will perform the task correctly. The cost of a major overhaul may be less than the additional cost of the correct pump.

The other scenario is not as cut and dry. If, for whatever reason, the volume cannot be increased then you must work with the discharge fluids.

One of the easiest methods is to use a by-pass valve and send enough fluids back to the supply side to get the pump running as close to BEP as possible. One needs to make sure that it will be possible to by-pass as well as pump the correct amount of fluids to the process side.

If mechanical seals are wearing prematurely because of circulation the previous method of by-passing will solve some problems. It is also possible to flush the seal with pumpage from the discharge side or flush with a cooler outside source of fluid. Keep in mind that seal failure from circulation is a result of heat build up in the stuffing box. Anything to dissipate this heat should prolong the life of the seal.

To combat the pure effects of radial load where by-passing is not an option there are a couple of solutions. First, if the pump is not designed around ANSI or API specifications get one that is. Second, change metallurgies. Go to a metal that is more durable yet not as brittle as the material currently used. And finally, go to a pump that has a larger impeller with smaller ports.

All of these options will have an initial price tag that will include hours of labor, parts and the cost of downtime. But if done correctly, the life cycle cost of the equipment will be greatly reduced. The result, a more efficient process.

RIGHT ON THE CURVE

Unfortunately the performance curve does not just have one good side and one bad side. Running right on the curve is just as detrimental as running left only in different ways.

Right on the curve will be defined as any portion of the performance curve that is to the right of the best efficiency point for any rated impeller. (This definition is not published as being factual for all given performance curves, it is used strictly as a guide point for this paper and as a general rule.)

There are many reasons why pumps are operated on the right portion of the curve. Misapplication, using surplus equipment because it's inexpensive and available, and conditions of the process have changed over the years. No matter the reasons, the effects are the same and they can cause premature pump failure and as a result, a less efficient operation.

Net Positive Suction Head Required

Every end suction centrifugal pump has an 'X' amount of positive suction head that it requires to perform correctly at the various points on the curve. This amount varies as a result of the speed in which the pump is running and in particular, the design of the impeller. Although the amount of NPSHR varies according the variables of the pump, it is a fixed number according to the conditions being pumped. Or it is fixed depending on where you are on the curve.

As the conditions of pumpage move farther to the right the net suction head required increases. If the net positive suction required becomes larger than the net positive suction available we have problems. The two major problems concerning a lack of NPSH available are cavitation and thrust.

Cavitation is that point where gas pockets or air bubbles escape from the liquids being pumped at the eye of the impeller. As these bubbles travel through the impeller vanes toward the discharge nozzle they begin to collapse as a result of the increased pressure. This collapsing of air pockets, called implosions, can and will create problems within the pump. Internally the implosions attack the metal or material surrounding the cavitation points. These points are generally the impeller tips and the cut water area at the discharge nozzle. Vibration and noise are the external results of cavitation that can usually be detected without inspecting the pump internally.

The results of cavitation can be costly. Obviously premature failure to the impeller is a possibility as well as failure to the pump case. Another potential problem caused by the vibration is premature seal failure. And finally, a "pain in the neck" type problem caused by the air pockets is the possibility of vapor locking.

Vapor locking or air locking is that point where the air bubbles become great enough in volume to stop the pumping process. Until the pump is emptied of the air, it will not pump. Although this problem is more of an aggravation than a problem, it will cause seal failure.

As the seal chamber is emptied of fluid and filled with air or gas, the seal has no lubrication and runs dry. Mechanical seals will fail without a lubricant and coolant of some type.

Just prior to the actual events of cavitation, or that point where the net positive suction head available becomes zero and lower, the centrifugal pump actually begins to pull a vacuum. It actually pulls the fluid being pumped into the eye of the impeller. When this is taking place the impeller begins to thrust forward toward the supply of liquid. This thrust is being absorbed by a thrust bearing, found in most centrifugal pumps. (see fig 2) Just as the radial bearing is designed to absorb the radial load, the thrust bearing is deigned to absorb the axial load. However, when the thrust becomes more than the bearing is designed for or there is continuous thrust for long periods of time you will see premature bearing failure. A lost thrust bearing will invariably cost you an impeller, a pump case, both bearings, the mechanical seal, and a full day of down time as a minimum.

Solutions to the Right

As with running left on the curve, there are ways to get back to the best efficiency point when running right.

