LOW SHEAR PUMP SELECTION CONSIDERATIONS FOR PRODUCED WATER APPLICATIONS

Pumps are required in produced water treatment applications where there is insufficient pressure available to efficiently treat the produced water. A typical application is pumping of water from the low-pressure part of the separation system. Correct pump selection for this application is important with regards to the efficiency of downstream treatment equipment, pump system maintenance load, CAPEX, and OPEX. This article is intended to give a compact overview of some of the main factors involved in the pump selection. References to relevant articles are added for further reading. The topics discussed are; evaluation of the pump types, a discussion on the level of low shear that is acceptable, and evaluation of pump turndown solutions.

Pump Type Evaluation

In addition to the general requirements for capacity and head, produced water pumps are often required to be low shear [1,2], i.e. having minimal negative impact on the oil droplet size. Different pump types have different levels of shearing of the oil droplets in the produced water [3]. For produced water applications, positive displacement pumps, mainly progressive cavity and lobe pumps, and centrifugal pumps are the most common choices.

Most positive displacement pumps are regarded as low shear pumps [3]. Single stage centrifugal pumps, however, are not regarded as low shear. On the other hand, single stage centrifugal pumps do have other advantages over positive displacement pumps. These advantages are mainly related to:

- Larger capacity
- No requirement for closed outlet protection
- More robust pump design, i.e. lower OPEX
    - lower maintenance load
    - less sensitivity to particles and chemicals
    - higher mean time between failures (MTBF)
- Lower CAPEX
- Smaller footprint

Because of these advantages, single stage centrifugal pumps are a popular choice despite the fact that they are a source of high shear [2,3,4]. To reduce the shearing of oil droplets, several design and operational considerations are applied by many operators or manufacturers. The most common considerations are [4]:

- Limiting the maximum speed
- Choosing a pump design with high hydraulic efficiency
- Oversizing the pump and/or the discharge nozzle
- Limiting the head per stage

While the recommendations of high hydraulic efficiency and low pump head are undisputed, limiting the pump speed and choosing an oversized pump are measures which are challenged [3].

Though limitation of the pump head is a proven way to reduce shear, it has practical limitations. Generally, a maximum head of 50 psi / 3.4 bar is advised [4]. Regardless of the pump type, low shear performance is however highly dependent on the oil viscosity and the inlet droplet size to the pump. A general rule for maximum head is therefore considered not to be a good approach, as it so highly depends on the particular application at hand. Though limitations to the pump head are a good method to reduce shear, it simultaneously severely restricts the applicability of single stage centrifugal pumps in produced water systems.

Figures 1 and 2 shows the results from experiments performed with single stage centrifugal pumps to evaluate the effect of pump speed and sizing on shearing of oil droplets. For both graphs, the x-axis gives the differential pressure over the pump and the y-axis gives the relative change in the droplet size (Dv50). The point on the top of the y-axis indicates no droplet break-up, meaning that all points below imply droplet break-up.

Figure 1 shows the effect of reducing the speed. As can be seen from the figure, the results show no correlation between reduced pump speed and reduced droplet break-up, as the high-speed pump gives the same droplet break-up as the lower speed pump for the same flow (Q) and dP.

