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Comparison of oil types regarding air release and foam-ing in dry case operation

Part Two

4 Comparison of the oils in dry case operation

Utilizing the dry case operation as an example for an application with very high re-quirements for the air release capability two different oil types were compared. For the comparison a standard mineral oil, in this case Shell Tellus S2M46, and an optimized synthetic oil, Shell Tellus S4ME46, were chosen. The oils were compared on the drive-line test stand used for the efficiency measurements (s. Figure 3). Thus the layout of the hydraulic circuit (s. Figure 2) and the overall system setup were very similar to a real world application. First some characteristics of the oils will be given. Second the test equipment and procedure as well as the results are described.

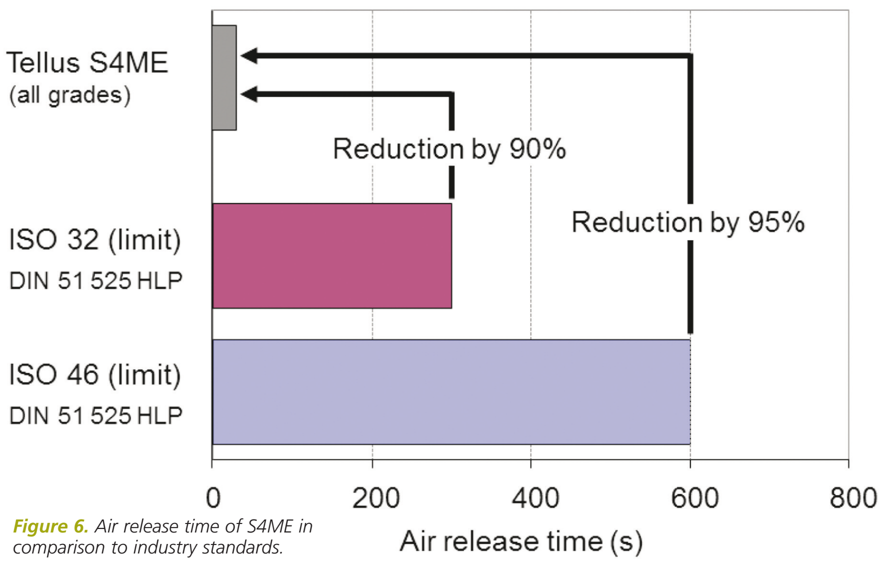

Figure 6. Air release time of S4ME in comparison to industry standards.

4.1 Characteristics of the chosen oil types

Shell Tellus S2M is a zinc-based mineral oil, whereas Tellus S4ME is a zinc-free and ashless synthetic oil with higher efficiency, wear protection, life-time and air release capability. Table 2 summarizes the basic oil properties of the chosen oil types.

Figure 6 shows the air release time of S4ME in comparison to industry standards un-der laboratory conditions. It can be seen, that the time required for air release is re-duced significantly for all viscosity grades. Hence for the dry case operation under real-istic conditions a better air release behaviour can be assumed.

Table 2. Physical characteristics of Tellus S2M46 and Tellus S4ME46.

Property	Method	Tellus S2M46	Tellus S4ME46
Viscosity grade	ISO 3448	46	46
Fluid type	DIN 51502 ISO 6743-4	HLP HM	HLP HM
Kinematic viscosity at 0°C mm²/s at 40°C mm²/s at 100°C mm²/s	DIN 51562-1	 580 46 6,9	 450 46 7,7
Viscosity index	ISO 2909	98	135
Density at 15°C kg/m³	DIN 51757	879	832
Flash point (COC) °C	ISO 2592	230	250
Pour point °C	ISO 3016	-30	-51

4.2 Test equipment

For the observation and documentation of the oil quality, i.e. the air content of free air, the system was equipped with facilities such as sighting tubes and transparent panes at the tank (s. Figure 7).

The tank was equipped with transparent side panes at the upper side (1) and at the front side (2) where the inlet and the suction pipe were placed. Therefore the oil condi-tion could be observed directly after entering the tank and before leaving the tank through the suction pipe. Four sighting tubes were mounted in the system: in the return pipe from the motor (3), at the outlet of the tank (4), in the return pipe of the cooler (5) and in the suction pipe of the pump (6). The condition of the oil leaving the tank could be observed at (4). At (6) the oil stream that entered the pump could be observed. This oil stream was a mixture of the oil coming from the tank and the returning oil from the cooler which was generally less foamed.

