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CASE STUDY

Heavy Naphthenic Process Oils to Increase Scorch Time, Winter Safety and the Life of Tire Tread

Summary

Material: **HyPrene heavy naphthenic process oils**
Application: **Tire tread formulation**
Key benefits: **Advantages in processability, process safety, abrasion resistance, faster cure time and winter traction**

The Challenge

Tires are designed to help optimize both the performance and safety of vehicles. A good tire must provide **traction, optimize fuel consumption, improve vehicle handling, provide driving comfort with low noise and have a long usable life**. Performance optimization depends on the specific end use of tires. The right balance of properties, for a specific application, is in part achieved by adjusting the various raw materials in the tire tread formulation. Process oils are important ingredients that affect the performance of the tire tread. They are used as extenders and/or plasticizers in rubber formulations.

Choosing the right process oil is vital to optimize the overall performance of the tire tread. Selection of the process oil requires considerations of the compatibility with the elastomer, processability and performance. Rubber compounders must choose a product that provides the **right balance of durability, stopping distance, grip, rolling resistance and safety**. The magic tire triangle illustrates the trade-offs involved in tire tread formulation. Maximizing a single attribute would mean compromising on the other properties. Rubber formulators must try to achieve a good balance of properties for a given application.

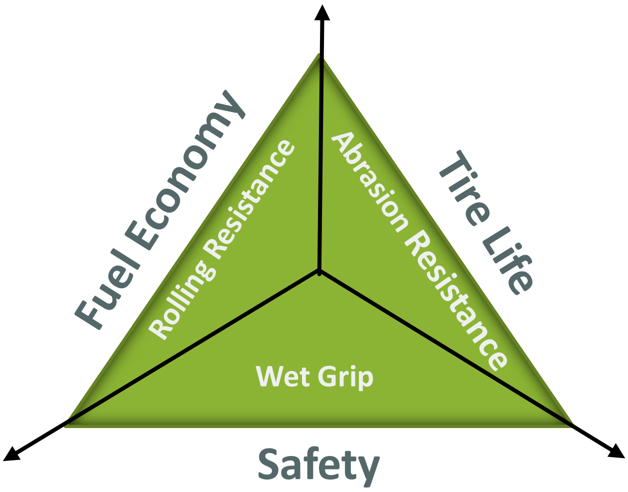

Figure 1: *Magic Tire Triangle*

The Solution

Ergon produces naphthenic and paraffinic process oils, base oils and insulating oils. Ergon's products are produced at two different refining locations where naphthenic and paraffinic crudes are refined using modern processing such as, high severity hydrotreating. Ergon's HyPrene process oils are produced to exact specifications and are designed for a variety of processing applications. HyPrene products have low pour points, good solvency power, low odor levels, excellent color and color stability characteristics.

A study was conducted to compare the properties of two grades of HyPrene process oils, suitable for use in tire formulations, to that of a traditionally used product called Treated Distillate Aromatic Extract (TDAE). The HyPrene products used in the study were HyPrene L2000 and HyPrene BO150. These products are used globally in tire treads today.

- **HyPrene L2000** is a severely hydrotreated heavy naphthenic process oil (HNO) which provides good solvency for the rubber processing industry. It has a low pour point and a low odor level.
- **HyPrene BO-150** is a heavy naphthenic black oil (HNBO) made from a blend of hydrotreated process oils and heavy resids. It was primarily developed to be a clean process oil for aromatic process oil replacement for use in the rubber industry.

The table below compares the physical properties of the three process oils used in the study. HyPrene BO-150 is the most viscous, followed by TDAE and HyPrene L2000.