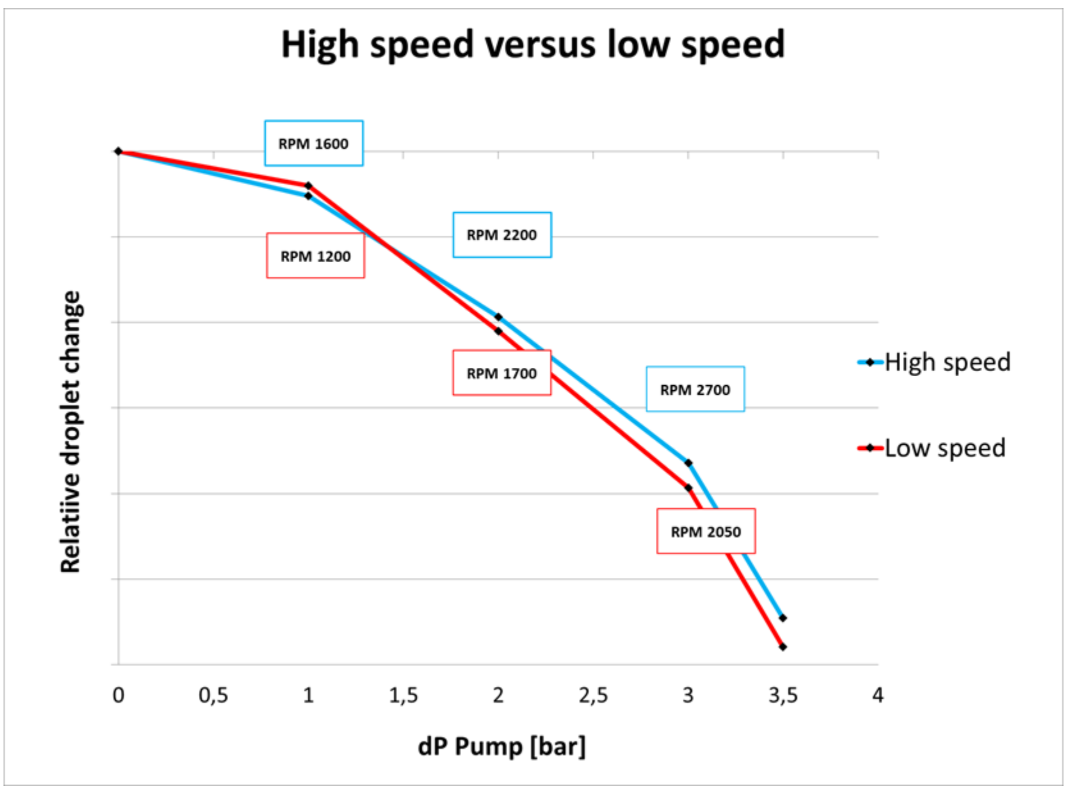

Figure 1: Comparison between a high speed and a low speed pump with regards to droplet break-up [5].

Figure 2 shows the effect of oversizing a single stage centrifugal pump on droplet break-up. These results indicate that an oversized pump actually causes more droplet break-up than the normal sized pump for the same pump speed, Q and dP.

