Benefits of Metallocene PAO in Automotive Gear Oil formulation SAE 75W-90

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1. Introduction

The global demand for energy is forecast to increase over the next few decades, and this growing demand is driven by several factors, including global population growth of approximately 1.7 billion people by 2050.[1] Carbon emission regulations have also been implemented by many different countries throughout the world, requiring energy efficient solutions in different industries, including the industrial and transportation industries.[2]

The development of new drive concepts with improved fuel economy is one of solutions being implemented by the heavy-duty automotive industry to achieve the balance of meeting increased energy demand and new carbon emission regulations.
These new drive concepts can achieve better performance through, among other things, hardware upgrades and next generation lubricant technologies.

This study focuses on Automotive Gear Oils (AGO), which are trending toward lower viscosities for improved fuel economy, while simultaneously extending oil drain intervals. In the heavy-duty transportation sector, higher viscosity 80W-90 fluids are still dominant, however, with the shift to lower viscosity oils[3], an important performance criterion for new AGO formulations is to provide sufficient oil film thickness to maintain the required wear protection. Next-generation synthetic base stock technology can enable lubricant manufacturers to achieve lower viscosity AGO with sufficient oil film thickness.

Overall, the synthetic base stock demand for lubricants is projected to grow by approximately 1.2% annually until 2027.[4] In the automotive gear oil segment, the growth rate for synthetic lubricants is expected to be 6.3%,[5] driven, in part, by automobile performance requirements, consisting of improved fuel economy with lower viscosity lubricants and extended oil drain intervals.

This study examines the performance impact of high-viscosity metallocene polyalphaolefin (mPAO) in a 75W-90 automotive gear oil formulation in comparison with other base stock technology.

2. Metallocene Polyalphaolefin (mPAO)

Conventional high Viscosity PAO features a prominent “backbone’ with short and long side chains on either side.

Alternative technology based on metallocene catalysts can produce high viscosity PAOs that have a narrow molecular weight distribution and a uniform, isotactic comb-like structure.[6]

ExxonMobil[7] has been a pioneer in the development of metallocene technology and marketing of proprietary metallocene polyalphaolefin (mPAO) base stocks that offer rheological advantages and enhanced lubricant benefits compared to conventional PAO (cPAO).[8]

The software modeling of C_{60} hydrocarbons, comparing the molecular structures of conventional and metallocene PAO, can be found in Figure 1.

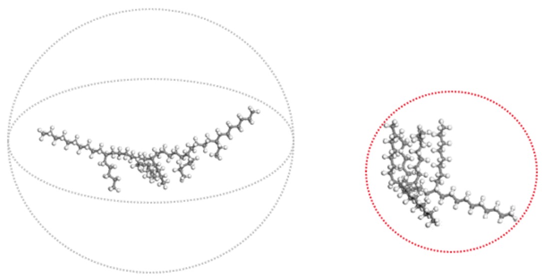

Fig. 1 Comparison of structures (C_{60} hydrocarbons)

- There are more carbons in the main chain of the cPAO and more carbons in the branches of the mPAO
- The resulting cPAO is extended and has a larger sweep volume with more chain interactions
- The resulting mPAO is more compact and has a smaller sweep volume with fewer interactions.

These structural differences have a direct impact on the performance of mPAO which compared to equivalent cPAO will have a higher VI, a lower low temperature viscosity, a better oxidation stability and a higher shear stability.[9]

ExxonMobil’s mPAO platform includes three viscosity grades with a KV100 of 65 cSt, 150 cSt, and 300 cSt. A comparison of the basic properties with conventional PAO can be found in Table 1 below.

