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Static and Dynamic Barite Sag Potential of Typical Oil-Based Drilling Fluid

PIRE Project Annual Review Meeting

Titus N. Ofei[1], Bjørnar Lund[2], Sigbjørn Sangesland[1], Harald Linga[2]

[1]NTNU, [2]SINTEF

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Objective & Scope of Study

Objective:

- To examine the influence of static and dynamic conditions on barite sag of typical oil-based drilling fluid (OBDF).

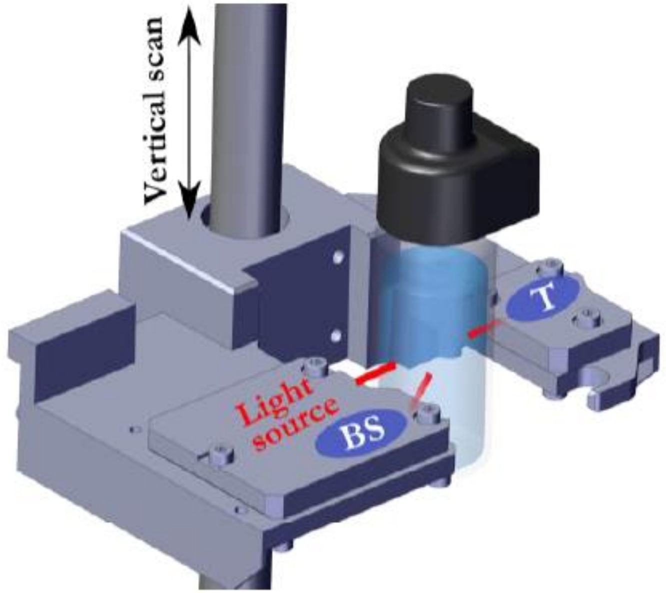
Scope:

- A typical OBDF with oil/water ratio of 80/20 is used.
- The OBDF was hot-rolled at 120^{o}C and 100 psi (6.9 bar) for 2-1/2 days.
- Static and dynamic tests were carried out at 25^{o}C and atmospheric pressure condition.

EXPERIMENTAL APPROACH

Experimental Approach for Static Test

Turbiscan Lab Expert



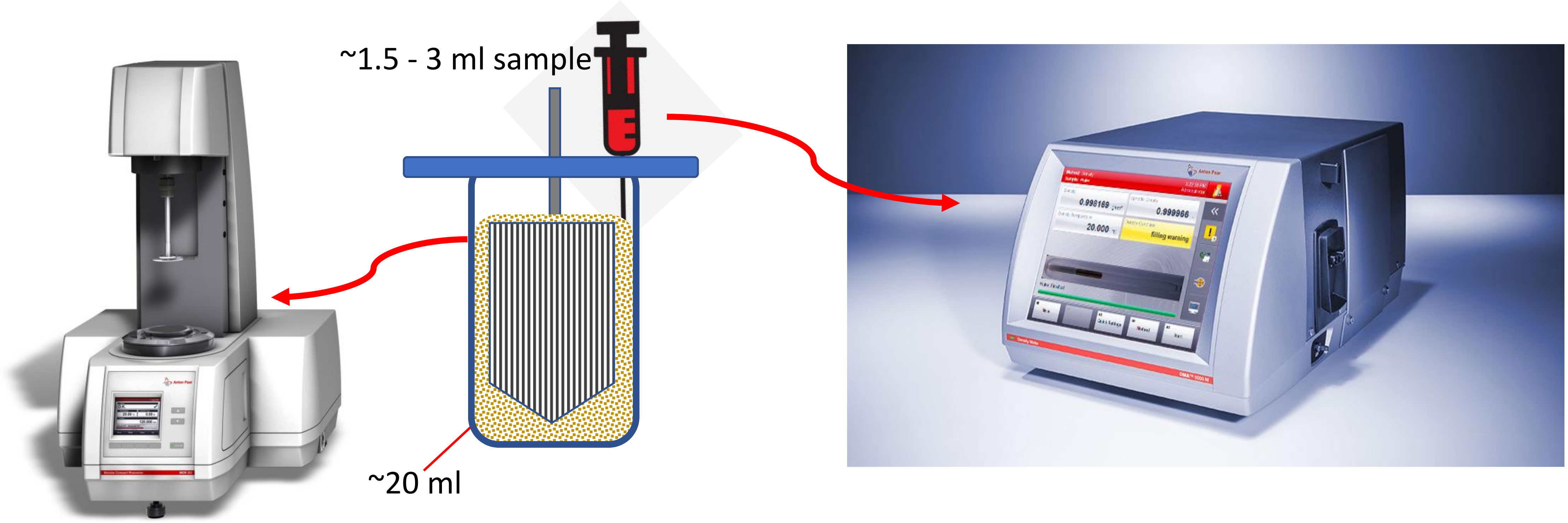
Stokes Law Theory

$$V = \frac{d^2 . g . (\rho_p - \rho_f)}{18 . v} \cdot \frac{(1-\phi)}{\left[1 + \frac{4.6\phi}{(1-\phi)^3}\right]}$$

Settling of a Suspension of Hard Spheres
Europhys. Lett. 1994, *25*, 651

- Principle of Static Multiple Light Scattering (SMLS)
- Monochromatic infrared light souce (wavelength $\lambda = 880nm$)
- Two sensors (Transmitted and Backscattered signals) collect light at 0° and 135° respectively.
- Wide range of particle size: $\mathbf{10nm}$ **to** $\mathbf{1000\mu m}$ and concentrations from $\mathbf{10^{-4}\%}$ **to** $\mathbf{95\%}$.
- Can quanitfy mean particle size, particles settling speed, kinetic destabilization, etc.

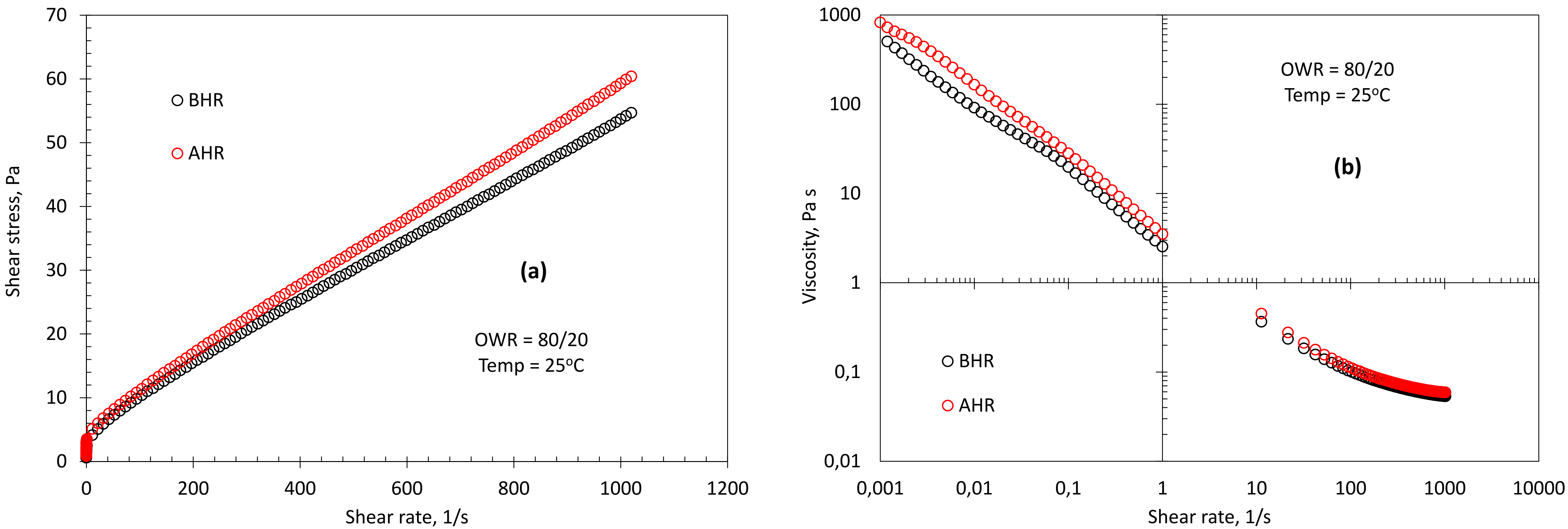
Experimental Approach for Dynamic Test



- The grooved bob-in-cup measuring system was used to measure the viscosity with time of the OBDF at different shear rates from 10.22 to 0.001 (1/s).
- Each experiment was conducted for a total of 3 hrs after which about 1 - 3 ml of sample was taken from the top of the cup and its density measured.
- The Anton Paar density meter DMA 5000 was used to measure the density of the OBDF after being sheared at different shear rates by the rheometer.

