Evaluation of EV formulations for passenger car and light duty commercial vehicles

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1. Abstract

EV gear fluids require a careful balance between low viscosity, high efficiency and equipment protection. This work will give an overview of how it is possible to make ultra low viscosity fluids for EVs whilst preventing equipment damage and also look at strategies for formulating for light duty commercial vehicles.

2. Introduction

The aim of this work is to address the challenges of formulation at extremely low viscosities and the potential solutions which esters can offer looking at this from both a performance and a safety point of view, firstly looking at single components and their properties before looking at fully formulated fluids with an aim of achieving <3 cSt and is this a realistic proposition.

In addition, A new base oil technology which can potentially be used in any of these types of architecture will be introduced in this work with some basic physical properties and initial tribological test data shown.

3. MTM testing conditions

Figure 1 – Traction at 18N, 3m/s and 61N, 1m/s, 40ºC
Figure 2 – Traction curve at 16N, 2m/s and 40 and 100ºC

4. Results

4.1 Creating a fully formulated fluid

For this work a new technology EV specific additive package was used which had a relatively minor impact on the viscosity of the base oil mixture.

Addition of Ester 1 and 2 in this work as shown from the properties in Table 1 will help improve the flash and NOACK of a formulation. The higher the level of ester addition, the greater the improvement will be especially for NOACK where the relationship is more linear than with flash However, when formulating with esters, there will be a maximum treat rate that will be allowed before elastomer swell becomes too great.

This will depend on the polarity of the ester and also the elastomer material being used. All of the blends in the table were formulated towards a target viscosity of 2.75 ± 0.25 cSt at 100°C. Although Ester 3 could be used for formulating at low levels, it was not considered in the full formulation work because of its high NOACK value.

Table 3 – Physical properties of fully formulated blends

Name	KV 40 cSt	KV 100 cSt	Flash >180ºC
Gp. III 2 cSt	10.55	2.91	No
Gp. III 2 cSt + 50% Ester 1	10.82	2.99	Yes
40% Gp. III 2 cSt + 40% Gp. III 3 cSt + 20% Ester 2	10.86	2.97	Yes
60% Gp. III 2 cSt + 15% PAO 2 +25% Ester 2	8.43	2.51	No

From the traction curves in Figures 1, the addition of ester was able to significantly reduce the level of traction. This was the case under all conditions tested. A dotted line represents high load (61N) and low speed and a solid line low load (18N) and high speed. Speed or load did not alter the order. The Ester 1 formulation had the lowest traction (dark green line) but also contained the most ester.

From the formulation data, it can be seen that Ester 1 and 2 can be used to formulate <3 cSt fluids with Ester 2 possibly the best candidate for pushing formulation viscosity as low as possible whilst still maintaining sensible Flash and NOACK values.

Significantly below 2 cSt even esters show high NOACK values and so treat rates are limited.

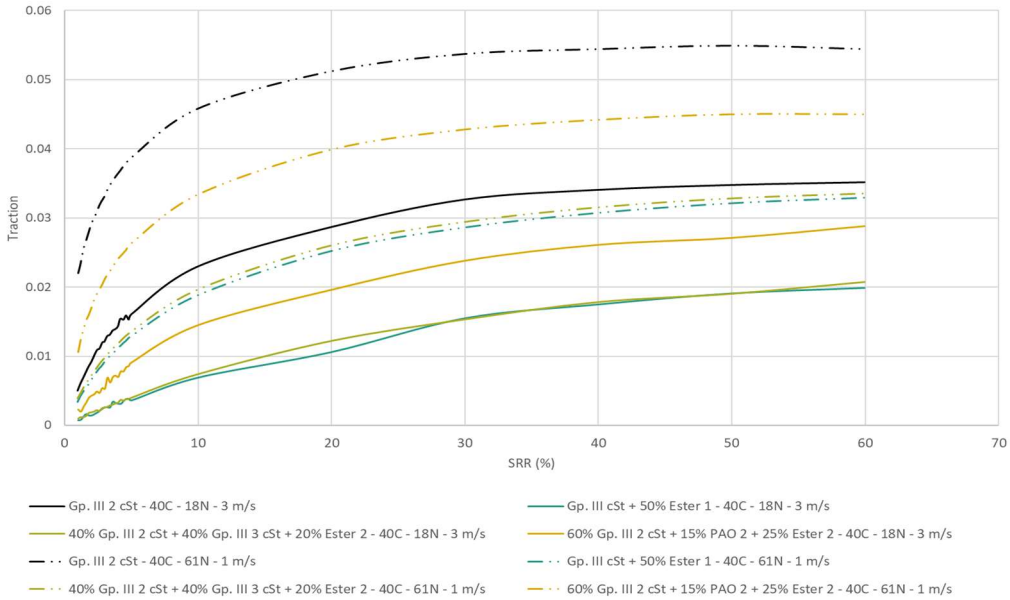

Fig. 1 Traction of fully formulated fluids 40ºC

4.2 New base oil for commercial vehicle EV

A novel, new base oil (Ester 4) was synthesized and evaluate which is suitable for use in electrified vehicle applications. The physical properties of this fluid are shown below. The viscosity of the fluid is too high for very low viscosity formulations but it suitable for higher viscosity commercial vehicle fluids and in particular rear axles.

Table 2 - Physical properties of Ester 4

Ester 4	KV 40 cSt	KV 100 cSt	VI
	140	16.7	148
	Pour point C	Ox. Stability mins	Biodeg %
	-9	1748	74

In its neat form, Ester 4 shows exceptional oxidative stability. In a simple rapidoxy screening test (ASTM D206-18) Ester 4 lasted 1748 minutes. In the same test, a Group III 4 cSt base oil lasts around 60 minutes and a fully saturated ester lasts around 180 minutes. This almost 10 fold increase in oxidative stability is our highest value observed in this test without the use of antioxidant. When formulating with Ester 4, it is important to balance treat rates with pour point, and the use of PAO or other ester can be utilised here.

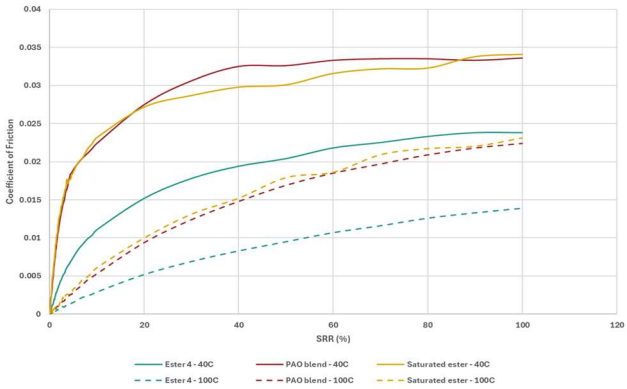

Fig. 2 Traction curves at 40 and 100C of Ester 4, saturated ester and PAO blend

Ester 4 also shows excellent low traction properties. As shown in Figure 7 when compared against a PAO blend or a high quality, fully saturated ester (all ISO 150), Ester 4 shows significantly lower traction at both 40 and 100°C.

As efficiency is even more important in commercial vehicles than in passenger car due to the high battery weight and cargo weight, Ester 4 could be a useful baseoil for formulators.

5. Conclusion

NOACK and Flash (or similar) are important safety features which are essential to a specification and can only be compromised so far. Formulating with Ester 2 it is possible to achieve a fully formulated fluid with a viscosity as low as 2.5 cSt.

The new basestock Ester 4 shows incredibly high oxidative stability and low traction. It has potential to be formulated in a variety of ways in the future and looks to be suitable for commercial vehicle style formulations..