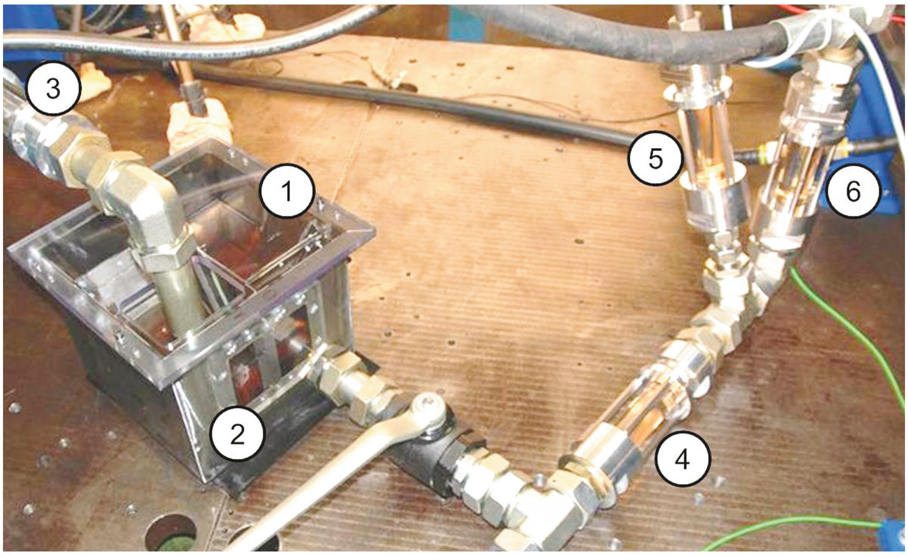

Figure 7. Hydraulic tank with side panes and sigthing tubes.

In former projects (s. [Rah12], [Un12]) several tank configurations were realized and the influence on air release was investigated. For the comparison of the oil behaviour two of these different test tanks or tank configurations were chosen. These test tanks are shown in Figure 8. On the left side test tank no 1 with a possible volume of 10-20 litres is shown. A diffusor with a horizontal guide plate is placed at the inlet of the tank (1). The horizontal guide plate is situated near the upper oil level. Two screens inside of the tank help to guide the oil stream, to prevent the foam from spreading over the tank surface and to enhance air separation by bubble formation. On the right side of Figure 8 test tank no 2 with a possible volume of 5-10 litres is shown. At the inlet (2) a vertical tube ends few centimetres above the oil level. Two screens inside of the tank should prevent the foam from spreading over the oil surface. At both test tanks the oil flows from the inlet at the upper left side around the vertical guide plate in the middle of the tank to the suction pipe at the lower right side of the tank. The oil volumes of the tanks during testing were about 17 litres (test tank no 1) and 10 litres (test tank no 2).

First the system was operated with Tellus S2M46. After the corresponding measure-ments and investigations the system was filled with Tellus S4ME46 and flushed twice by emptying and refilling it.

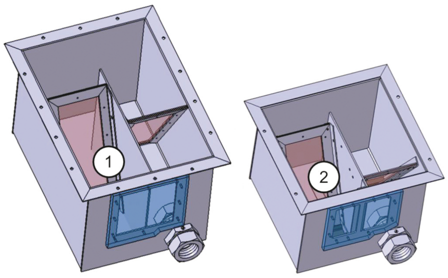

Figure 8. Test tank no 1 (left) and no 2 (rigth).

Except of the oil types and the test tanks there were no changes in the test setup and equipment to gain comparable and reliable results.

For the documentation a photo and a video camera were deployed. Based upon the pictures and videos the effectivity of measures in the tank or differences resulting from the oil could be evaluated. The complete test stand was implemented in a box that was artificially illuminated and insulated from external light.

4.3 Test procedure

The comparison was done at stationary and transient operating conditions. For the stationary comparison the hydraulic motor was first driven at 800 rpm for several min-utes to attain quasi-stationary conditions. Then a first series of pictures was taken. Af-terwards the speed was quickly raised to 4100 rpm and then kept constant again for several minutes. Subsequent pictures were taken.