Physical Property	Test Method	HyPrene L2000	HyPrene BO-150	TDAE
Viscosity, SUS @ 100°F (37.8 C)	ASTM D7279	2098	4117	3006
Viscosity, SUS @210°F	ASTM D7279	101.5	147	102.7
Refractive Index @ 20°C	ASTM D1218	1.5076	1.5288	1.5295
Aniline Point, °F (°C)	ASTM D611	208.3 (97.9)	184 (84.4)	155.7 (68.7)
Glass Transition Temp °C	ASTM D3418	-53	-57	-52
Flash Point, COC, °F (°C)	ASTM D92	495 (257.2)	490 (254.4)	510 (265.6)
Color, ASTM	ASTM D6045	2.0	D8.0	8.0

Table 1: *Comparison of the physical properties of the three process oils*

Each product was tested in three different tread formulations with varying filler systems to examine the performance across the formulations. The three different filler systems contain mostly silica, carbon black, or a combination. All other variables were held constant. The three filler systems tested were:

- 70 phr silica and 5 phr carbon black (70/5): Serving as the high silica formulation for low rolling resistance (LRR). 5 phr carbon black was added to dissipate static charge.
- 35 phr silica and 40 phr carbon black (35/40): Tested as the general balanced formulation.
- 0 phr silica and 75 phr carbon black (0/75): The high carbon black filler loading, representing a replacement tire formulation.

The tire tread testing included scorch and cure time measurements, abrasion resistance testing and the measurement of the tensile storage modulus. All tests were performed by an independent third-party lab, using blind samples.

Scorch Time (T_2)

Scorch time is the time period during which a rubber compound can be worked at a given temperature before vulcanization begins. A longer scorch time increases the process safety margin and helps avoid premature cure and ruining of the batch. T_2 scorch times for the three process oils, with three different filler loadings, were measured using an MDR Rheometer (ASTM D2084). Figure 2 shows the results of the test. HyPrene BO-150 had the longest scorch time, which translates to the best process safety margin. Figure 2 also shows that the scorch time decreased with decreasing silica content.

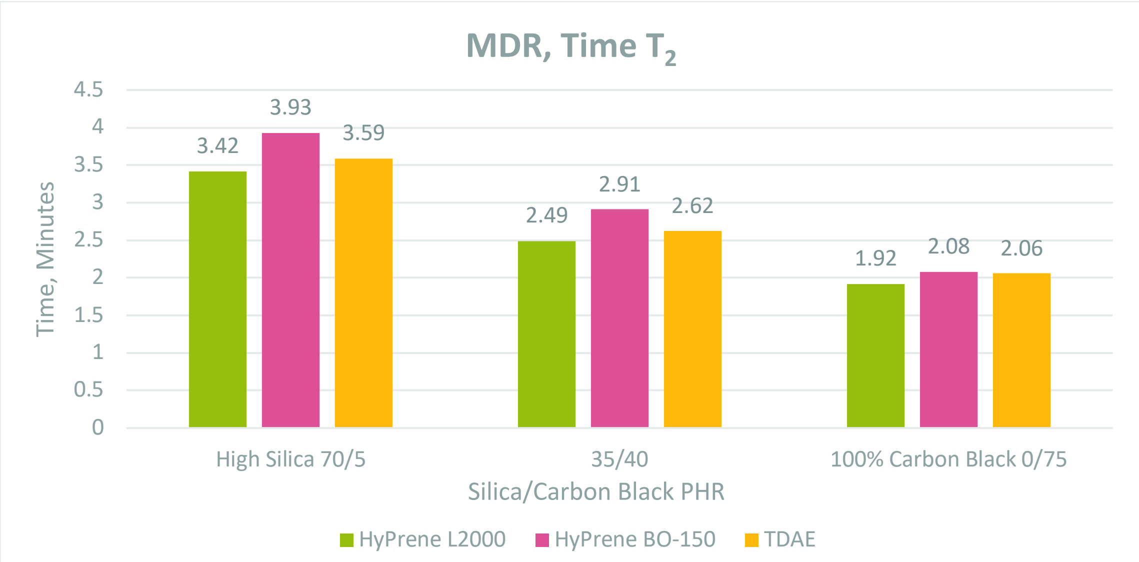

Figure 2: *Comparison of T_2 scorch time for the three process oils with different filler loadings*

➢ Cure Time (T_{90})

T_{90} cure time is the time required to achieve 90% cure. Faster cure can save valuable processing time and increase productivity for manufacturers. T_{90} cure times for the three process oils, with three different filler loadings, were measured using an MDR Rheometer (ASTM D2084). Figure 3 shows the results of the cure time tests. HyPrene L2000 had the fastest cure time in the 100% carbon black formulation, as well as in the 35/40 formulation. The cure times for all three process oils were very similar for the high silica formulation.

