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High Temperature High Shear Viscosity

hts-VROC®: Characterization of Synthetic Oils at High Temperature and High Shear

Introduction

Engine oils play a key role in the lubrication and performance of internal combustion engines. These lubricants reduce wear on moving parts and often contain additives to inhibit corrosion and improve sealing and cooling. Characterization of engine oil fluid properties under conditions similar to those present in combustion engines is fundamental to properly establish performance and degradation with use. RheoSense's *hts*-VROC® unit allows measurement of viscosity over a wide range of shear rates and temperatures. Our new system provides the same features and specifications as *m*-VROC® with the added capability of testing at temperatures as high as 105°C.

In this application note, we present *hts*-VROC® measurements at 40°C and 100°C on two conventional oils Pentosin 5W-30 and Pennzoil 5W-30. Additionally, we studied a sample motor oil aged for 12,000 miles to exemplify *hts*-VROC® capabilities to monitor oil health.

Test Materials & Applications

Pentosin and Pennzoil 5W-30 are conventional high performance multi-grade engine oils. In this study, we tested both new and used (12,000 miles of operation) Pennzoil.

Standard certified viscosity mineral oils N35 Lot. 13301 and N10 Lot. 14101 (Cannon Instruments) were used to test our instrument accuracy and repeatability at 40°C and 100°C.

Testing Protocol:

1. Loading: Test sample is loaded into a syringe and mounted into the syringe pump.
2. Measuring: Using *hts*-VROC® software, viscosity is measured as a function of shear rate and/or temperature. For all tested materials displaying a shear-dependent viscosity, the Weissenberg-Rabinowitsch-Mooney (WRM) correction is applied to obtain "true shear rate" and "true viscosity" [1].
3. Cleaning: No cleaning is necessary between different synthetic oils as long as they are soluble with each other. After testing, heptane can be used to flush the chips.

Results

In Figure 1, we present viscosity of the three synthetic oil samples at 40°C with shear rates ranging from 100 to 100,000 1/s.

To cover this wide dynamic range, we used three chips with different maximum pressure limits and channel depths. We observe good overlap between chips. More details on the chips utilized in this study are presented in Table 1.

Pennzoil 5W-30 presents the lowest viscosity and used Pennzoil presents the highest. As expected, lower viscosities

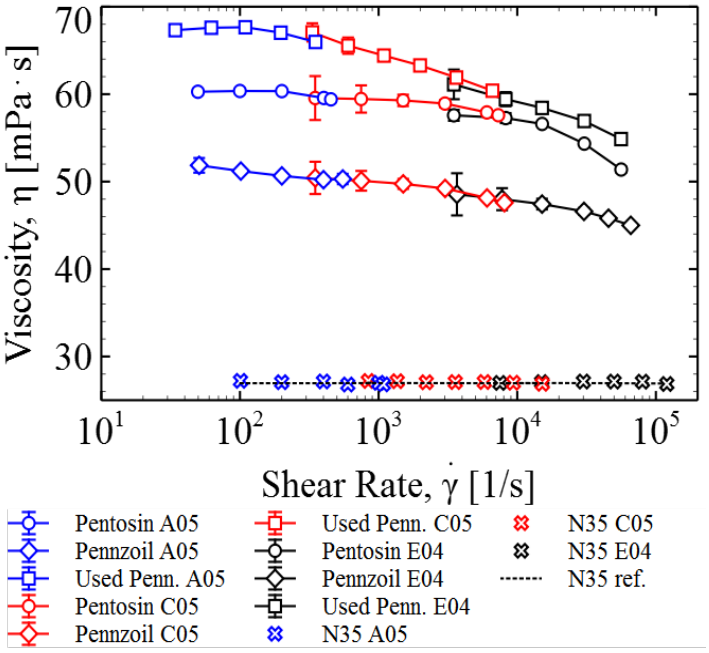

Figure 1. Viscosity of Pentosin (Circles), Pennzoil (Diamonds) and used Pennzoil (squares) as a function of shear rate at 40°C. Chip accuracy was tested with standard oil N35 reference viscosity (Crosses).

Table 1. hts-VROC Chip denomination, max. pressure limit and channel depths.

Chip	Max. Pressure Limit [Pa]	Channel Depth [µm]
A05	10,000	50
C05	200,000	50
E04	1,800,000	40

are observed at 100°C (See Figure 2). At this temperature, we were able to cover a shear rate range from 100 to 1,000,000 1/s. We observe that Pennzoil still has the lowest viscosity at 100°C while in this case, Pentosin and used Pennzoil present similar viscosities across the whole range of shear rates. At both temperatures, we tested *hts*-VROC® system using mineral standard oils and obtained excellent agreement with the certified reference values.