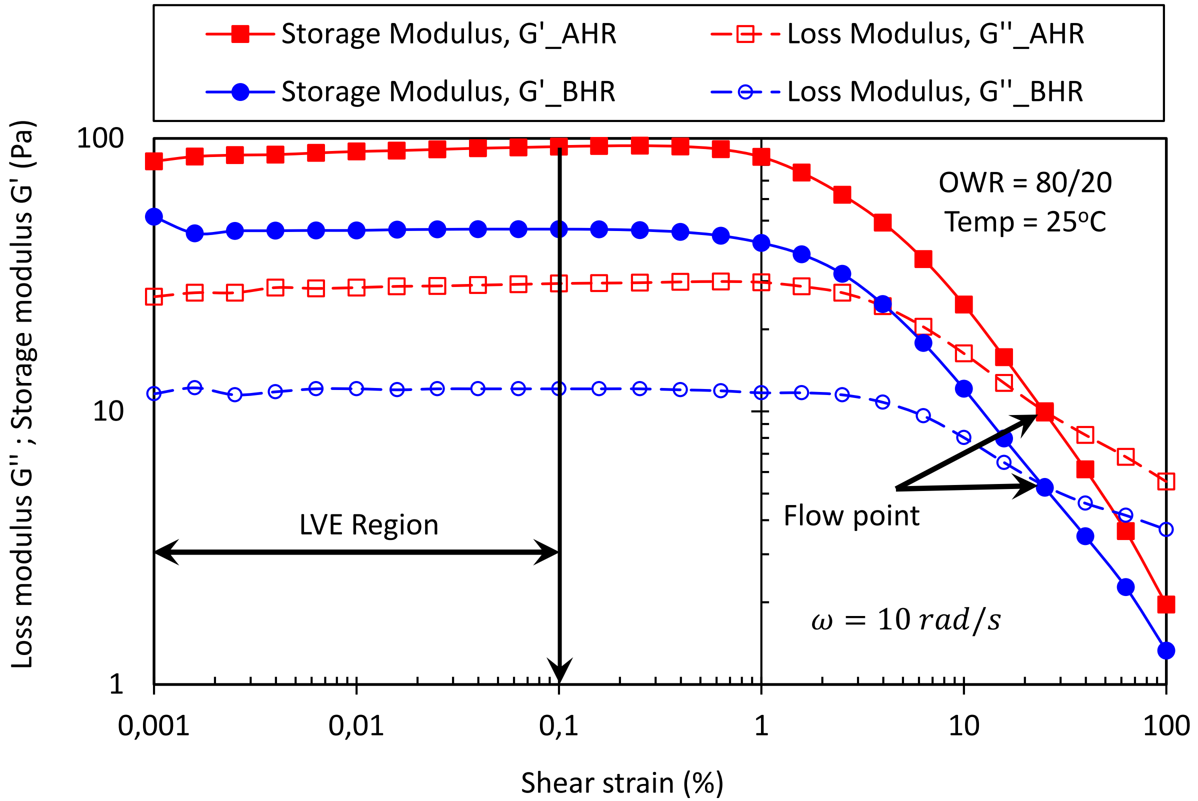
VISCOELASTIC PROPERTIES

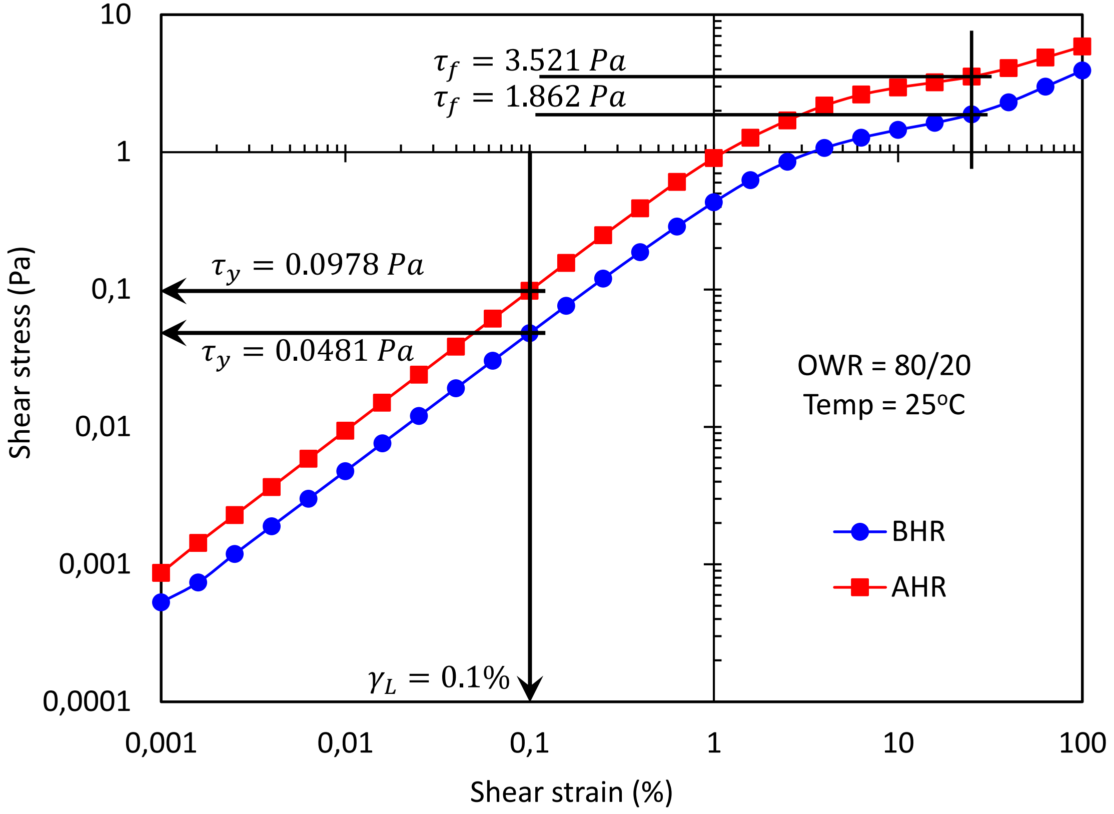
Flow Curve Analysis



- Results show a shear-thinning behaviour of the OBDF.
- Viscosity of the OBDF increases slightly after hot-rolling.

