# The Effect of Base Oils on Thickening and Physical Properties of Lubricating Greases

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## 1. Introduction

Lubricating greases are formulated products consisting of a base oil (50-98%), a thickener (2-50%), and various performance additives (0-10%) such as antioxidants, corrosion inhibitors, antiwear, and extreme pressure additives, depending on the application. Grease is used instead of oil where retention is important, where less frequent application is required, to seal out dirt and contaminants, and to protect from corrosion. Accordingly, manufacturers and users measure several unique physical properties of grease; pumpability, dropping point, mechanical stability, and oil separation. In general, for most soap-thickened greases, base fluid viscosity and grease consistency are independent properties of a lubricating grease. The viscosity of the base fluid is determined by the viscosity of the fluids used, as well as the effect of some additives. The consistency of a grease is determined by the type and concentration of the thickener in the product.

There are three basic types of hydrocarbon base oils used in grease today. These are naphthenic oils, paraffinic oils, and synthetic isoparaffinic hydrocarbons. A fourth base oil, aromatic oils, has been replaced due to health and safety concerns. The paraffinic oils can be further subdivided into Group I, Group II, and Group III type of oils [1]. PAO remains the only synthetic base oil evaluated in this study.

Advances in refining technology have greatly impacted the supply side of the market. Over the last 10 years, more than 7.5MM tonnes per year of Group I production capacity have been shuttered with most capacity additions, either expansions or new constructions being in Group II and III products. [2]

API Group I base oils contain a considerable amount of sulfur and a saturates level less than 90%. While most commercially available Group II and Group III base oils have essentially nil aromatic content, Group I and severely hydroprocessed naphthenic base oils have been processed to remove the carcinogenic PAHs while leaving the other aromatics intact. The removal of the PAHs are necessary to produce a “clean” base oil that meets the Health, Safety, and Environmental (HSE) regulations of the applications for which they are used.

Solvency is affected most by the aromatic content and then by the naphthenic content. As the aromatic content decreases, the solvency decreases and as the naphthenic content increases, the solvency increases. When aromatics are hydroprocessed, they are converted to naphthenes. Therefore, naphthenics are an outstanding way to increase the solvency of the formulation while meeting HSE requirements.

Solvency is impacted by several, somewhat-related, factors and can be assessed in terms of aniline point, viscosity index (VI), and viscosity-gravity constant (VGC). Aniline point, ASTM D611 [3], characterizes solvency via a compatibility test between the oil and aniline which is an aromatic amine. The lower the aniline point, the higher the solvency of the base oil.

The VI, ASTM D2270 [4], which is a dimensionless number, is used to characterize the variation of the kinematic viscosity of a petroleum product with temperature. The VI correlates with chemical structure, with aromatics having the lowest VI, then naphthenics, and paraffins having the highest VI; therefore, a higher VI indicates a lower solvency.

VGC, ASTM D2501 [5], describes the general relation between specific gravity and Saybolt viscosity. As the VGC increase, the solvency increases. VGC is often used in conjunction with aniline point since VGC is independent of molecular weight.

The thickener in a lubricating grease is the component that sets grease apart from fluid lubricants. Thickeners are molecules, polymers, or particles that are partially soluble in lubricating fluid; they arrange themselves in such a way that they impart a semi-solid consistency to the grease.

The amount of thickener used during manufacture remains linked to the desired physical properties of a finished grease. Since the soap or clay is typically more expensive than the base oil, minimizing the soap or clay content while maintaining the physical properties is paramount. The amount of thickener necessary to form the microstructure depends on the interactions between the thickener and the base oil, which depends on the solvency of the base oil. The higher the solvency, the more the interaction and the less thickener required to produce a grease with the targeted NLGI grade, ultimately lowering the overall formulation cost.

For this study, we will examine the difference between several naphthenic based oils, two different paraffinic oils, a PAO, and a bright stock as it relates to processing and properties of lithium 12-hydroxy, lithium complex, aluminium complex, calcium sulfonate and clay based greases. We will also illustrate simple economic benefits of lower thickener concentration.

## 2. Design of Experiment

In this study, NLGI Grade 2 greases were prepared using five different thickener systems (1) lithium 12-hydroxy stearate, (2) lithium complex, (3) aluminium complex, (4) calcium sulfonate, and (5) clay. One exception was with the synthetic hydrocarbon clay based grease. It was not possible to produce an NLGI Grade 2 grease without drastically altering the process variables, so in this case, an NLGI Grade 00 grease was produced. According to the 2015 NLGI Annual Production Survey [6], lithium 12-hydroxy greases account for nearly 55% of the total grease manufactured in the reporting countries. Lithium complex grease adds another 20%, so that lithium based greases account for nearly 75% of production. In North America, lithium 12-hydroxy grease is 26% while lithium complex grease is 39% for a total lithium based grease of 65%. Seven different base oils were used for each type of thickener. These included four naphthenic bases oils (two ISO VG 150, one ISO VG 460, and one ISO VG 1000), one paraffinic Group I base oil (ISO VG 100), one paraffinic Group II base oil (ISO VG 100), and a synthetic hydrocarbon PAO (ISO VG 150). The greases were all produced in the same reactor under similar conditions. The physical properties of the base oils are given in Table 1, with increasing relative solvency from right to left.