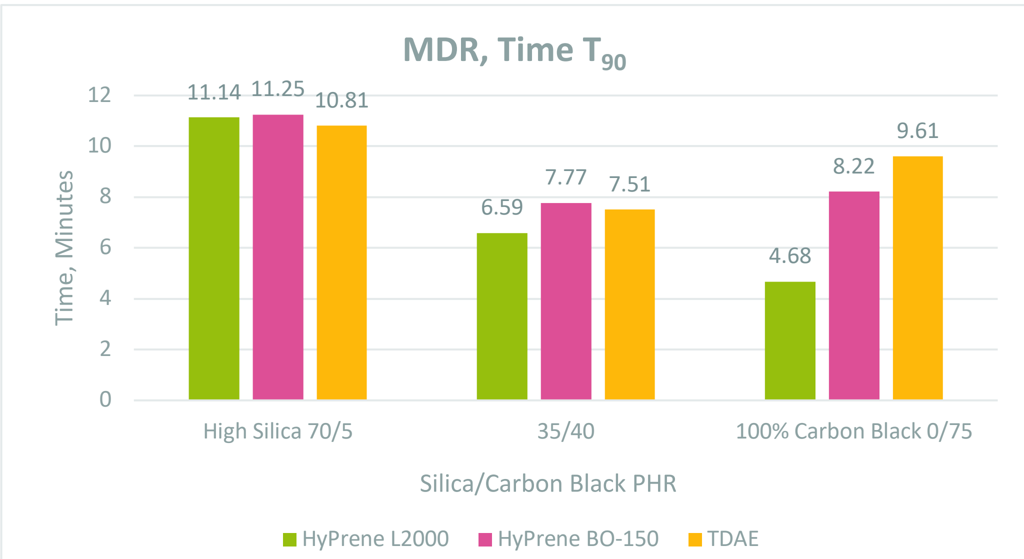

Figure 3: *Comparison of T_{90} cure time for the three process oils with different filler loadings*

➢ Pico Abrasion – Abrasion Index

Pico abrasion is used to simulate the ability of the tire tread to withstand abrasion. A higher Pico abrasion index indicates less material loss or higher abrasion resistance during the abrasion test. The Pico abrasion index (ASTM D2228) was measured for the three process oils, with three different filler loadings. Results presented in Figure 4 show that HyPrene L2000 produced the best abrasion resistance in 35/40 and 100% carbon black tire tread formulations. In the high silica formulation, HyPrene L2000 showed significantly better abrasion resistance than TDAE.