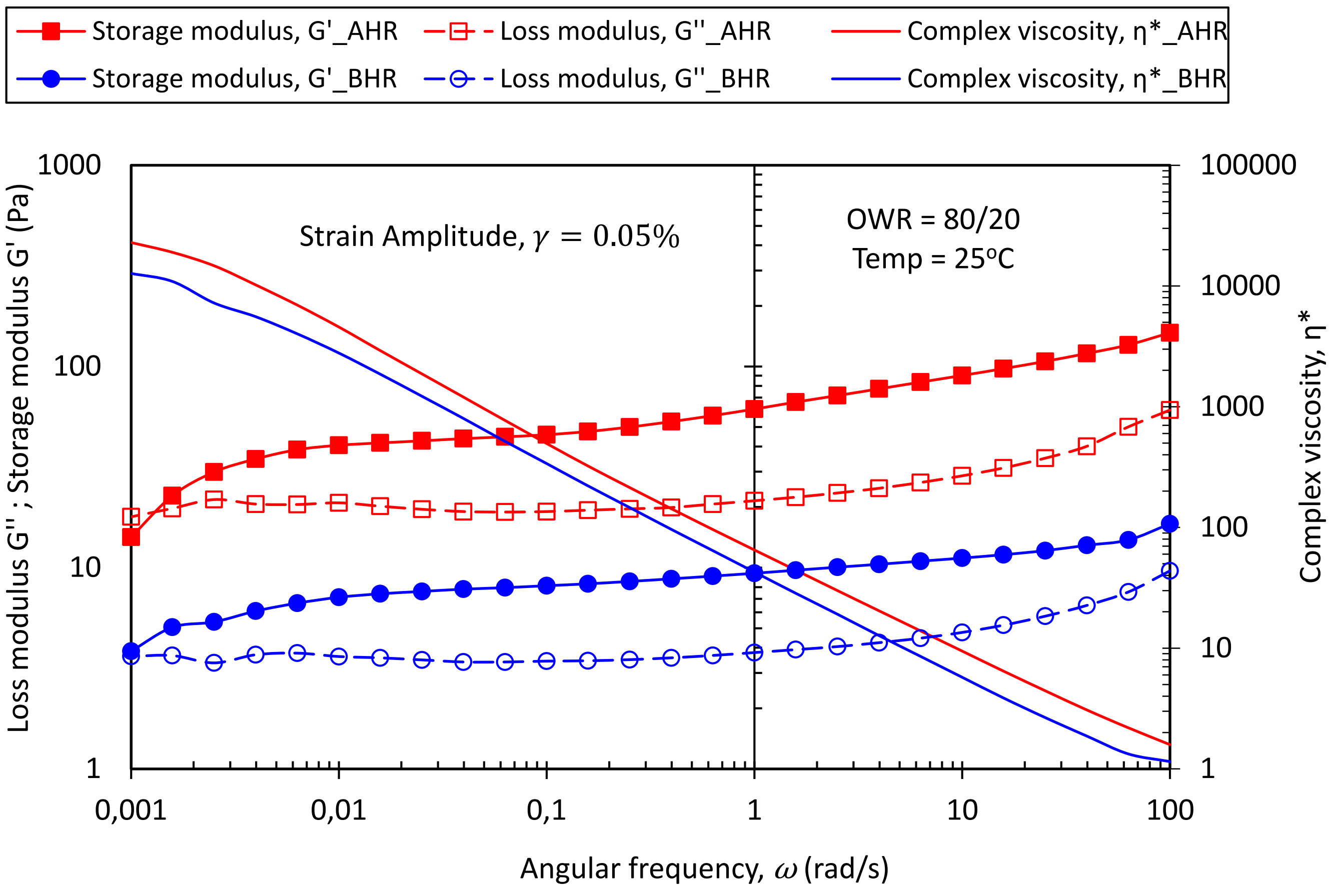
Amplitude Sweep Analysis

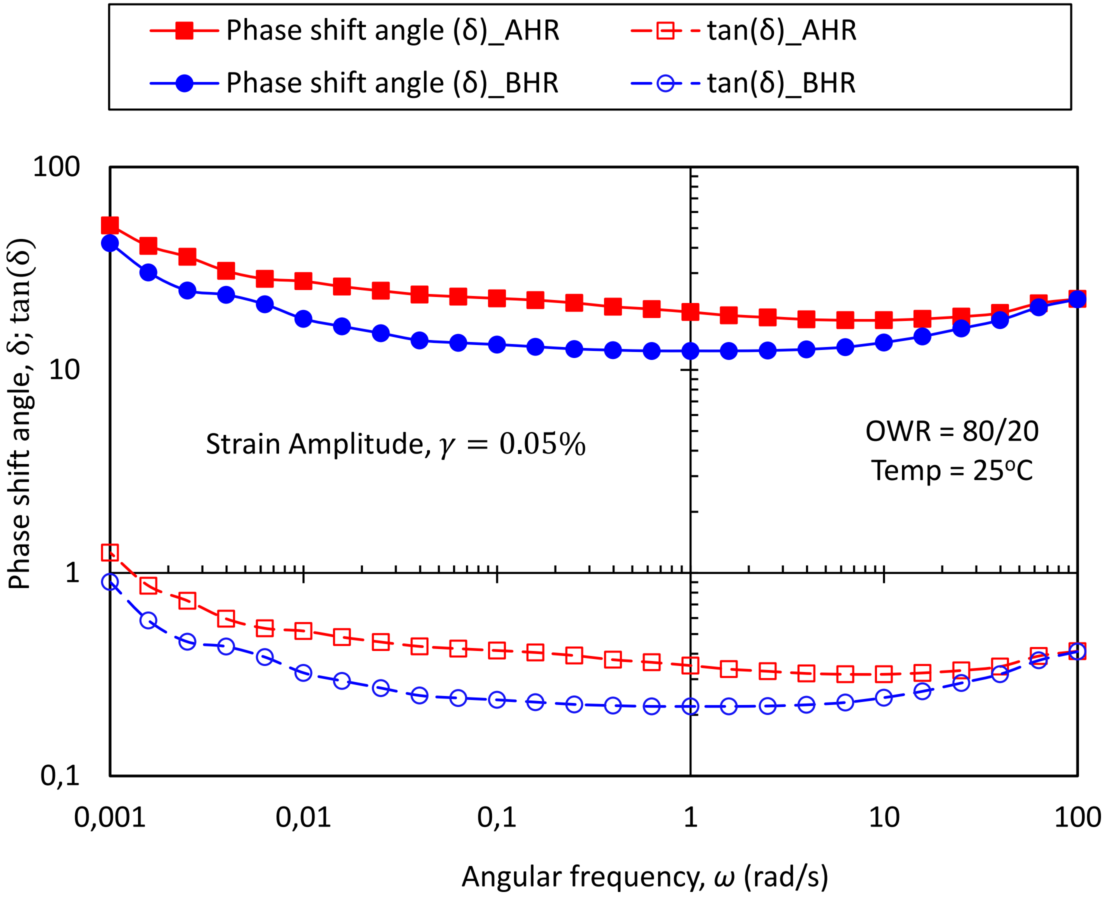




- The amplitude sweeps provide the dependency of the loss modulus, G'' and storage modulus, G', characterising the viscous and elastic properties of the fluid sample, respectively over a range of relevant strain for a given frequency of oscillation. This allows for the quatification of the viscoelasticity of the material.
- The results show that the OBDF is predominantly elastic since G' is greater than G'' within the LVE region.
- After hot-rolling the fluid sample, both viscous and elastic properties increased as compared to the propeties before hot-rolling.
- Hot-rolling the fluid sample resulted in an increase in both yield strength and flow stress.

