Considerations for a PD pump and a centrifugal pump to perform on the same duty

technical bulletin

There are many facets to performance which must be considered when selecting and sizing a pump for a given duty. One of the key decisions may be whether to use a positive displacement pump or a centrifugal pump and there are advantages and disadvantages to both depending on the duty and requirements, such as pumping high viscosity fluids, pump reliability, safety requirements and leakage management. When considering a centrifugal pump there is also a greater interaction of properties so as one property is changed other resultant characteristics properties will need to be evaluated, for example the impact of specific gravity or viscosity on flow and head.

Selecting a centrifugal pump or positive displacement pump

Positive displacement and centrifugal pumps operate in very different ways and so varying the duty or specification, such as the flow, head or fluid properties has a different effect on the other elements of performance for each pump type. The table in Figure 1 shows some examples of changing one requirement on other properties for each pump type.

Property change	Centrifugal pump	Positive displacement pump
Change in head		
- Flow	Changes	Near constant
- Efficiency	Changes	Changes
Change in pumped fluid Specific Gravity		
- Differential head	Remains constant	Remains constant
- Flow	Remains constant	Remains constant
- Discharge pressure	Changes	Changes
- Power	Changes	Changes
Change in pumped fluid viscosity		
- Head	Changes	Remains constant
- Flow	Changes	Changes
- Discharge pressure	Changes	Remains constant
- Power	Changes	Remains constant

Figure 1

As such, selecting between a centrifugal pump and a positive displacement pump or replacing a positive displacement pump with a centrifugal one for any given duty, needs careful consideration, particularly if requirements such as those above will change during the operation of the pump, either regularly or over the lifetime of the pump.

Positive displacement pumps

A positive displacement pump's flow rate is proportional to the displacement rate and independent of system pressure. The average capacity of a positive displacement pump at constant speed is, within the design limits of pressure, practically constant, even though flow rate pulsations occur as individual displacements are forced into the discharge pipe. The flow control of a positive displacement pump is therefore accomplished by either changing the displacement rate or changing the displacement volume. Power consumption at a given pressure is proportional to speed. Pump efficiency for positive displacement pumps is seldom published.

If a change is made to a system such that it moves a pump's operating point to a new flow, then for a positive displacement pump, the outlet pressure and input power will change but there will be very little change in the flow. See Figure 2.

