LOW SHEAR PRODUCTION

In oil and gas production, large gravity based separators are used to separate the different phases; water, oil, and gas, into clean phases. The produced water is cleaned in a number of treatment stages to reduce the oil content to an acceptable level. This water is either reinjected into the reservoir to increase the hydrocarbon recovery, injected into a disposal well, or discharged over board. A typical North Sea offshore oil production system consists of two to four stages of bulk separation and two or three stages of produced water treatment, as illustrated in Figure 1.

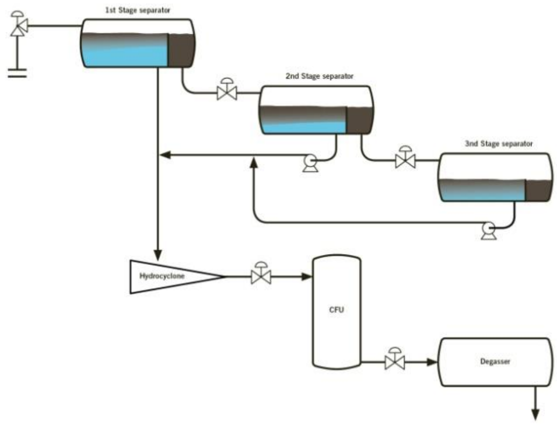

Figure 1: Typical North Sea bulk separation and produced water treatment system

Upstream and in-between the different separators and produced water treatment stages, valves and pumps are installed to control flow and pressure. These valves and pumps are regarded as a necessary evil with regards to the separation efficiency. Shear forces acting on the fluids passing through the valves and pumps cause emulsification and droplet break-up which have a detrimental impact on downstream separator efficiency.

A number of measures can be employed to counteract the negative impact on separation efficiency from these valves and pumps. The residence time of a separator can be increased, more treatment stages can be utilised, heat can be applied, separation enhancing production chemicals can utilised, etc. These measures can, however, have a significant negative impact on the CAPEX; increased footprint and weight, and OPEX; power and chemical consumption. A more constructive way is therefore to deal with the cause of the issue/problem, which is to reduce the negative effect of the valves and pumps on the separation efficiency.

SEPARATION THEORY

Oil water separation in gravity separators occurs by droplets from the dispersed phases traveling through the continuous phases to the phase interphase. The maximum vertical velocity (terminala velocity) of a droplet in fluid can be described by the equilibrium of the forces acting on the droplet, being buoyancy, gravity and drag. This results in Stokes' Law:

$$v_t = \frac{g \cdot d^2 \cdot (\rho_c - \rho_d)}{18\mu_c}$$

Where:

v_t Terminal velocity [m/s]
g Gravitational constant [m/s²]
d Droplet diameter [m]
ρ_c Density continuous phase [kg/m³]
ρ_d Density dispersed phase [kg/m³]
μ_c Dynamic Viscosity continuous phase [Pa·s]

The diameter of the droplet has the largest impact on the rising velocity. Doubling the droplet diameter will result in a quadrupling of the velocity. Droplet size therefore has a large impact on the separation efficiency, and maximizing the droplet size is vital for efficient separation.
Flow in pipes, valves and pumps of a petroleum process system, is normally turbulent. Hinze has formulated the maximum droplet size that can exist in a turbulent flow regime:

$$d_{max} = We_{crit}^{3/5} \cdot \left(\frac{\sigma}{\rho_c}\right)^{3/5} \cdot \varepsilon^{-2/5}$$

Where:

We_{crit} Critical Weber number [-]
σ Interfacial tension [N/m]
ε Mean energy dissipation rate per unit mass [W/kg]

The critical Weber number, density and interfacial tension are all dependent on the fluid properties and composition, and can therefore be regarded as constant. The only variable left to influence the maximum droplet size is therefore the *mean*

energy dissipation rate per unit mass, ε. In order to increase the maximum droplet size, ε has to be decreased.
For the flow through a valve ε can be defined as:

$$\varepsilon = \frac{\Delta P_{perm} \cdot Q}{\rho_c \cdot V_{dis}}$$

Where:

ΔP_{perm} The permanent pressure drop [Pa]
Q Flow rate [m³/s]
V_{dis} Volume used for energy dissipation [m³]

Hence, in a given flow system, the only parameter that can be used to reduce the mean energy dissipation is the volume involved in dissipating the required energy, V_{dis}. By controlling this volume the mean energy dissipation rate, and thereby the droplet size, can be controlled, which in turn has a large impact on the separation efficiency.

LOW SHEAR PRODUCTION

The philosophy of *low shear production* is that low shear solutions should be used where needed to prevent separation problems. Shear in itself is not necessarily a problem and a certain level of shear can even be required, either to promote coalescence or enhance gas-liquid separation in the event of foaming. Too much shear has however a negative impact on separation efficiency.