For the transient comparison the motor was first driven at 900 rpm to reach a quasi-stationary condition in the tank. Following the speed was raised from 900 rpm to 4200 rpm at a constant rate of 15 rpm/s. Then the speed was kept constant for about 15 s and then lowered back to 900 rpm at the same rate. After having reached the lower speed level of 900 rpm it was kept constant for about one minute.
Therefore each run has a total length of about 8 and a half minute.
The stationary as well as the transient comparison were done in dry case operation with both test tanks and both oils at two temperature levels of 50°C and 80°C. The load at the hydraulic motor and the speed of the Diesel engine powering the pump were always kept constant, as both have no influence on the foaming within the motor hous-ing or the air separation in the tank. The oil temperature could be controlled by switch-ing the oil cooler on or off. Before each measurement run the complete system was driven for half an hour minimum to warm it up and to attain quasi-stationary conditions at all components. The whole system was implemented in a sealed, i.e. soundproofed, box, so that the ambient air temperature reached a stationary level too. Thus it can be assumed equal for all test series. Further ambient conditions with effect on air separa-tion and foaming, such as air humidity or air pressure, could not be influenced. All other conditions were kept constant as far as possible.

4.4 Results

The following results shall demonstrate the differences of the two oils in their optical appearance at different operating conditions. The corresponding pictures show results with the smaller test tank no 2, as the operating conditions are more critical. The reten-tion time of the oil is shorter and thus less time for air release is available. For the lar-ger test tank no 1 the tendencies are similar however. The pictures on the left side al-ways show the results for Tellus S2M46 and on the right for Tellus S4ME46.

Stationary comparison

Figure 9 shows the oil appearance at the side pane for stationary operating conditions. According to chapter 3 the air release is generally better at high temperatures, i.e. low viscosity of the oil, and worse at low temperatures respectively. The foaming however increases with the speed of the hydraulic motor. For the most disadvantageous operat-ing condition, in this case 50°C and 4100 rpm, also the views of the top pane as well as of the sighting glasses at the tank outlet and the suction pipe are shown.

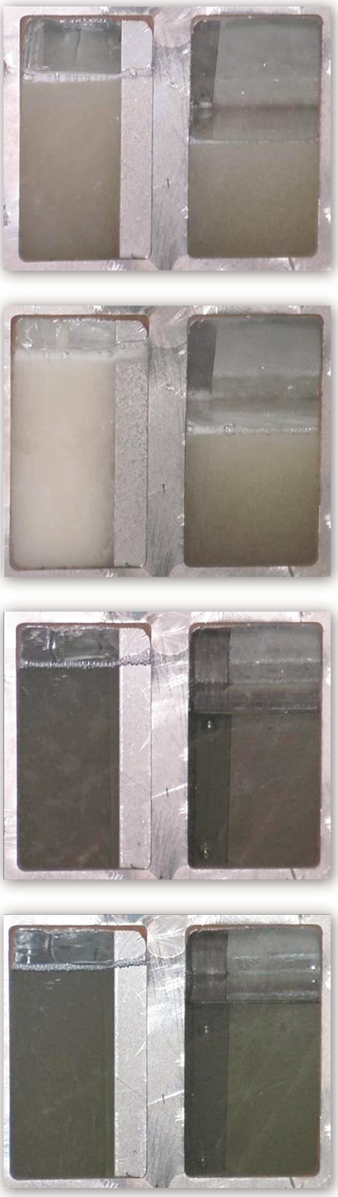

Figure 9. Oil appearance at stationary conditions- tank no 2, 50°C, side pane.