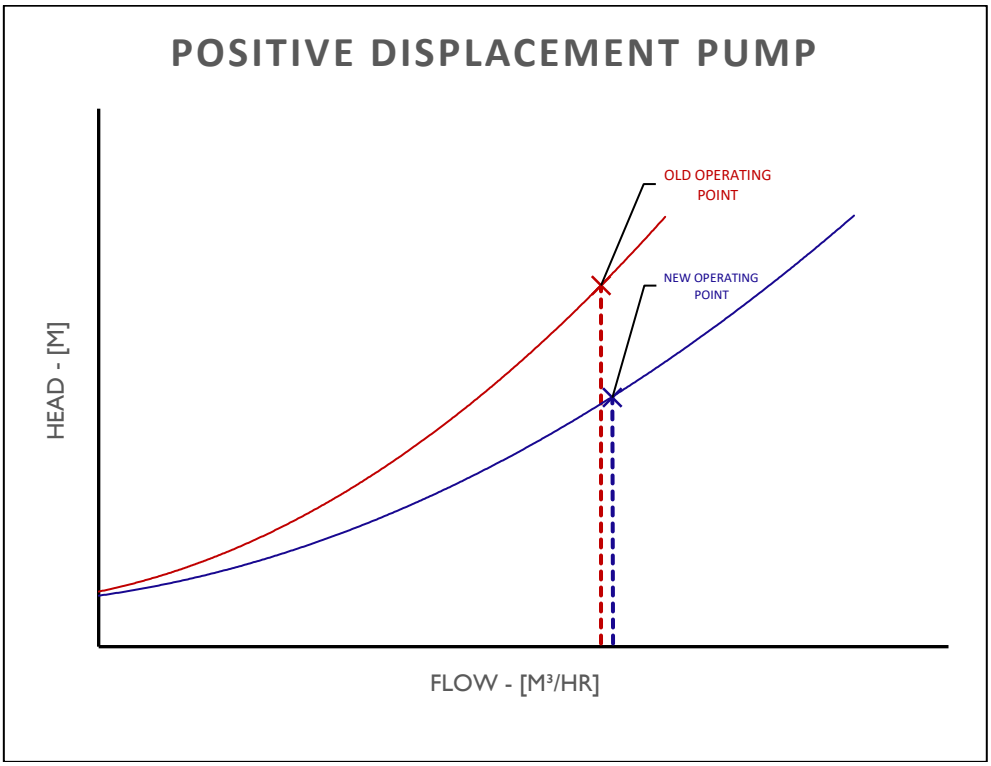

Figure 2

Centrifugal pumps

The capacity of a centrifugal pump varies from a maximum flow with minimal developed head to zero flow at a definite limiting pressure. The operating point of a centrifugal pump depends on the interaction of the pump and system curves. The operating point for a single impeller diameter operating at a constant speed occurs where the head and flow curves for the pump and system intersect. The efficiency, power and NPSHR of the pump are then influenced by that operating point.

Centrifugal pump selection should be made so that the combination of pump and the system curve give a flow corresponding to the customer's requirements, known as the Duty Point. However, to conserve energy and improve reliability, the duty point is selected so that it is close to the part of the pump performance corresponding to maximum efficiency, known as the Best Efficiency Point (BEP).

If a change is made to a system such that it moves a pump's operating point to a new flow, then for a centrifugal pump, the flow, head, power and NPSHR will all change. See Figure 3.

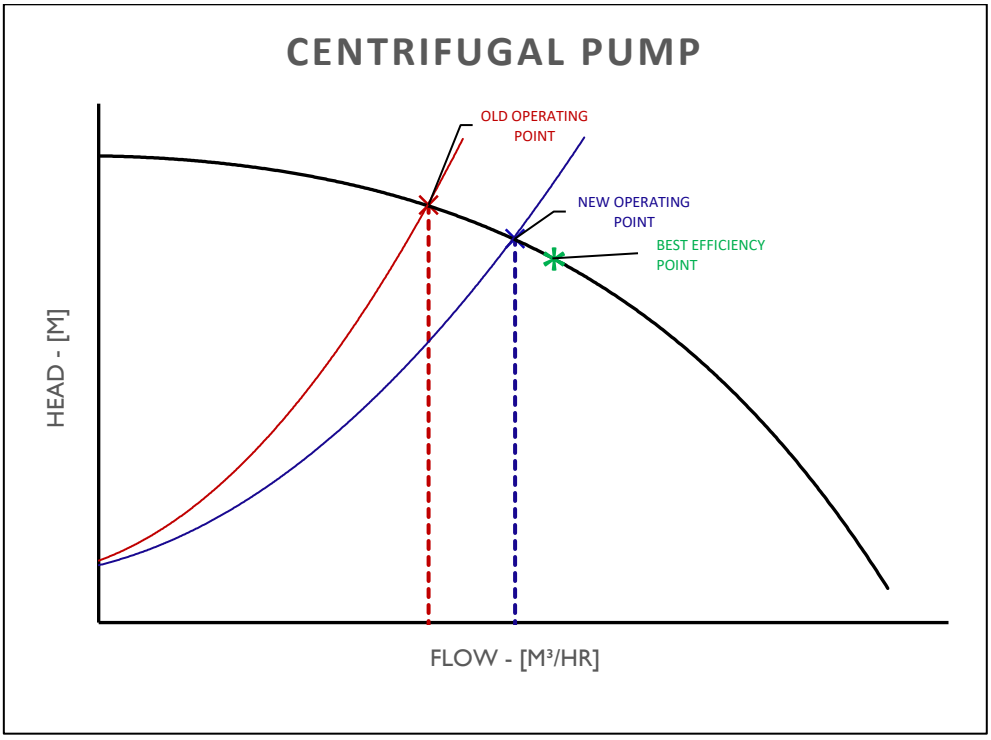

Figure 3

Pumping systems usually work across a range of flows and pressures and a successful design for a centrifugal pump must take account of more variables than a positive displacement pump. As such, when selecting a centrifugal pump more data is needed about the application and duty than a when selecting a positive displacement pump.