Frequency Sweep Analysis

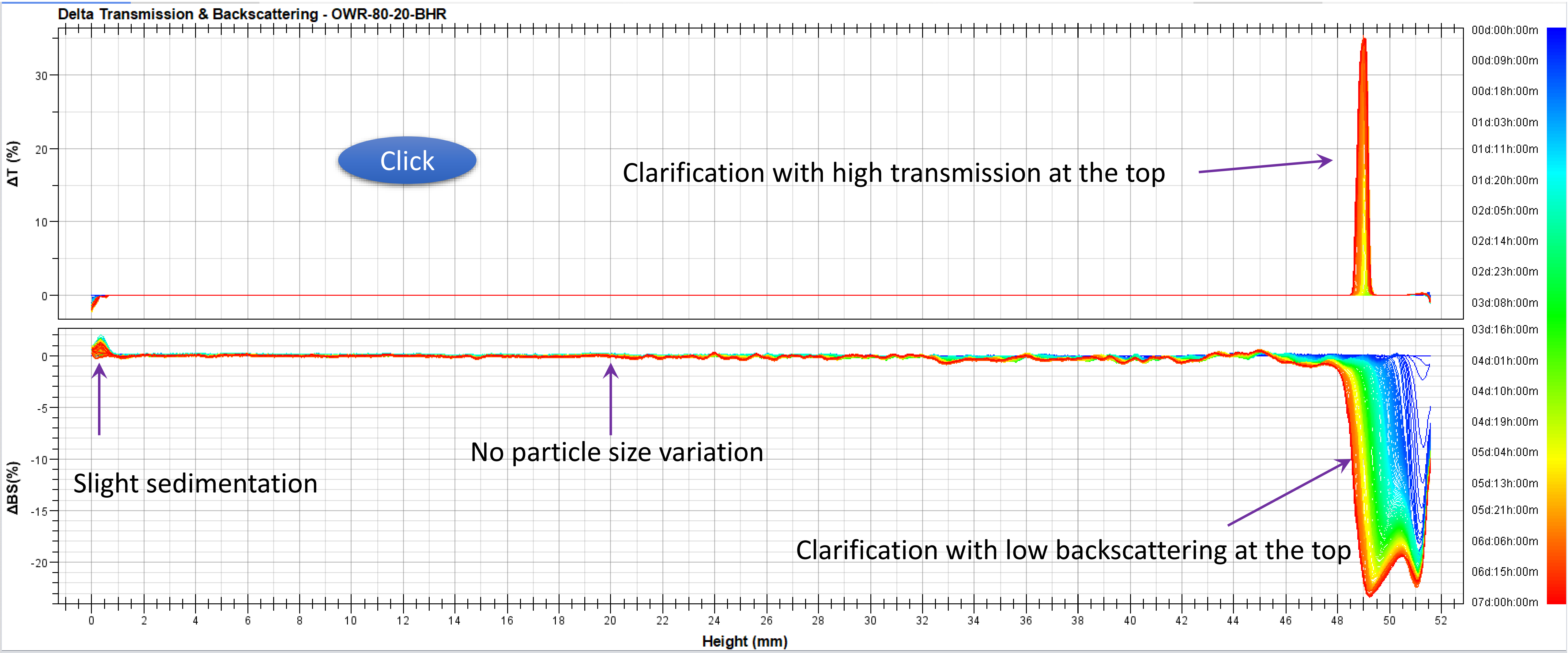




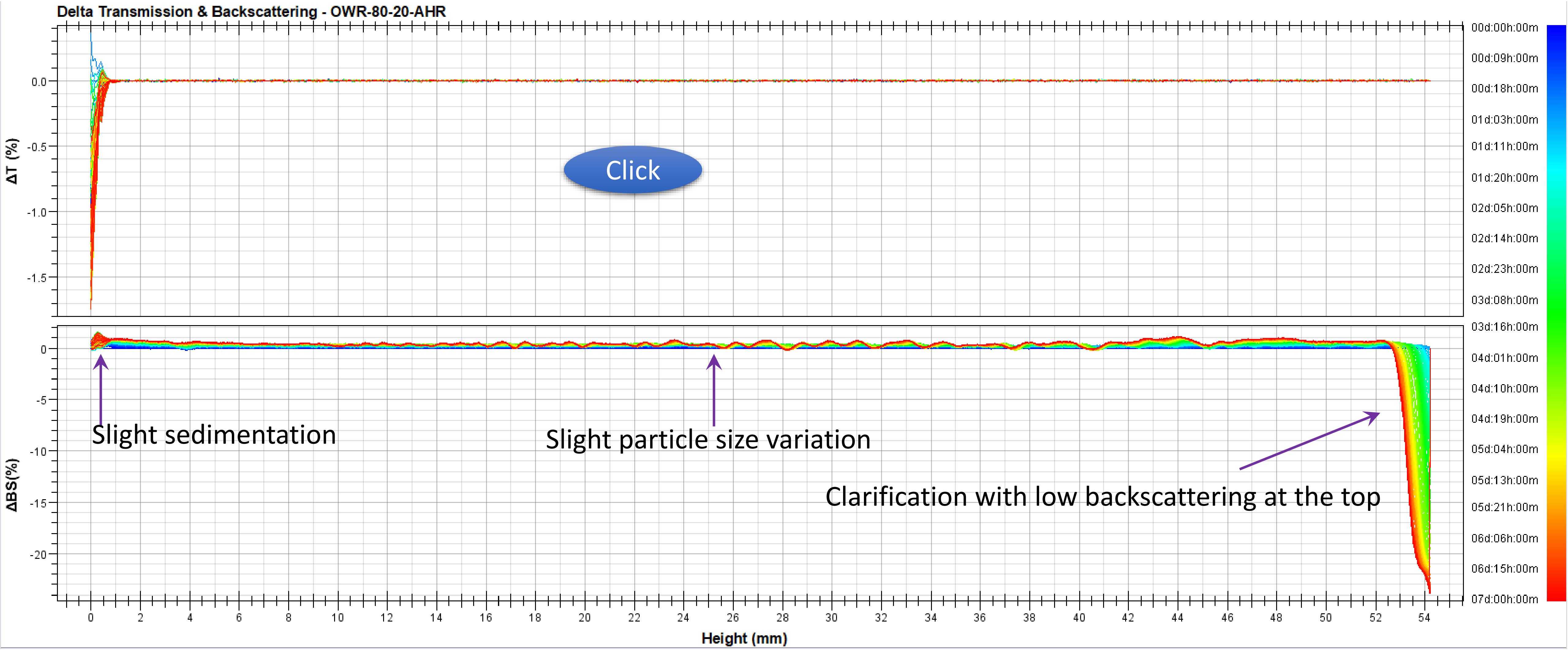
- The frequency sweep provides information on the behaviour and inner structure of the fluid as well as the long-term stability of dispersions.
- Within the LVE region, the fluid sample after being hot-holled becomes more elastic as well as more viscous compared to before hot-rolled condition.
- The inner structure remains rigid within almost the entire range of angular frequency.
- With increased complex viscosity of the hot-rolled fluid sample, possible long-term dispersion stability could occur, evidenced by low barite sag potential.

