A QUAKER CHEMICAL COMPANY

Quick-Study for Product Design Engineers






Tips for Lubricating Plastic Parts

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Quick Overview

Lubricants improve the performance and life of gears, bearings, slides, and other plastic parts — *if they are formulated specifically for lubricating plastic components.*

This Quick-Study contains tips that will help you choose the best lubricant for your plastic part, with special notes on gears, bearings, slides, no-lube plastics, and how to avoid the Stick-Slip phenomenon.

The Basics: *What is grease and how does it work?*

Oil
(up to 90%)

Thickener
(15 to 30%)

Additives
(5 to 10%)

Solid Lubricants
(5 to 10%)

Oils Lubricate. They form a protective film between two surfaces to prevent friction and wear.

Thickeners hold the oil in place, much like a sponge holds water. When mated parts move, the thickener is sheared and releases oil to form a lubricating film between moving parts. Thickeners reabsorb oil when motion stops.

Additives enhance critical performance qualities of a grease, such as low temperature torque, corrosion protection, and oxidation resistance.

Solid Lubricants like PTFE, MoS_2, and graphite are load carrying additives that improve the lubricity of a grease, especially on start-up.

Mineral Oil or Synthetic Oil?

Deciding factors: Temperature limits and part performance

Operating Temperatures for Oils

Mineral	-30 to 100°C
PolyAlphaOlefin (PAO) Synthetic HydroCarbon (SHC)	-60 to 150°C
Ester	-70 to 150°C
PolyAlkylene Glycol (PAG)	-40 to 180°C
Silicone	-75 to 200°C
PerFluoroPolyEther (PFPE)	-90 to 250°C

If your part needs to run at temperatures lower than -30° or higher than 100°C, you'll need a synthetic oil — or a mineral-synthetic blend. Esters and PAGs blend well with SHC (PAO).

Crib Notes on Mineral Oil

- Usually the most cost-effective choice if operating temperature range does not exceed -30 to 100°C.
- Can get quite thick or frozen at cold temperatures, making them tougher to shear at start-up, which is necessary to release oil from the thickener to produce a lubricating film between two surfaces.
- Can become very volatile at high temperatures, which reduces the strength of the lubricating film, increasing friction and wear.

Crib Notes on Synthetic Oils

- More than wider temperature ranges, they have higher "Viscosity Indexes," i.e., their viscosity remains more consistent as temperatures change, which ensures consistent performance at temperature extremes.
- Oil film is generally stronger than mineral oil, making them better able to handle heavier loads and faster speeds.

Make sure your oil and plastic are compatible, otherwise the part may crack or craze, leading to premature failure

A Guide to Oil-Plastic Compatibility

Plastic		Mineral	PAO	Ester	PAG	Silicone	PFPE
Acrylonitrile butadiene styrenes	ABS	🟡	🟡	🔴	🔴	🟢	🟢
Polyamides (nylons)	PA	🟢	🟢	🟢	🟡	🟢	🟢
Polyamide-imides	PAI	🟢	🟢	🟢	🟢	🟢	🟢
Polybutylene Terephthalates (polyesters)	PBT	🟢	🟢	🟡	🟡	🟢	🟢
Polycarbonates	PC	🟡	🟡	🔴	🔴	🟢	🟢
Polyethylenes	PE	🟡	🟡	🟡	🟡	🟢	🟢
Polyetheretherketone	PEEK	🟢	🟢	🟢	🟢	🟢	🟢
Phenol-formaldehyde (phenolics)	PF	🟢	🟢	🟢	🟢	🟢	🟢
Polyimides	PI	🟢	🟢	🟢	🟢	🟢	🟢
Poly-oxymethylenes (acetals)	POM	🟢	🟢	🟢	🟡	🟢	🟢
Polyphenylene oxides	PPO	🟢	🟢	🔴	🔴	🟢	🟢
Polyphenylene sulfides	PPS	🟢	🟢	🔴	🔴	🟢	🟢
Polysulfones	PSU	🟢	🟢	🔴	🔴	🟢	🟢
PolyPropylene	PP	🟡	🟡	🟡	🟢	🟢	🟢
PolyTetraFluoroEthylene	PTFE	🟢	🟢	🟢	🟢	🟢	🟢
Polyvinyl chlorides	PVC	🟡	🟡	🔴	🔴	🟢	🟢
Thermoplastic Polyurethane	TPU	🟢	🟢	🟡	🟡	🟢	🟢