Choke

The most obvious application for low shear technology is normally the choke valve. Even a moderate or low pressure differential over a choke valve can cause significant emulsification of the fluids. Tests performed with simulated and live field conditions have shown that a low shear choke valve, like the Typhoon® System, can have a tremendous impact on the separation efficiency of downstream separators. Tests with the Typhoon® System show that a 50 to 90% reduction in the oil-in-water (OiW) quality downstream of the separator is possible when replacing a conventional choke valve with a low shear version. Figure 2 shows results of a test where the water quality is shown for both the Typhoon® System and a conventional valve, as a function of the water cut.
Also the water-in-oil content can be reduced with a low shear choke valve.

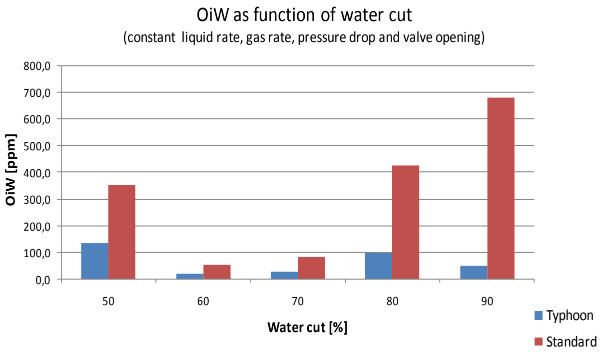

Figure 2: Water quality as a function of the water cut. Low shear Typhoon system in blue, conventional valve in red.

Tests have also shown that there is a long term benefit of a low shear valve where there is a significant distance between the choke and the separator, for example for Subsea and tie-in applications.

Injection choke

For normal gas or water injection, shear in the injection choke is not problematic. For EOR purposes where polymer is mixed with the injected water however, shear can have a significant negative effect on the polymer quality. Too much shear causes degradation of the polymer, increasing the amount of polymer required to obtain the correct viscosity. Conventional choke valves can cause up to 70-80% degradation of the polymer. A low shear injection choke for these polymer applications can significantly reduce the amount of polymer required. This has a direct effect on the OPEX but possibly also on the CAPEX as less storage space is required. The low shear injection choke for polymer water applications, developed by Typhonix in collaboration with Total, reduces the degradation to less than 20%.

Control valve

Shear in level control valves, either between separators or in the produced water treatment system, can have a significant negative effect on the downstream separation. Tests have shown that even with just 0.5 bar differential pressure over a valve, a low shear valve can increase downstream separation efficiency significantly. In cases where there is a high pressure separator for two-phase separation followed by a low pressure separator for three phase separation, there is much to gain by reducing the amount of emulsification of the water and oil phase over the level control valve between these separators.

Pump

Pumps are utilised to increase water pressure from the low pressure separators to the pressure required to further handle this water. This could be to either recirculate this water to higher pressure separators, or to the required pressure for the water treatment system. Traditionally a number of different pump types, ranging from simple and robust single stage centrifugal pumps to more complex twin screw or progressive cavity pumps, are used for this purpose. The use of low shear pumps is important to keep the dispersed oil droplets as large as possible. Typhonix has developed multistage centrifugal pumps particularly targeting produced water applications. The new pumps may be split in the two different application areas of 1) Low shear; where oil droplets shall be maintained, and 2) Coalescing; where oil droplets shall be enlarged. Both pump versions combine the robustness of the centrifugal pump with the low shear benefits from the progressive cavity pumps.
These pumps can have a significant positive effect on the efficiency of downstream separation equipment. Figure 3 shows test results of the Coalescing Pump contrasted with results of a single stage centrifugal pump and an eccentric screw pump. It is demonstrated that the Coalescing Pump can promote a significant droplet growth compared to the conventional pumps. Moreover, it is shown that the Coalescing Pump gives increased droplet growth when oil concentration is increased or when inlet droplet size is reduced. This implies that the pump counteracts separator upsets where the water quality is deteriorated.

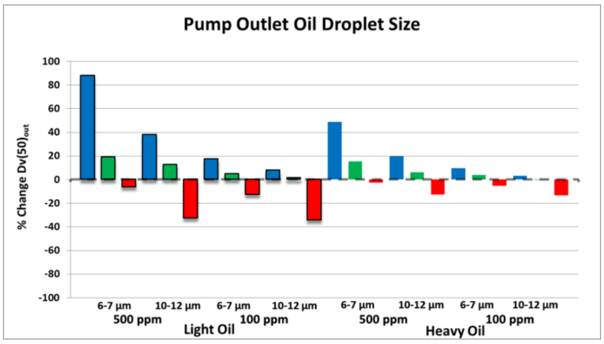

Figure 3: Change in mean pump outlet droplet size for different test conditions and crudes. Coalescing (blue), Progressive cavity (green) and single stage centrifugal (red).

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