STATIC SAG ANALYSIS

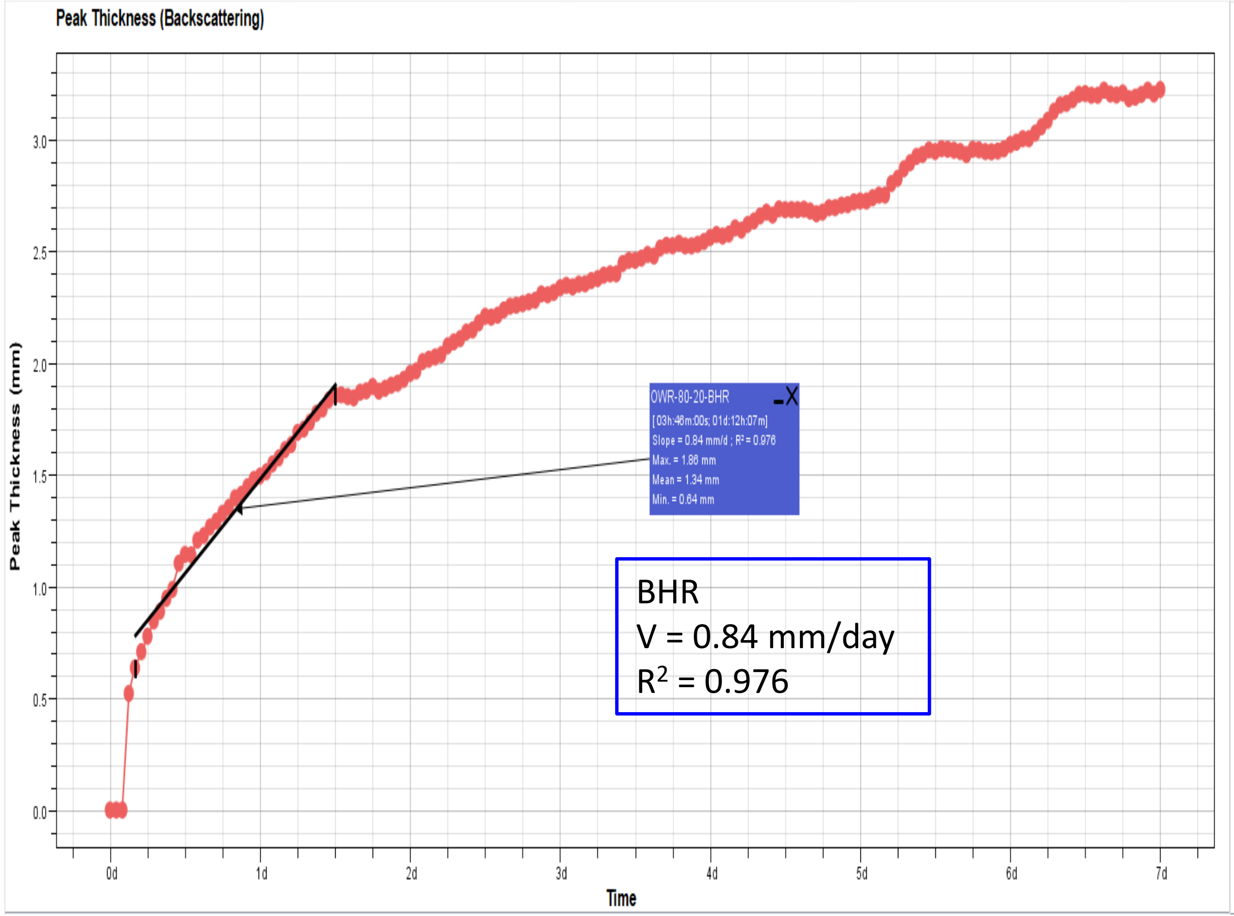
Static Sag Analysis - BHR

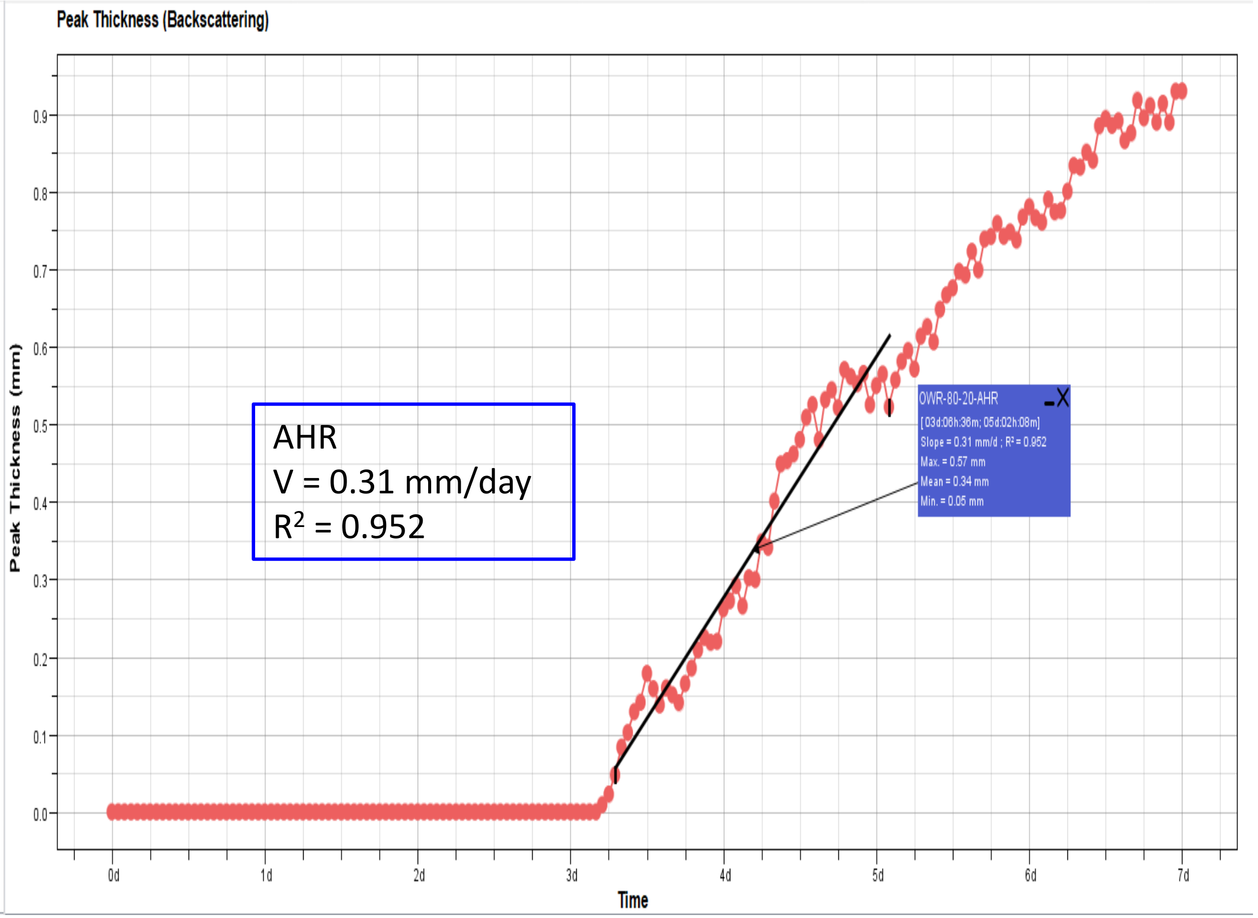


Static Sag Analysis - AHR

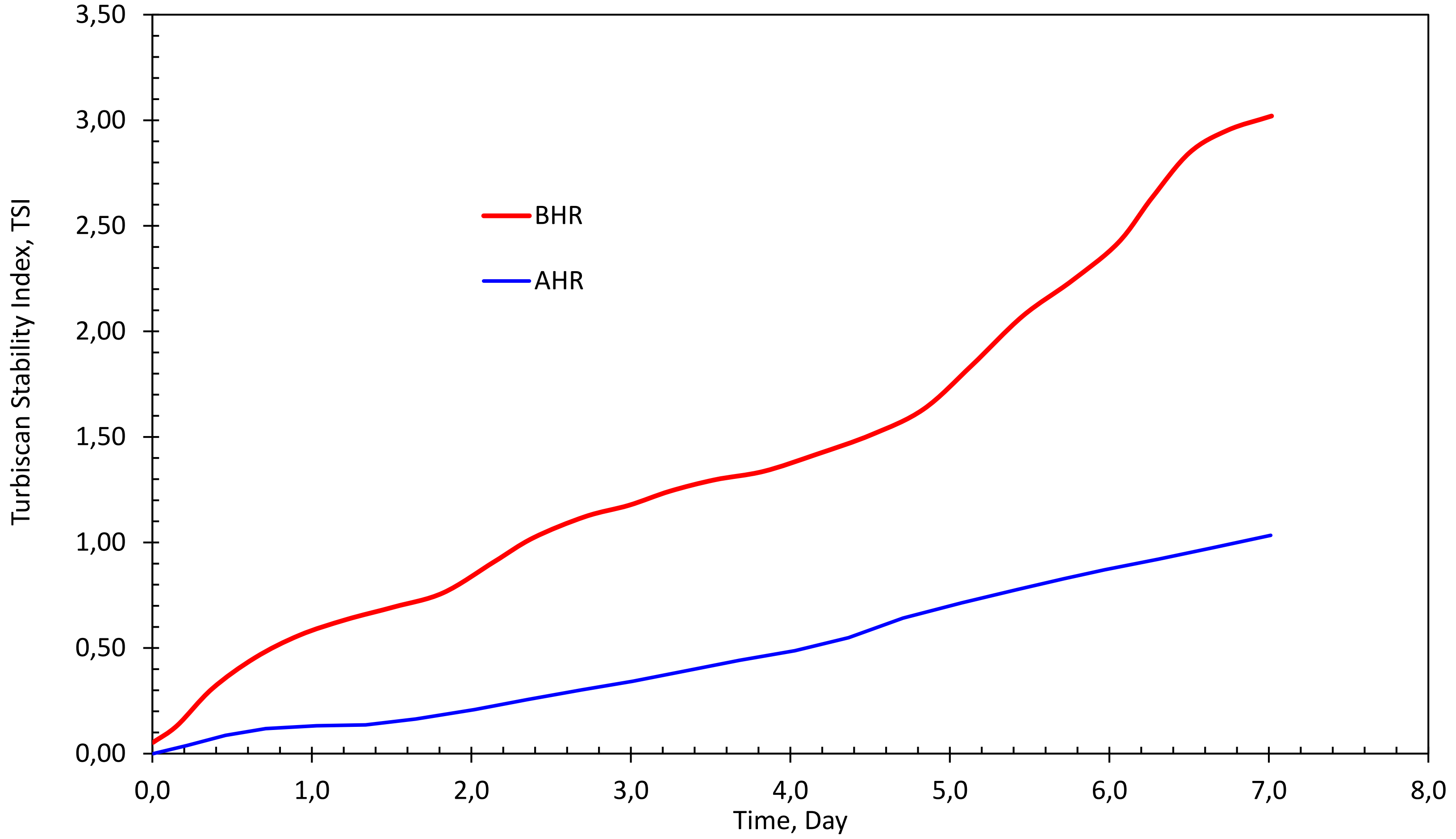


