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Performance Needs of Tomorrow's Driveline Lubricants

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PERFORMANCE NEEDS OF TOMORROW'S DRIVELINE LUBRICANTS

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ABSTRACT

There is a trend with driveline lubricants toward improved thermal stability, vehicle component durability and fuel efficiency. These improvements can significantly reduce vehicle operating costs and improve customer satisfaction. Of these improvements, the fuel efficiency is getting a substantial attention due to recent focus on CO_2 emission control in Europe, Japan and CAFÉ requirement in U.S.A. Lower viscosity axle oils and transmission fluids are currently being evaluated as potential solutions since these lubricants tend to reduce the churning losses and can improve the fuel efficiency. However, these lubricants should provide adequate gear and bearing protection, while increasing the overall efficiency of the driveline components. In this paper, the development of new fuel efficient axle was discussed with the focus on the effect of base oils, additives, and viscosity modifiers on the fuel efficiency of driveline components.

Key Words: Fuel Efficiency, Axles, Gear Oils

1. INTRODUCTION

Lately, there is a renewed interest on fuel economy due to government regulations in Europe and Japan and change in vehicle populations in North America. Strict emission requirements in Europe forced OEMs to improve fuel efficiency, thereby, lowering the level of emissions. This also applies to Japanese OEMs since they manufacture vehicles in Europe as well as export cars from Japan.

Most OEMs have used design changes, such as lower vehicle weights and aerodynamic designs, as a tool to improve the vehicle efficiency. However, these changes increase oil temperatures. Therefore, thermal stability and component durability became a key issue.

The key challenge facing these vehicle manufacturers is meeting government-mandated fuel economy requirements while maintaining durability. Driveline fluids must provide long-term durability and operating temperature control in order to increase equipment life under severe conditions while maintaining fuel efficiency. Higher operating temperatures for prolonged periods can adversely affect metallurgical properties and reduce fluid film thickness, both of which can lead to premature equipment failures. Therefore, operating temperature is an important indicator of durability.

In this paper, the development of fuel efficient gear oils will be discussed with the emphasis on the effects of base oils, viscosity modifiers, and additives.

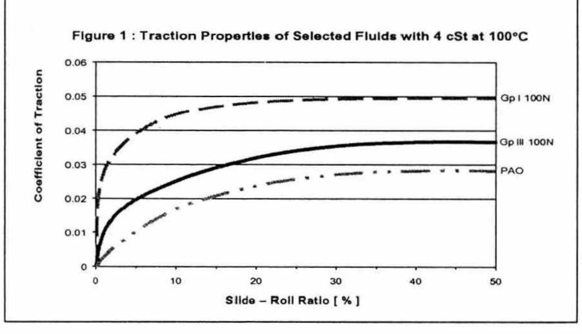
2. DEVELOPMENT OF FUEL EFFICIENT GEAR OILS

The first steps in the process were to optimize the lubricant subsets with respect to their potential losses using traction measurements in the laboratory. This was followed by evaluation in a laboratory full-scale axle test to measure efficiency and stabilized operating temperatures.

2.1. Optimization of Lubricants for Fuel Efficiency

Traction is a physical property related to predominantly to the molecular structure , therefore, it is not usually associated with additives[1]. The traction coefficient is a reflection of energy dissipated under highly loaded lubricated contact due to shear. Therefore, traction behavior can be used as one indicator of the efficiency of lubricants.

A mini traction machine (MTM)[2] was used to evaluate lubricants in the full fluid film elastrohydrodynamic (EHD) regime. Group I, Group III, and a synthetic PAO were used for the evaluation. In traction profiling, 75°C provided the greatest separation among candidates although the same relative order was observed at higher temperatures. Figure 1 shows the traction response of three base oils. Each of the fluids shown in Figure 1 is approximately 4 cSt at 100°C. The response shows that as the structure of the base fluid becomes more linear the internal resistance or traction decreases.