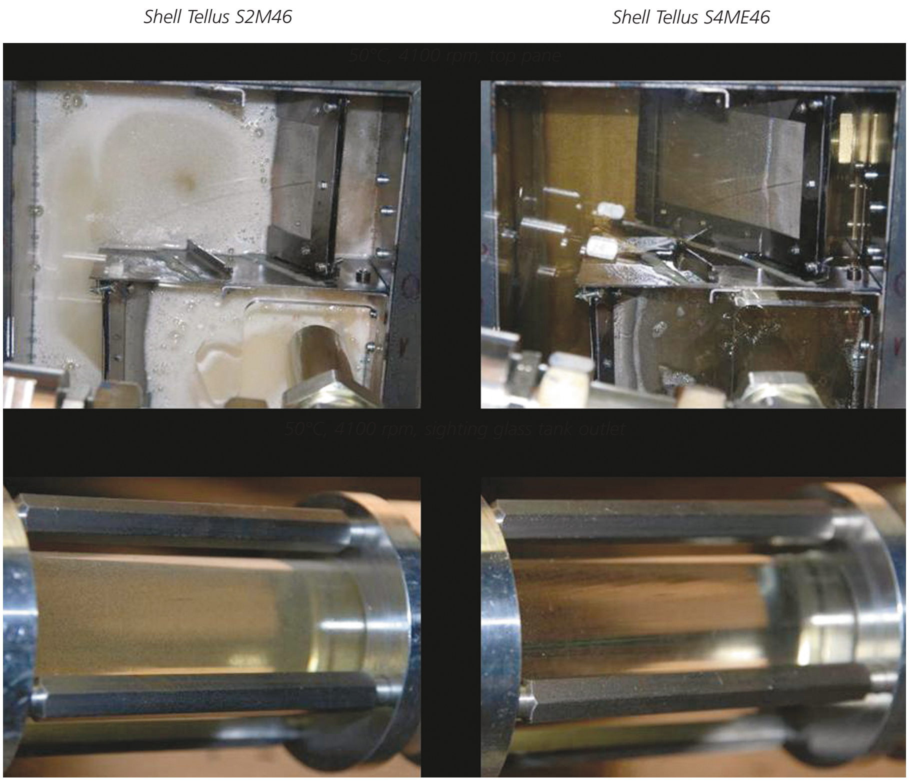

Figure 10. Oil appearance at stationary conditions - tank no 2, 50°C, top pane and sigthing glas tank outlet.

The tank inlet is placed on the upper left side of each single photo and the suction pipe at the bottom of the right side (compare Figure 8). The content of free air, which is in this case the indicator for the air release capability of the oil, can be estimated from the colour of the oil. The whiter the oil is the higher is the content of free air or foam re-spectively. For an oil temperature of 50°C and both motor speeds the content of free air is lower for Tellus S4ME46. For Tellus S2M46 the content of free air clearly increases with the motor speed, whilst for Tellus S4ME46 this effect is less observable. In addition the effect of the measures in the tank, i.e. the screens, can be seen for Tellus S2M46, as the content of free air is lower on the right or suction side of the tank. For S4ME46 this effect is less distinctive, due the generally lower content of free air. Figure 10: Oil appearance at stationary conditions - tank no 2, 50°C, top pane and sigthing glas tank outlet

Figure 10 shows further results for the most disadvantageous operating condition (50°C, 4100 rpm). For Tellus S4ME46 there is no foam on the oil surface, whereas for Tellus S2M46 the surface is completely covered. According to that the oil at the tank outlet is almost opaque for S2M46. At the suction pipe this is less distinctive, as the oil at this place in the system is a mixture of the oil coming from the tank and the cooler.

As the air release capability of oil is better at higher viscosities i.e. oil temper-atures the quality of the oil is better for 80°C than for 50°C. Hence the oil contains less free air, which can be seen in Figure 11. Again this is less distinctive for Tellus S4ME46 due to the generally lower content of free air.

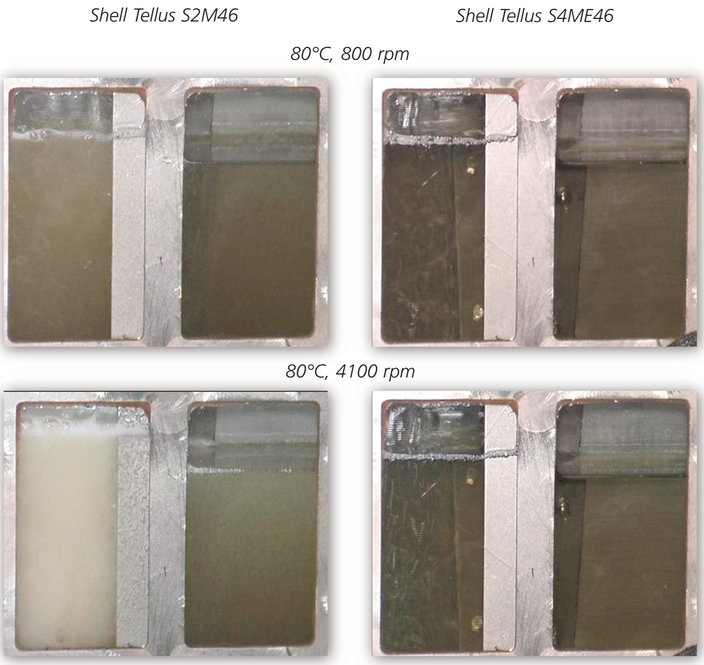

Figure 11. *Oil appearance at stationary conditions - tank no 2, 80°C, side pane.*