Static Sag Analysis – Particles Settling Speed





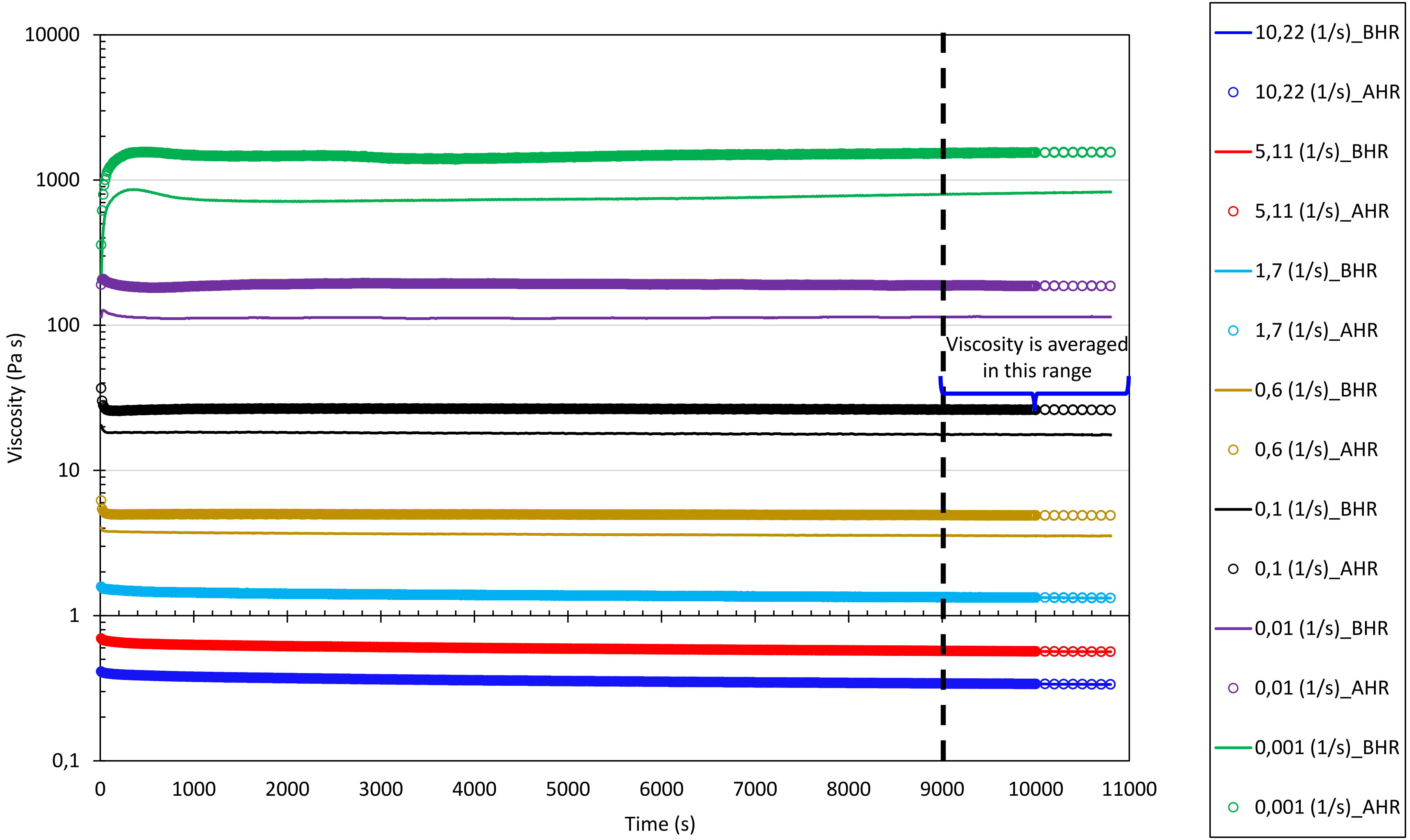
Static Sag Analysis – TSI



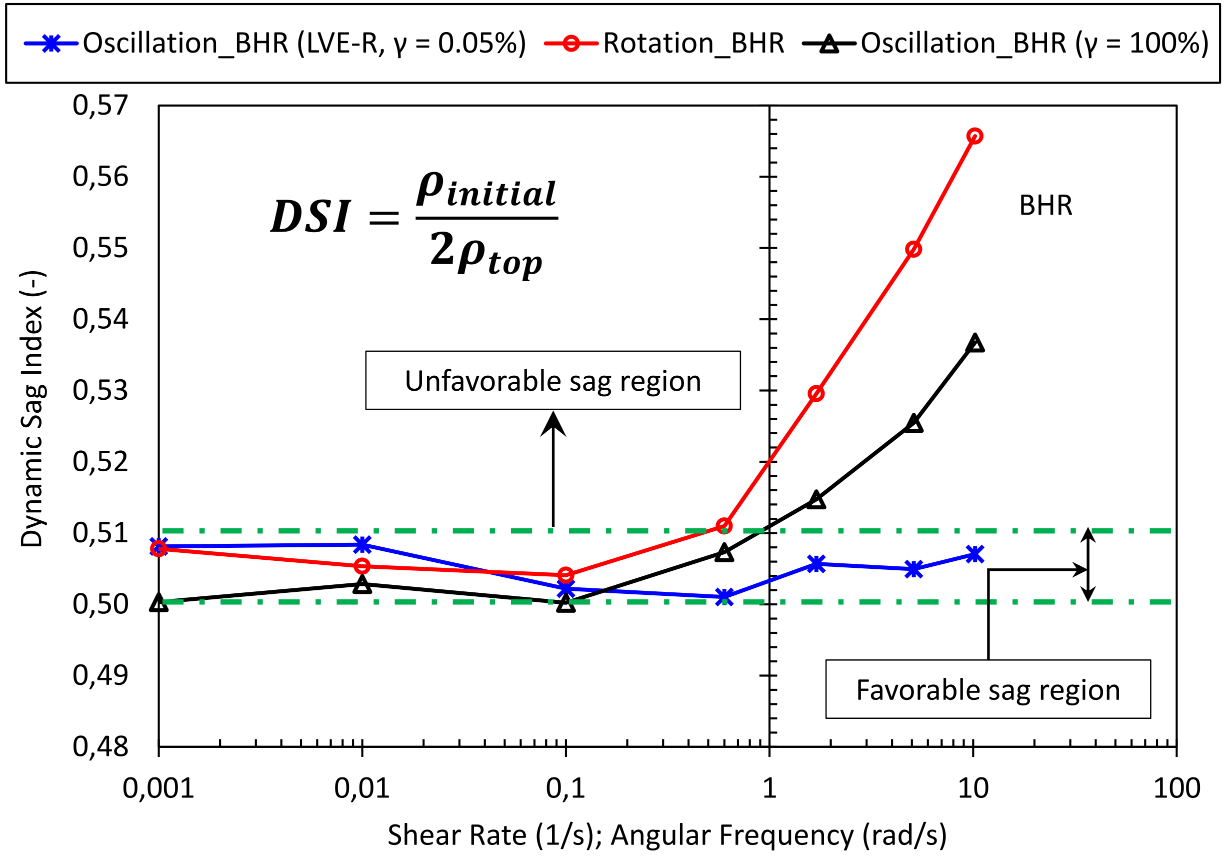
The higher the TSI, the faster particles settle in the smaple fluid.