The easiest method is to artificially restrict the discharge conditions. Or, as discussed earlier, throttle the pump. There are a number of ways to accomplish this. Some easy and inexpensive, and some elaborate and costly.

A manually operated gate valve on the discharge side of the pump relatively close to the discharge nozzle is probably the least expensive. It is also the most inefficient method. The inefficiency is not a result of the design of the gate valve but because it is manually operated. System pressures and flows may change while unattended and as a result the pump falls off of BEP one way or the other.

A back pressure valve that is automatically actuated by the pump discharge pressure is probably the most expensive but also the most efficient. As the system changes the valve is actuated automatically to hold the pump at the best efficiency point. If the system is designed to continually change this is probably the best method.

Either way will extend the life of your pump and as a result increase the efficiency of your process.

A final method to control the problem of running right on the curve is to purchase a pump that is sized to the conditions needed while running at BEP.

AT BEP

For several pages now we have discussed the potential problems of running away from the best efficiency point of a given impeller diameter with a given centrifugal pump. But nothing has been said about the dangers of running at BEP. As stated earlier in this paper running at BEP was/is the ultimate goal. This is where you get the maximum run life out of a centrifugal. It is where your horsepower dollars are being best utilized. It is also, under specific conditions, where you can see specific problems.

The specific conditions are: a pump speed of 3600 rpm, a relatively small discharge nozzle (1" to 1.5"), a relatively large impeller (10" to 13"), and running at BEP. Under these specific conditions a pump can experience velocity head loss. As a result the desired volume will not be pumped and may result in a process that is not as efficient as should be. This problem is usually the result of an oversight by the application department and will not result in damage to the equipment.

Positive Results of BEP

Not all centrifugal pumps can be sized to operate at the best efficiency point. When they can, however, the results are overwhelmingly positive. The pumps life is extended greatly and is typically downed by the life of the mechanical seal which is greatly extended by running at BEP. The efficiency of the pump at BEP will reduce your electricity cost or fuel cost depending on the pump driver. And the result of all of this is a reduction in down time and a more efficient operation.

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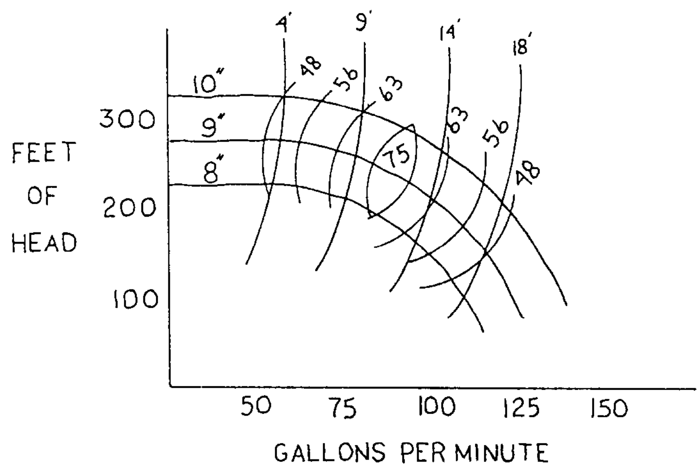

Figure 1

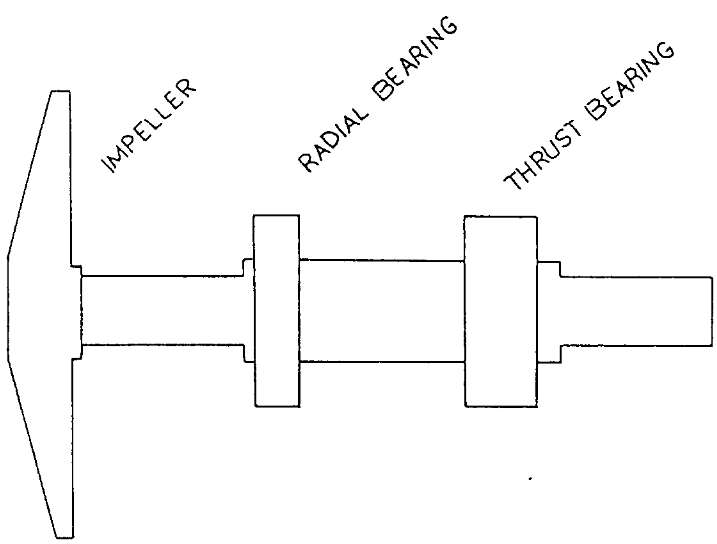

Figure 2