| Generic Name | 150 N1 | 150 N2 | 460 N3 | 1000 P3 | 100 P1 | 100 P2 | 150 S1 |
|---|---|---|---|---|---|---|---|
| Description* | Nap | Nap | Nap/Par Blend | Group I Par | Group I Par | Group II Par | PAO |
| ISO VG | 150 | 150 | 460 | 1000 | 100 | 100 | 150 |
| Vis 40°C, cSt | 143.9 | 142.9 | 475.3 | 958.2 | 106.1 | 117.3 | 148.4 |
| Vis 100°C, cSt | 11.0 | 10.5 | 26.3 | 43.0 | 10.9 | 12.1 | 21.1 |
| Viscosity Index | 39 | 25 | 72 | 82 | 84 | 92 | 168 |
| Aniline Pt, °F | 197.5 | 191.3 | 231.5 | 248.5 | 248 | 256.8 | >300 |
| Viscosity-Gravity Constant (VGC) | 0.853 | 0.832 | 0.832 | 0.819 | 0.799 | 0.799 | 0.765 |
| Specific Gravity, 60/60°F | 0.917 | 0.901 | 0.915 | 0.914 | 0.873 | 0.875 | 0.853 |
| Carbon Type, D2140 | | | | | | | |
| %$C_A$ | 11.3 | 19.7 | 9.3 | 7.4 | 0.6 | 0.0 | 0.0 |
| %$C_N$ | 37.7 | 14.2 | 31.2 | 26.6 | 30.0 | 32.8 | 20.2 |
| %$C_P$ | 51.0 | 66.1 | 59.5 | 65.9 | 69.4 | 67.2 | 79.8 |
| Refractive Index | 1.502 | 1.505 | 1.502 | 1.502 | 1.479 | 1.479 | 1.464 |

**Table 1.** Experimental base oil physical properties

Each grease was characterized by % thickener, unworked penetration, worked penetration (60x and 10,000x strokes), mechanical stability after 10,000 strokes, and US Steel mobility test. In addition, roll stability, oil separation, and dropping point were reported for some of the greases. In order to simplify the formulations, performance additives such as antioxidants, anti-wear, and corrosion inhibitors were not included.

## 3. Conclusions

This study examined the effect of naphthenic, paraffinic, and synthetic (PAO) base oils on the thickening capabilities of lithium 12-hydroxystearate, lithium complex, aluminum complex, clay base, and calcium sulfonate complex greases and their associated physical properties. Experimental results, presented in Figure 1, illustrate a significant relationship between base oil solvency and thickener yield; a relationship with real economic value for grease manufacturers.

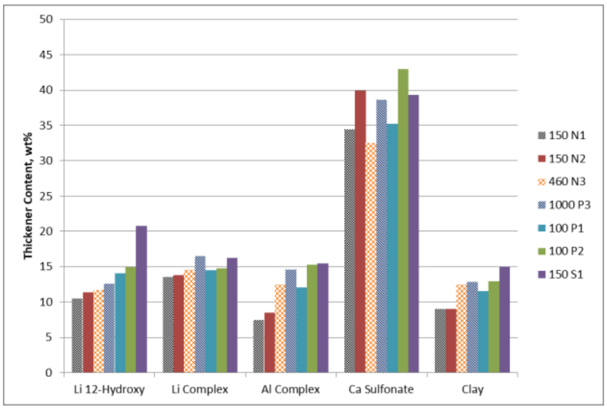


**Figure 1.** Thickener content required for NLGI Grade 2 greases with different base oils, wt%

Physical properties including mechanical stability, roll stability, dropping point, oil separation, and mobility also exhibited favourable results with increasingly solvent base oils. These observations remind us that base oil selection and preference should differ according to the requirements of the application. Paraffinic chemistries maintain a leading role in engine oil applications; however, it is evident throughout our study that a specialized application, such as grease, values "clean" solvency rich chemistries like those found in naphthenic base oils.

## 4. References


[1] API 1509, "Appendix E — API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils".

[2] "Lubes 'N' Greases 2016 Guide to Global Base Oil Refining", Supplement to Lubes 'N' Greases, Vol 22, Issue 6, June 2016.

[3] ASTM D611-12 (2016), "Standard Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents", Annual Book of ASTM Standards, Vol. 5.01.

[4] ASTM D2270-10 (2016), "Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40°C and 100°C", Annual Book of ASTM Standards, Vol. 5.01.

[5] ASTM D2501-14 "Standard Test Method for Calculation of Viscosity-Gravity Constant (VGC) of Petroleum Oils ", Annual Book of ASTM Standards, Vol. 5.01.

[6] NLGI Grease Production Survey Report for 2015.