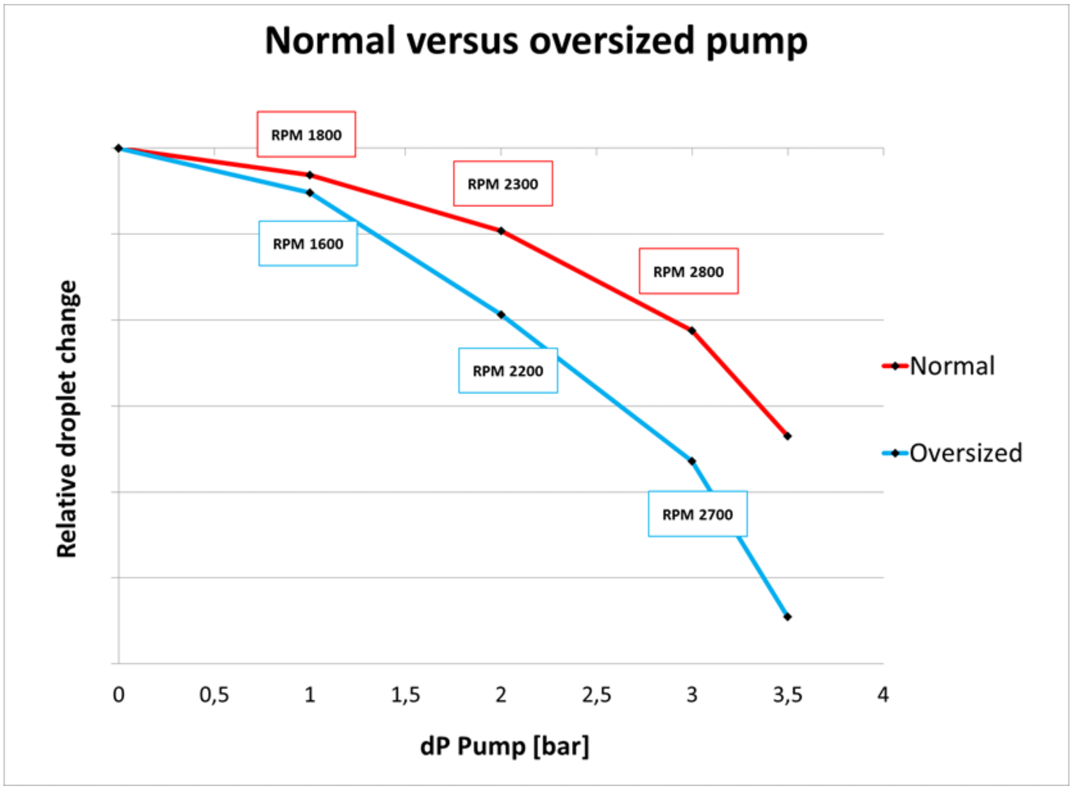

Figure 2: Comparison between a normal and an oversized pump with regards to droplet break-up [5]

It is clear from these results that more research is required to fully understand the factors involved with droplet break-up in centrifugal pumps.

From a low shear point of view, it is clear that single stage centrifugal pumps have a very limited operational envelope compared to that of positive displacement pumps. A multi stage centrifugal pump, on the other hand, may be used to overcome this limitation. The drawback of these pumps is that they will have a higher CAPEX and footprint compared to single stage pumps, for the same head and capacity.

The main benefit of multi stage centrifugal pumps, is that they have the same robust design as single stage pumps, in addition to having a much larger operational envelope with regards to low shear performance, higher hydraulic efficiency, and lower noise and vibration. Another advantage of multi stage centrifugal pumps is that the amount of shear (or turbulence) in the pump can be controlled by optimizing the pump's design. A multi stage centrifugal pump can even be designed to increase, rather than maintain, the droplet's size. Figure 3 shows an example of a coalescing multi stage centrifugal pump, characterized by larger droplets at the outlet compared to their initial size at the inlet. Growing the droplets significantly increases the efficiency of downstream produced water treatment equipment, as their efficiency is highly dependent on the droplet size [6,7].

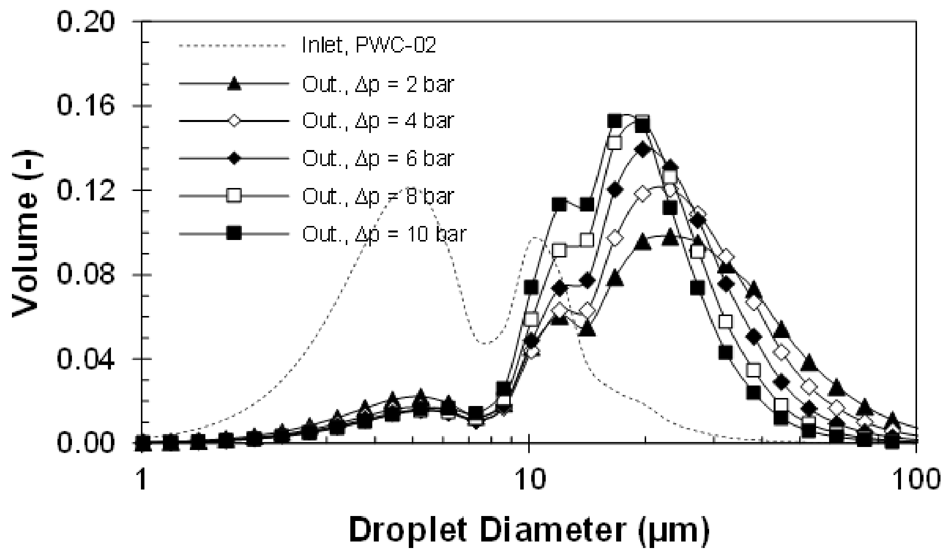

Figure 3: Example of a coalescing centrifugal pump inlet and outlet droplet size distribution for different pumping pressures [7]

Low Shear Requirements

The most suitable pump for a particular application is of course dependent on the requirements of the produced water treatment system. The required oil droplet size is, for example, dependent on the type of separation equipment utilized [8]. Different droplet size requirements for different technologies are visualized the Figure 4. Here the low shear performance of three pumps, and the cut size of three produced water treatment equipment, are compared. In this example, the measured outlet droplet size of the three different centrifugal pump designs (one single-stage, two multi-stage) is also presented. The black dotted line shows where the inlet and outlet droplet sizes (Dv50) are the same, indicating no change in the droplet's size across the pump. Above this line, the Dv50 has been increased, and below this line, the Dv50 has been reduced.