Table. 1 Basic property data of cPAO and mPAO

Test	Method	Units	cPAO 40	cPAO 100	mPAO 65	mPAO 150	mPAO 300
Kinematic viscosity 100 °C	ASTM D445	cSt	39	100	65	156	303
Kinematic viscosity 40 °C	ASTM D445	cSt	396	1240	614	1649	3358
Viscosity index	ASTM D2270	None	147	170	179	210	241
Pour point	ASTM D5950/D97	°C	-36	-30	-42	-33	-33
Brookfield viscosity @-26ºC	ASTM D2983	cP	102,000	745,000	85,400	345,000	778,333

3. AGO Formulation with mPAO

The study has examined the impact of mPAO on the low-/high-temperature properties and shear stability of a 75W-90 AGO comparing against a polyisobutylene (PIB) containing AGO formulation. The formulation details are shown in Table 2 below. The Group III base stock, additive package (add pack), pour point depressant (PPD), and high shear-stable polyisobutylene (PIB) viscosity modifier (176 cSt at 100°C) are commercially available products. The PAO formulation was developed by combining mPAO (300 cSt at 100°C) with the same low-viscosity base oil, additive package and pour point depressant (PPD) at the same treat rates.

Table 2 shows that, due to the higher KV100 of mPAO than PIB, a smaller treat rate of the high-viscosity base stock is required in the mPAO formulation to achieve the same KV100 as the PIB formulation. Also, due to the higher VI of mPAO, the kinematic viscosity KV40 of the mPAO formulation is approximately 15% lower compared to the PIB formulation and has enhanced low-temperature fluidity (Brookfield at -40°C) as shown in Figure 2, which might also contribute for improved fuel efficiency.

Table 2 Formulations with PIB and mPAO as 75W-90

Component / Formulation	75W-90 with a shear stable PIB	75W-90 with mPAO
Gr.III - 4 cSt (%)	56	61
Viscosity modifier – PIB (%)	35.5	-
Viscosity modifier – mPAO (%)	-	30.5
Add pack – the same (%)	7.5	7.5
PPD – the same (%)	1	1
KV40, cSt	108	92
KV100, cSt	16	16
VI	160	184
Copper corrosion 3h, 150 °C	2a	1b

4. Scope of the study

The following tests were conducted:

- Brookfield Viscosity test (ASTM D2983)
- KRL Shear stability test (CEC L-45-A-99)
- Thermal and oxidative stability test (CEC L-60-1)
- Oxidation stability test (CEC L-48-00)

The detailed test results will be shown during the presentation.

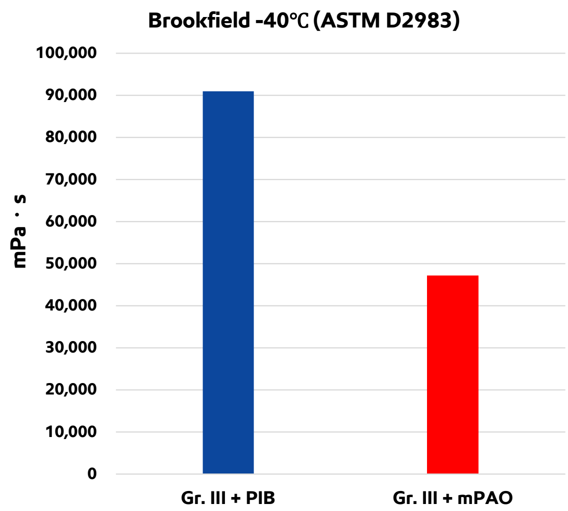

Fig. 2 Brookfield viscosity test results

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[1] Kline report in March 2023 (Y655 report).
[2] *See* "Passenger Vehicle Greenhouse Gas Emissions and Fuel Consumption," *International Council on Clean Transportation*, dated April 2024, *available at* https://theicct.org/pv-fuel-economy/.
[3] Kline report in March 2023 (Y655 report).
[4] https://www.exxonmobilchemical.com/en/products/synthetic-base-stocks/automotive-gear-oil
[5] *Id.*
[6] ExxonMobil data: RCI "Benefits of Metallocene PAO in Automotive Gear Oil formulation SAE 75W-90"
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[8] ExxonMobil data: RCI "High viscosity metallocene PAO: Technology that drives performance"
[9] *Id.*