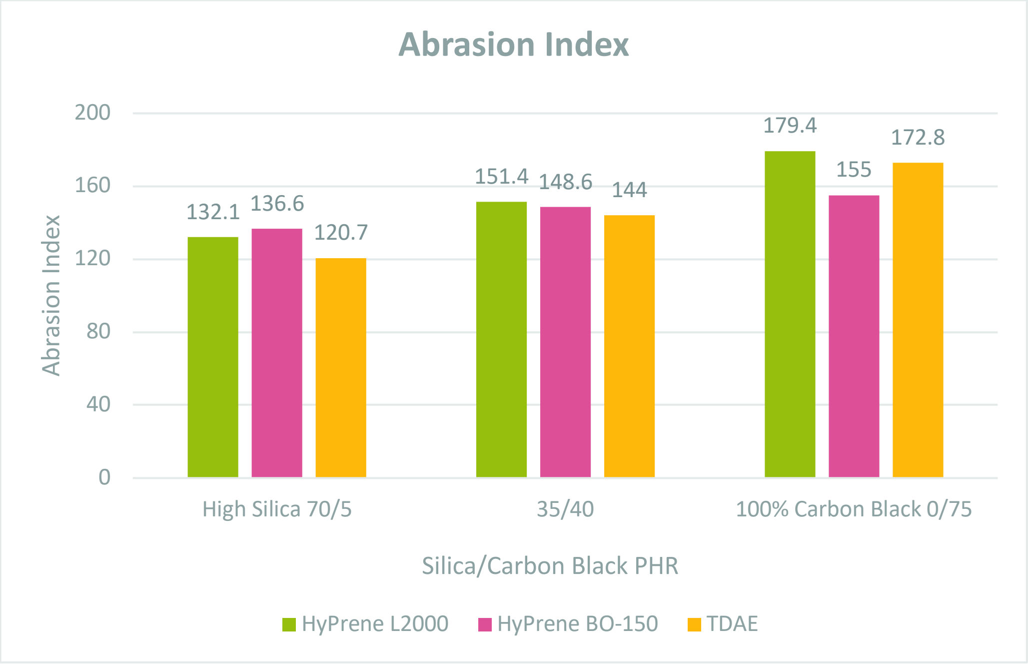

Figure 4: *Comparison of abrasion index for the three process oils with different filler loadings*

➢ Tensile Storage Modulus

The tensile storage modulus (E’) is a mechanical property that measures the stiffness of a solid material. E’ at -20°C is a predictor of winter traction; lower E’ values indicate better winter traction. Dynamic mechanical analysis (DMA) was conducted to measure the tensile storage modulus for each of the three process oils in the three filler formulations. HyPrene L2000 produced the best winter traction in all three tire tread formulations.

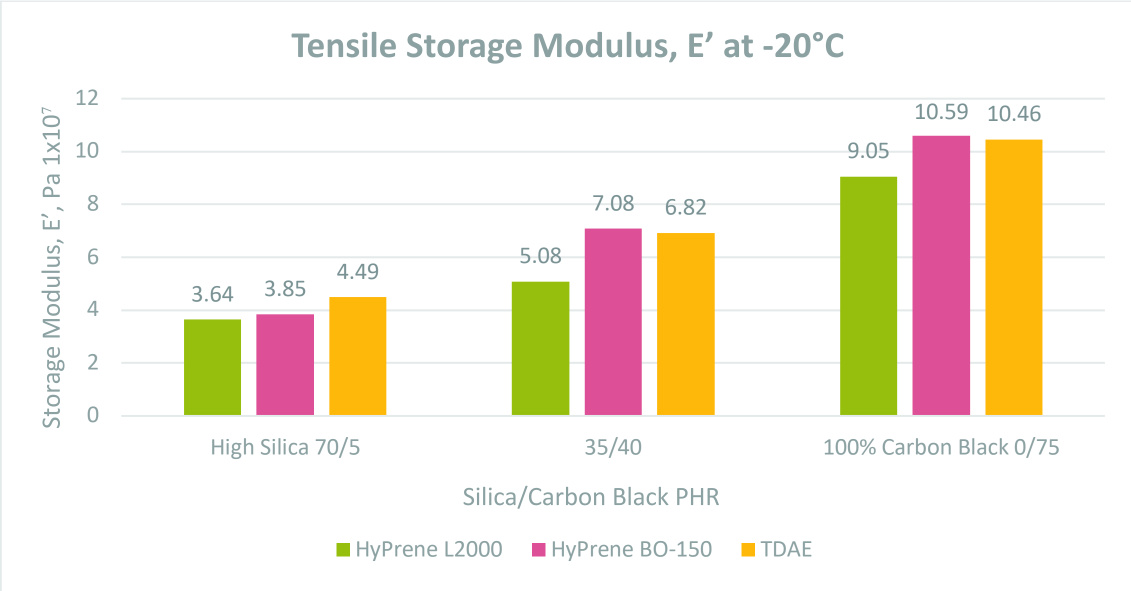

Figure 5: *Comparison of the tensile storage modulus E’ for the three process oils with different filler loadings*

Conclusion

HyPrene heavy naphthenic process oils L2000 and BO-150 offer advantages in processability, process safety, abrasion resistance and winter traction over TDAE. HyPrene L2000 offers enhanced abrasion resistance, faster cure time and improved winter traction. HyPrene BO-150 extends the process safety margin by increasing the scorch time. Tire tread formulators can take advantage of HyPrene process oils to improve processability and performance of their products. Incorporating HyPrene process oils in tire tread formulations can help them tailor material properties to match the desired specifications.