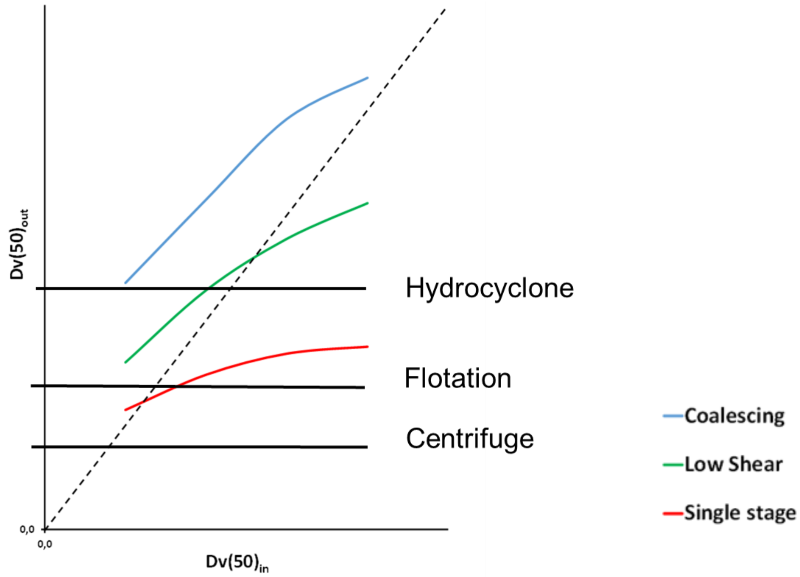

Figure 4: Shearing performance of three pump designs visualized against examples of produced water treatment equipment cut-size.

It is clear from this example, that the pump generating the red curve is suited to feed the centrifuge. This pump however starts breaking up droplets under the cut size of the flotation unit and would therefore reduce its separation efficiency. If this pump was used to feed a hydrocyclone, the majority of droplets entering the cyclone would be too small, therefore simply passing through the equipment without being removed. The pump generating the green curve and the pump generating the blue curve can both be used upstream a flotation unit and a hydrocyclone. Moreover, the coalescing design (blue) will most likely lead to a higher separation efficiency, compared to the low shear design (green), due to the increase in droplet size promoted by this pump.

Turndown Requirements

Pump turndown, i.e. its required operating range, is also something that should be considered when choosing a pump type and designing the pumping system. Turndown can be achieved in two ways. One is with use of a variable frequency/speed drive (VFD/VSD) to control the speed of the electric motor driving the pump. For positive displacement pumps, flow and pumping pressure are not coupled. This pump type therefore has a large turndown ratio when operated with a VFD. For centrifugal pumps on the other hand, flow and pumping pressure are closely coupled. Reducing the flow rate will have an impact on the pumping pressure and vice versa. Centrifugal pumps will therefore have a smaller turndown ratio compared to that of positive displacement pumps when operated with a VFD. Multi stage centrifugal pumps have a higher turndown ratio than single stage centrifugal pumps due to differences in the design.

The other method to create turndown is to use a constant pump speed set-up and facilitate turndown with a recirculation line, leading part of the pumped fluids back upstream the pump. The challenge with this solution is that the low shear performance of the pump is adversely affected by the shearing introduced by the recirculation control valve. The higher the turndown required, the more significant this effect will be. One way of reducing the shearing introduced by the recirculation control valve, may be the use of a low shear control valve.

Conclusion

When designing the produced water treatment system, correct pump selection is very important. Factors such as pump type, droplet size requirements for the produced water treatment equipment, and methods to obtain the required turndown without introducing high shear, have been presented in this article. These elements should be carefully considered when selecting a suitable pump. Positive displacement pumps and multistage centrifugal pumps are obvious choices when considering low shear pumps applications. The large turndown ratio and possibly lower CAPEX of the positive displacement pumps should be evaluated against the requirement to have closed outlet protection, the more robust design of centrifugal pumps, their lower OPEX, and the larger capacity. Multi stage centrifugal pumps and positive displacement pumps are suitable for most low shear produced water applications. Single stage centrifugal pumps can be considered when there is a very limited head requirement or in combination with produced water treatment equipment having a low droplet cut-size.

References

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