Changing requirements of the same centrifugal pump

When changing demands are made of the same pump, for example a change in fluid properties, such as when an oil well moves through its life and the percentage of produced water in the pumped fluid becomes greater, then the selection and sizing must be made using requirements that do not conflict.

Selecting and sizing a centrifugal pump is generally undertaken based on a specific application and duty, including the composition of the pumped fluid. The operating point for a fixed impeller diameter operating at a constant speed occurs where the head and flow curves for the pump and system curve intersect and the efficiency, power and NPSHR of the pump are then all influenced by that operating point.

Changing the specific gravity of the pumped fluid

As the specific gravity of the pumped fluid increases, the pressure increases accordingly, so to maintain the same discharge pressure the head needs to be deceased for the same pump. A fluid with a higher specific gravity also requires more power for the pump to maintain the same flow. The pump manufacturer must make the appropriate calculations and changes to the final pump design based using the actual specific gravity of the pumped fluid.

A pump is therefore sized and selected based on an application and duty using both the pump curves **and** the specific gravity of the pumped fluid. If the specific gravity of the pumped fluid later changes (either within the same process or should the pump be used on a different process), then the pump may not be working at best efficiency or may not be able to pump the fluid at the same flow or pressure. For example, a specification that demands a fixed discharge pressure but with a varying specific gravity for the pumped fluid can never be met using a fixed speed centrifugal pump. See Figure 4 which illustrates the effects of three different conditions of specific gravity and how the differential pressure and hence discharge pressure and power (all in red) are affected in each case.

Details	CASE 1	CASE 2	CASE 3
Specific Gravity	0.8	1.0	1.5
Flow Rate(m3/hr)	50	50	50
Differential Head (m)	100	100	100
Differential Press. (barg)	7.85	9.81	14.71
Suction Press. (barg)	0.5	0.5	0.5
Discharge Press. (barg)	8.35	10.31	15.21
Pump Speed (rpm)	2950	2950	2950
Impeller Diameter (mm)	280	280	280
Power (kw)	24.7	34.3	40.8

Figure 4

It is therefore crucial that we understand from the customer if the specific gravity of the pumped fluid is likely to change over time and the customer data sheet must acknowledge this and detail by how much the specific gravity will change so that either a pump can be selected that will work reliably across this range, or if that is not possible an alternative system design, such a variable speed pump, can be proposed.

Changing the viscosity of the pumped fluid

A further variable can be a change in viscosity of the pumped fluid. In this case the main impact of a higher viscosity fluid is a lower head and more power required. See Figure 5 which illustrates the effects of two different conditions of viscosity and how the other factors such as flow rate, pressures and power (all in red) are affected in each case.

Details	CASE 1	CASE 2
Specific Gravity	1.1	1.1
Viscosity (Cst)	1.0	200.0
Flow Rate(m3/hr)	50	44.65
Differential Head (m)	100	91.8
Differential Press. (barg)	10.79	9.09
Suction Press. (barg)	0.5	0.5
Discharge Press. (barg)	11.29	9.59
Pump Speed (rpm)	2950	2950
Impeller Diameter (mm)	280	280
Power (kw)	37.7	39.0

Figure 5

Conclusion

Selection and sizing of centrifugal pumps to work at best efficiency requires careful consideration of many factors and how these interact or may conflict with each other.

There are a number of positive reasons why a centrifugal pump may be preferred over a positive displacement pump, but in selecting and sizing a centrifugal pump to meet the same duty as a positive displacement pump, the way in which changes in one parameter result in changes in another are very different between the pump types. As such, where a duty was specified for a positive displacement pump, to select and size a centrifugal pump for the same duty and performance may require other information not usually considered when specifying the positive displacement pump.

When sizing and selecting centrifugal pumps, then a change in the pumped fluid property, such as specific gravity and viscosity, also has an impact on other parameters such as flow, head, power and efficiency, and so attention must be paid to where such changes in fluid properties are specified to ensure that these do not conflict with the required pump performance, otherwise technology such as variable speed pumps may be required to handle these duties.