Thickening agents, either viscosity modifier or synthetic base fluid such as PAO 100, can also affect the traction coefficients. Table 1 shows the traction properties of selected candidates with different viscosity modifiers. Based on the evaluation, the thickener E was selected for the full scale axle testing.

Table 1 - Traction Properties of Candidate Fluids Blended to 20 cSt at 100°C

OIL	BASE FLUID 4cSt @ 100°c	THICKENING AGENT *	TRACTION COEFFICIENT, 1.25 GPa, 2.5 m/s 75°C, 20% Slide –Roll Ratio
1	PAO	A	0.044
2	PAO	B	0.030
3	PAO	C	0.026
4	PAO	D	0.039
5	PAO	E	0.027
6	Group III	E	0.030
Ref	Synthetic SAE 75W-90		0.040
Ref	Mineral SAE 80W-90		0.052

* Thickening agent is either viscosity index improver, or synthetic base fluid
Note: All fluids above treated with the same additive

2.2 Full Scale Axle Testing for Evaluation of Durability

Even though traction measurements provide a useful insight for fuel efficiency and operating temperatures, a lubricant should be evaluated in an actual rear axle assembly, with careful monitoring of temperatures and torque losses. A test method was developed to evaluate the performance of the fluid under the rigorous operating conditions that the axle and vehicle were designed for[3,4].

Based on the traction data, a group of fluids were selected for the axle durability. These oils were compared with commercially used SAE 80W-90 mineral gear oil and SAE 75W-90 synthetic gear oil. It is critical to determine the response of this particular thickening component over a wide viscosity range. Table 2 provides a summary of this information.

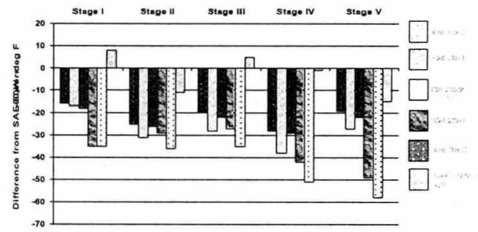
Table 2 - Candidates Based Upon Thickener E for Axle Durability Testing

OIL CODE	BASE FLUID (4cST @ 100°c)	VISCOSITY cSt @ 100°C	BROOKFIELD cPs @ -40°C
15-1	PAO	15	30,000
15-2	Group III	15	90,000
20-1	PAO	20	45,000
20-2	Group III	20	120,000
25-1	PAO	25	110,000
25-2	Group III	25	>150,000

Note: All fluids above treated with the same additive

Figure 2 shows the temperature responses expressed as difference from the results obtained on the SAE 80W-90 reference lubricant. To compensate for continuous axle break-in and permit a more meaningful comparison among candidates and references, a correction factor has been applied to all fluid operating temperatures reported at any given stage [5]. It was interesting to see all candidate fluids showed lower operating temperatures than the mineral- based SAE 89W-90 and SAE 75W-90 synthetic reference lubricant.

Figure 2 - Staged Durability: Differences in Operating Temperature from the Mineral SAE 80W-90 in a Standard Light Truck/SUV Axle



In general, the level of temperature reduction is greatest at any given stage for the 25 cSt candidates. The difference from SAE 80W-90 reference was greatest in Stage V. This is contrary to conventional thinking that higher viscosity fluids in general result in more losses due to viscous drag from churning.

The effect of additives on temperature control and efficiency was also observed from the study.

CONCLUSION

Lower viscosity axle lubricants are instrumental in improving fuel economy. However, popular light trucks and SUVs are often used for towing and other severe service. The lower viscosity axle lubricants often run at higher temperatures than desired and do not always provide adequate durability.

In this study, we showed a family of lubricants which provide a balance between the durability and the fuel efficiency. The lubricants were developed through the proper selection of base oils, thickening agents and performance packages. Higher viscosity axle lubricants provided the maximum temperature reduction. Still, with the proper choice of base fluid along with thickener and performance package, a high level of durability can be maintained at lower viscosities.

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