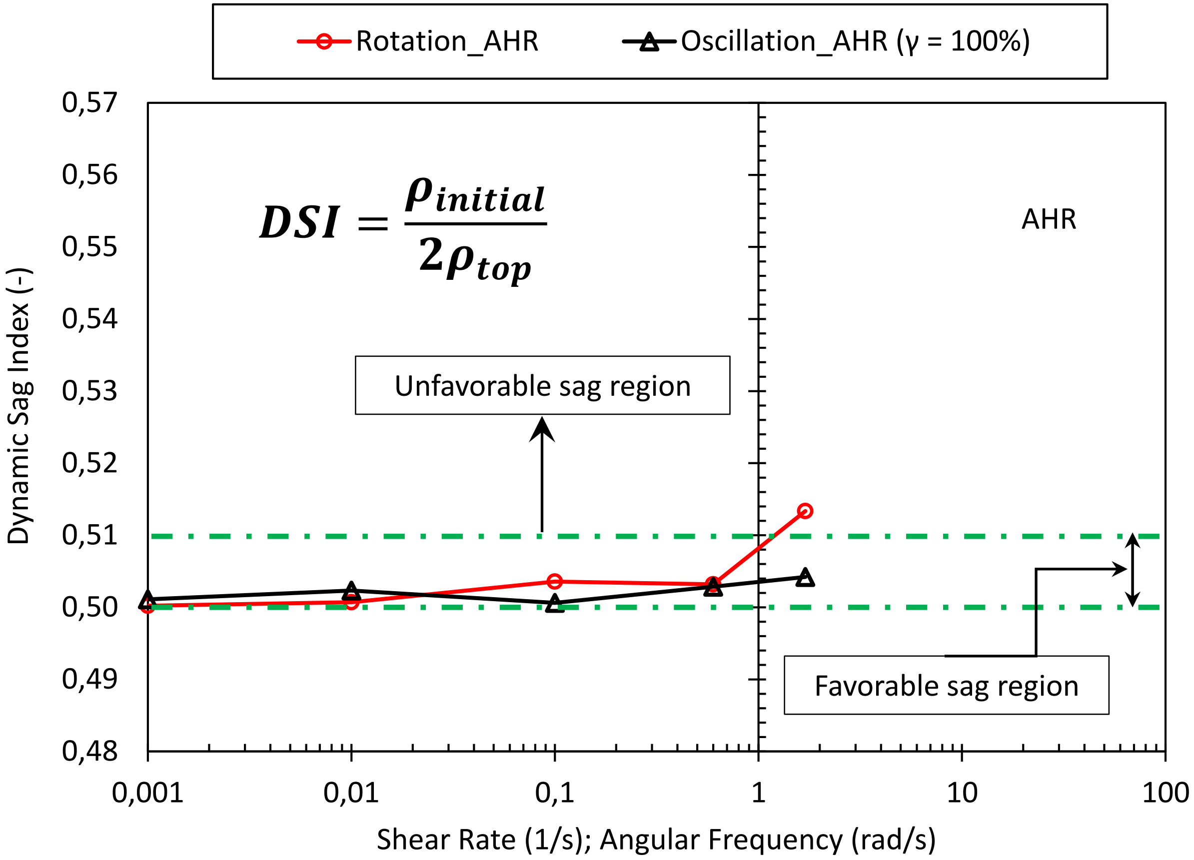
DYNAMIC SAG ANALYSIS

Dynamic Sag Analysis – Apparent Viscosity vs Time



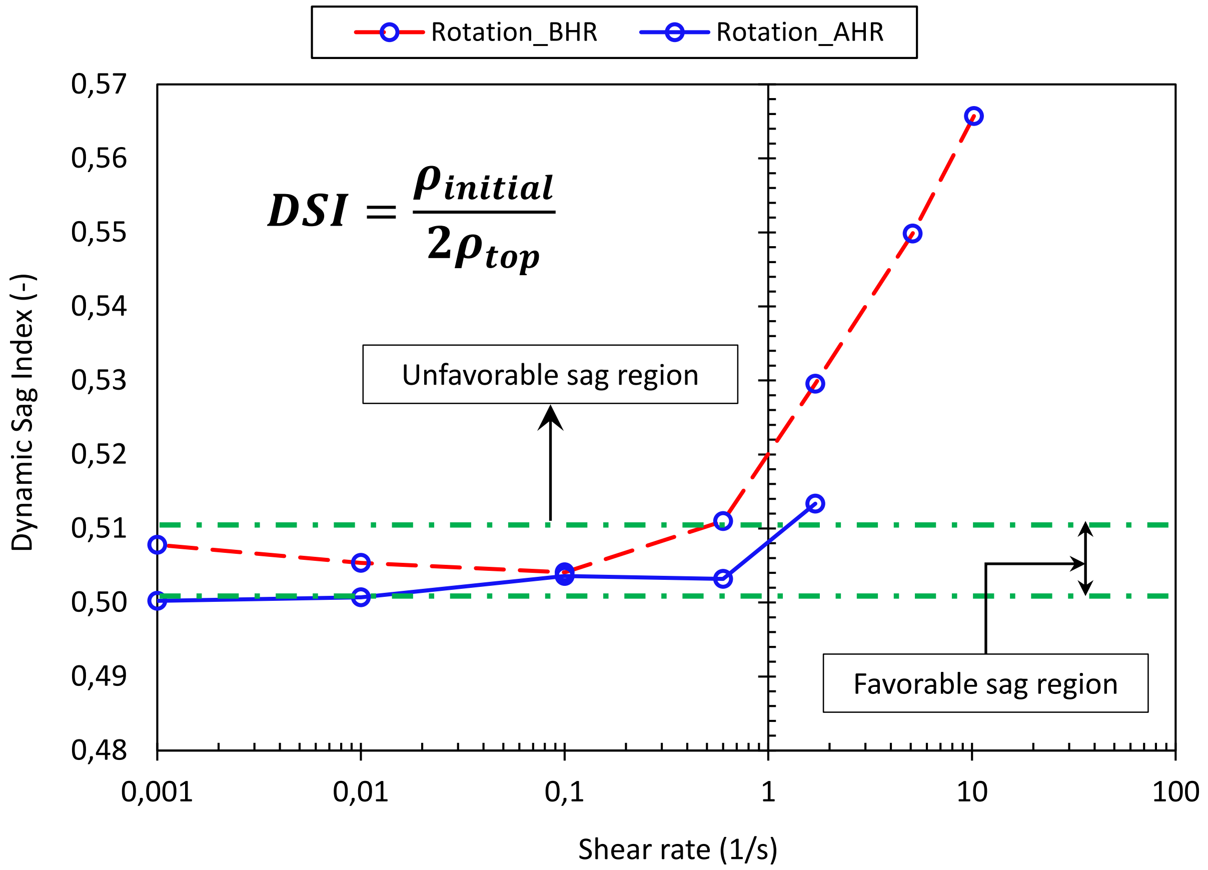
Dynamic Sag Index (DSI)

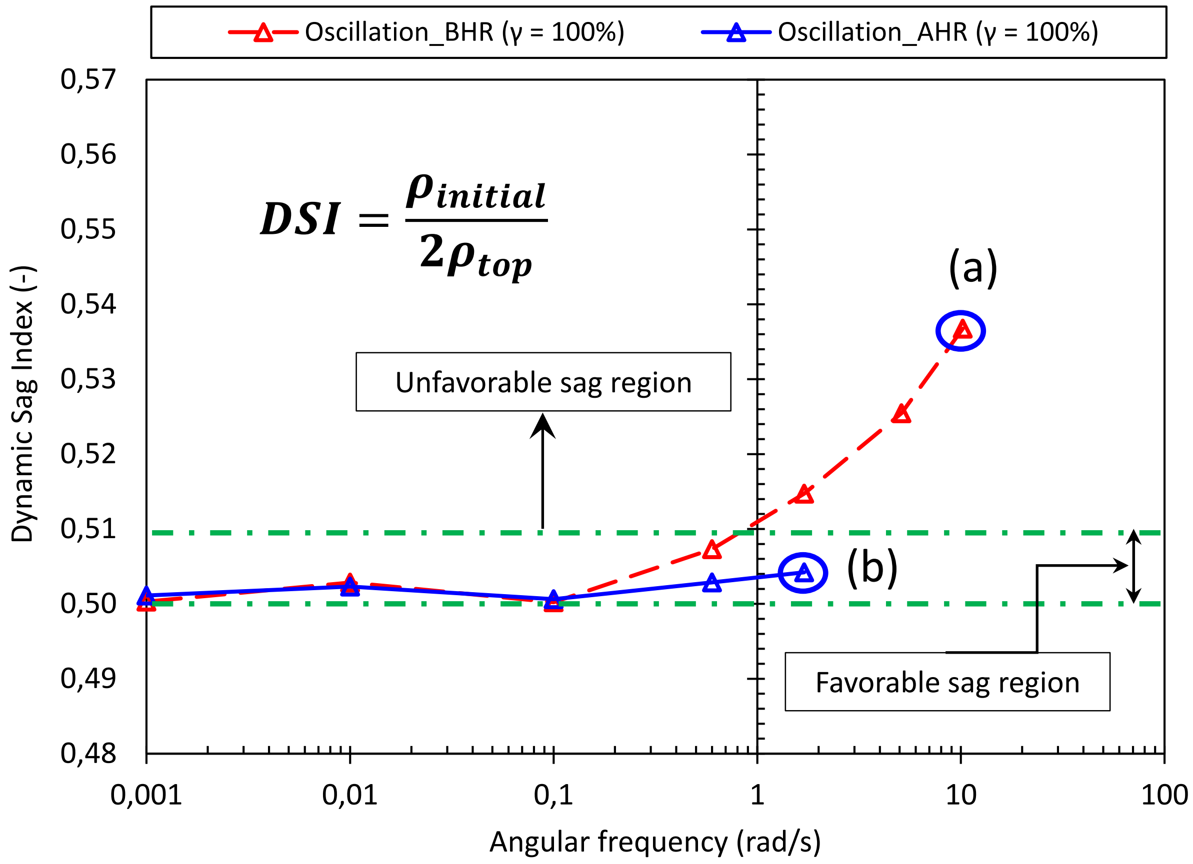




- For BHR sample within the ultra-low shear rate region, the barite sag potential is in the favorable region (DSI = 0.50-051) for all three dynamic conditons.
- For oscillatory condition within the LVE region, the DSI was within the favorable sag region for the entire range of angular frequency.
- For the current data set for the sample AHR, the DSI for both dynamic conditions are similar and within the favorable sag region.