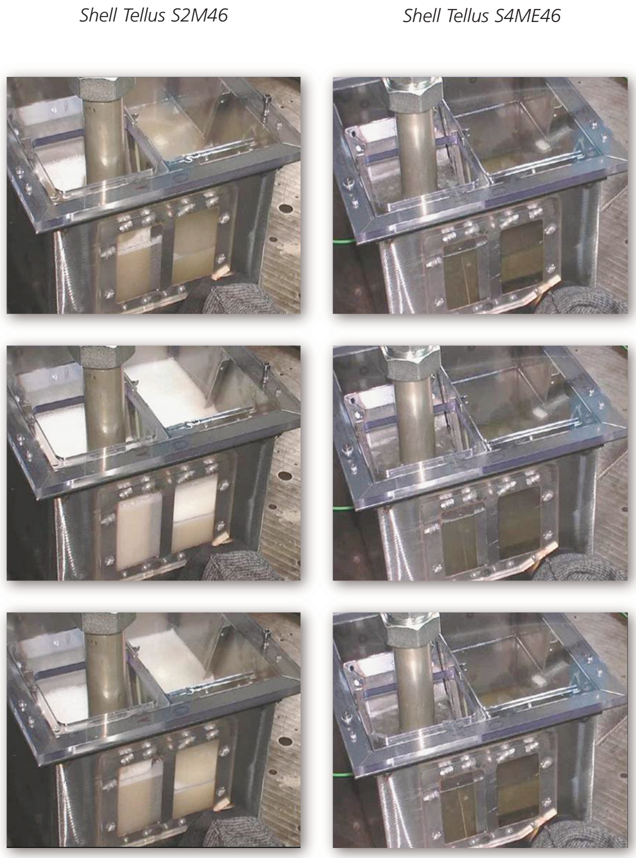

Figure 12. *Oil appearance at transient conditions - tank no 2, 50°C.*

Transient comparison

In Figure 12 the situation during transient operation is shown for both of the oils at 50°C, whereby the tendencies at 80°C were similar. The upper photos show the situa-tion at the beginning at 900 rpm, the middle photos were taken at 4200 rpm and the bottom photos were taken at the end at 900 rpm. Whereas the content of free air and foam within the tank critically increases for Tellus S2M46, this effect is almost not visi-ble for Tellus S4ME46.

5 Conclusions

The photos shown above are generally capable for showing the difference in air sepa-ration performance of the two investigated oils. Thereby the air separation behaviour of Shell Tellus S4ME46 as an example for an optimized synthetic oil is significantly better than that of Shell Tellus S2M46 as a standard mineral oil. This gets obvious at all in-vestigated speeds and temperatures and with the use of both test tanks. Nevertheless some error sources that might reduce the significance of the pictures have to be mentioned. The main error sources are in the field of the recording of pho-tos itself and the environmental conditions. The artificial illumination was not perfectly constant in the box. In addition to that the direction of the camera had some influence on the exposure to light of the camera. Further effects came from the difference in colour of the two oils. One of the most important influences on air separation is the tem-perature of the oil. The temperature was regulated by the control system. Like every control system the temperature control of the implemented system had deviations be-tween the target and the actual temperature.

It can be stated that by using special synthetic oils the air release and foaming behav-iour within the tanks of hydraulic systems can be improved significantly. Consequently the application of innovative concepts to enhance the system efficiency, such as the dry case concept, becomes possible. Beyond that the tank size in existing applications or space-critical machines could be reduced, which is particularly interesting for ma-chines with currently very large tanks due to the insufficient air release capability of the used oil.

As Tellus S4ME46 should also affect the system efficiency and wear in a positive way, corresponding comparisons between the two oils are a next step.

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