Oil viscosity typically decreases with use due to shear degradation of viscosity index improvers. However, the initial decrease is often followed by a gradual increase, which is caused by oxidation and accumulation of fine particulates [2]. Therefore, long term usage would lead to the significant increase in viscosity that we observe for used Pennzoil.

These results confirm, not only the high accuracy of VROC® technology, but also its suitability for the characterization of

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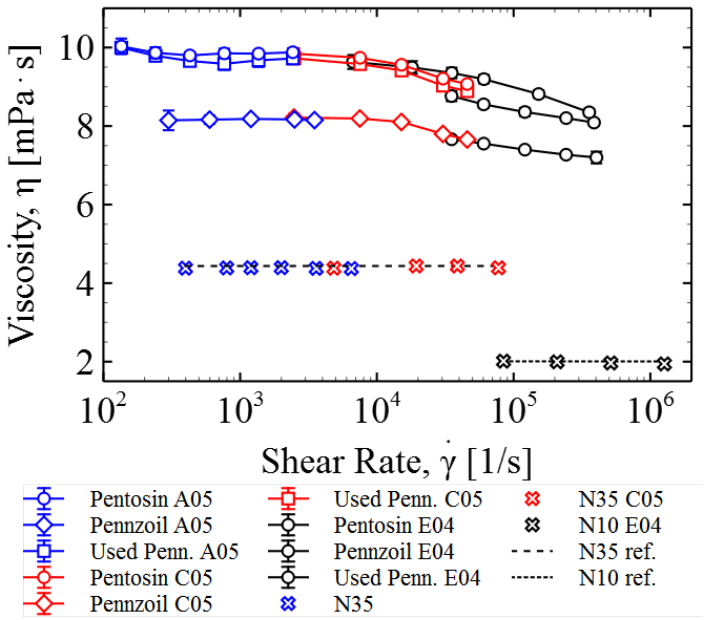

Figure 2. Viscosity of Pentosin, Pennzoil and used Pennzoil as a function of shear rate at 100°C.

the viscosity of fluids at high temperatures and high shear rates.

Non-Newtonian Behavior at High Shear

For all three samples, we observe slight non-Newtonian shear thinning behavior (i.e. viscosity decreases with increasing shear rate). This behavior is likely caused by the flow-induced alignment of the longer polymer molecules found in the additives included in these oils formulation. However, these effects only appear at high shear rates [3]. Testing the viscosity of a fluid at the shear rate relevant to a specific application is essential to properly assess performance. In real engine conditions, shear rate might vary from 10^2 to 10^7 1/s. Shear rate in conventional viscometers and rheometers is often limited by flow instabilities [1]. Our technology small-scale flow channel suppresses flow instabilities and therefore allows VROC® powered systems to measure true dynamic viscosity at shear rates as high as 1.4×10^6 1/s. This wide dynamic range makes them ideal for the characterization of non-Newtonian fluids under real flow conditions.

Summary

In this technical note, we demonstrate the suitability of *hts*-VROC® to characterize engine oils and other complex fluids over a wide range of shear rates and temperatures. VROC® technology is a powerful tool in the rheological characterization of fluids at high shear rates which are not accessible by convectional rheometers and viscometers. As an example of *hts*-VROC® capabilities, we present results for two new and one used multi-grade synthetic engine oils.

If you have questions or would like more information about this product or other applications, please contact us:

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References

[1] C. Macosko, Rheology: Principles, Measurements and Applications, Wiley, 1994.

[2] D. L. Alexander, "Change of High-Shear-Rate Viscosity of Engine Oils During Use: A Review," in *High-Temperature, High-Shear (HTHS) Oil Viscosity: Measurement and Relationship to Engine Operation.* American Society for Testing and Materials, 1989.

[3] C. J. Pipe, T. S. Majmudar and G. H. McKinley, "High Shear Rate Viscometry," *Rheol. Acta,* 2008.

BENEFITS OF *m*-VROC® SOLUTION

hts-VROC® offers precise shear viscosity measurements at high temperature and high shear rate. High accuracy and repeatability makes it ideal for R&D and QC applications.

Features include:

- Accuracy: 2% of reading.
- Repeatability: 0.5% of reading.
- Small sample volume.
- Shear Viscosity range: 0.2 – 100,000 mPa-s.
- Shear Rate range: 0.5 -1,400,000 s^{-1}
- Temperature control: 4-105°C