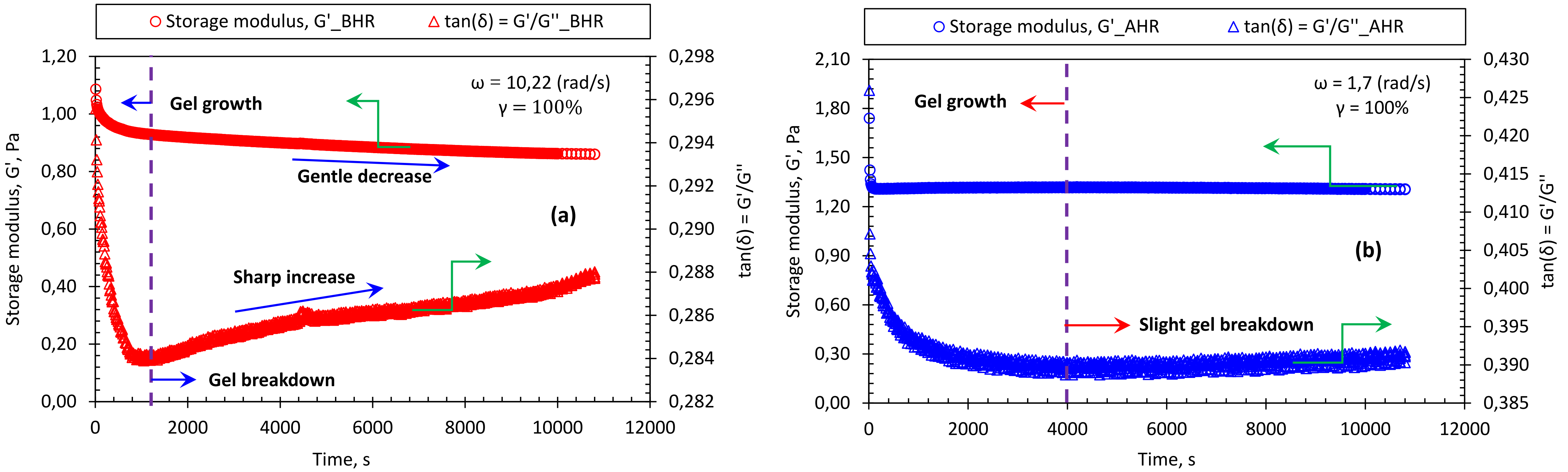
Dynamic Sag Index (DSI) – Cont'd.





- During rotational shear, there is low barite sag potential for AHR sample compared to BHR sample, however both samples have DSI within the favorable region at ultra-low shear rates. Unfavorable sag potential occurs above 0,6 s^{-1} and 1,7 s^{-1} for BHR and AHR samples respectively.
- Alternatively, during oscillatory shear, similar sag potential is recorded for both BHR and AHR samples within the ultra-low angular frequency, however a dramatic DSI was recorded for sample BHR in the low angular frequency region. Unfavorable sag potential occurs above 1,0 s^{-1} for BHR sample.

Dynamic Time Sweep



- As the storage modulus, G' reflects the elastic behaviour of the fluid, the tan(d) also defines the gel formation properties of the fluid.
- Typically, during gel growth for drilling fluids, tan(d) value will initially decrease sharply over the first few minutes, indicating the growth of structural dominance of the fluid, and then continue to decrease over the first 10-30 minutes before leveling out.
- Any major increase in tan(d) or decrease in G' afterwards are indicative of changes in gel structure and/or settling of barite particles.
- In the Fig. (a), there is initially a significant structural buildup as tan(d) decreases and G' increases over the first 1200 s for $\omega = 10{,}22\ rad/s$. However, above 1200s, tan(d) increases rapidly as G' also decreases. This indicates the breakdown of the fluid's gel structure and evidenced by barite sag.
- In contrast, Fig. (b) shows initial gel growth up to 4000 s for $\omega = 1{,}7\ rad/s$, afterwhich a slight breakdown in gel was observed, thus an indication of less sag.

Conclusion

The following can be concluded from this study:

- The visco-elastic properties of the OBDF sample increased slightly after being hot-rolled for 2-1/2 days.

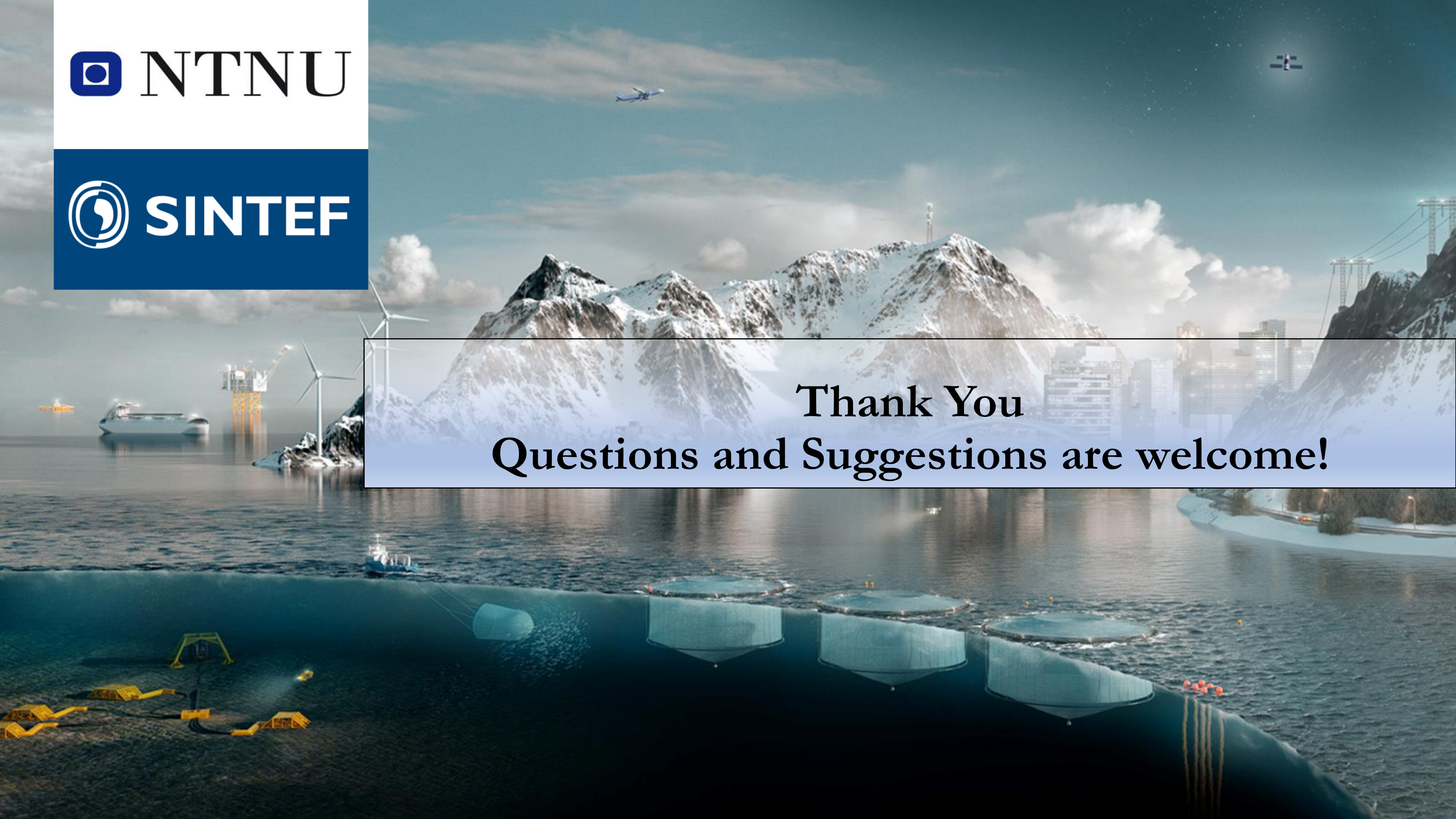
- Static sag analysis revealed low particle settling rate of 0,31 mm/day and longer dispersion period (i.e., low TSI) for AHR fluid sample with slight particle variation over the entire fluid.

- Pure rotational shear increased the dynamic sag index beyond the favorable sag region of DSI = 0.50-0.51 above shear rates of 0.6 s^{-1} and 1.0 s^{-1} for BHR and AHR samples respectively.

- Within the LVE region, oscillatory shear did not result in unfavorable sag potential over the entire angular frequency, however, oscillatory shear beyond the LVE region increased the sag potential above the favorable region above shear rate of 1.0 s^{-1}.

- Over the entire shear region, there is low barite sag potential for AHR fluid sample compared to BHR fluid sample.

- Dynamic time sweep test provides valuable information on the sag potential of the drilling fluids.



Thank You

Questions and Suggestions are welcome!