🟢 Should be safe 🟡 May or may not work 🔴 Don't try it

Basic Rules of Thumb for Selecting an Oil for Use with Plastics

- Silicone and PFPE are generally safe with all plastics.
- Synthetic hydrocarbons and mineral oils are usually compatible with most plastics, though high and low operating temperatures may rule out mineral oils.
- Use caution with ester and polyalkylene glycol. They are compatible with only a limited number of plastics.

Test, Test, Test

- Verify compatibility by testing under extreme load, speed, and temperature requirements.

Choose a thickener that's compatible with the oil, operating temperatures, and conditions

How Thickeners Perform under Operating Conditions

	Aluminum	Aluminum Complex	Amorphous Silica	Barium Complex	Bentonite	Calcium	Calcium Complex	Calcium Sulfonate	Lithium	Lithium Complex	Polyurea	PTFE	Sodium Complex
Adhesive	🟢	🟢	🔴	🟢	🟡	🟡	🟢	🟢	🟡	🟢	🟡	🔴	🟢
Autophoretic Paint Process	🟢	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟡
Corrosion	🟢	🟢	🟡	🟢	🟡	🟡	🟢	🟢	🟡	🟡	🟢	🟡	🟢
Dropping Point	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟡	🟢	🟢	🟢	🟡
Fretting	🟡	🟡	🟡	🟡	🟡	🟡	🟢	🟢	🟡	🟡	🟡	🟡	🟡
Low Friction	🟢	🟡	🔴	🟡	🔴	🟡	🟡	🔴	🟡	🟡	🟡	🟢	🟡
Salt Water	🟢	🟡	🟢	🟡	🟡	🔴	🟡	🟢	🔴	🟡	🟡	🟢	🟡
Water	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟡	🟡	🟢	🟢	🟢	🔴
Wear	🟢	🟢	🔴	🟢	🟡	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Worked Stability	🟢	🟢	🟡	🟢	🟡	🟡	🟡	🟢	🟢	🟢	🟡	🟢	🟡

🟢 Should be safe 🟡 May or may not work 🔴 Don't try it

Some oils and thickeners don't mix well

- Mineral, PAO, and ester oils mix with any thickener.
- Silicone oil mixes only with lithium, silica, and PTFE.
- PFPE oil can be thickened only with PTFE.

Thickeners begin to degrade at specific temperatures

- Aluminum <80°C.
- Barium Complex and Lithium <135°C.
- Aluminum Complex, Calcium Complex, Calcium Sulfonate, and Lithium Complex <175°C.
- Extreme temp thickeners include Polyurea (<200°C), PTFE (<275°C), and Amorphous Silica (<300°C).

Some thickeners are better suited to some operating conditions

- Low temperature performance, corrosion, fretting, low friction, salt water, and wear prevention are all factors to consider when selecting a thickener. *See table on left.*

Choosing the thickener to formulate a grease for plastic parts

How Thickeners Perform under Operating Conditions

	Aluminum	Aluminum Complex	Amorphous Silica	Barium Complex	Bentonite	Calcium	Calcium Complex	Calcium Sulfonate	Lithium	Lithium Complex	Polyurea	PTFE	Sodium Complex
Adhesive	Should be safe	Should be safe	Don't try it	Should be safe	May or may not work	May or may not work	Should be safe	Should be safe	May or may not work	Should be safe	May or may not work	Don't try it	Should be safe
Autophoretic Paint Process	Should be safe	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	Should be safe	Should be safe	May or may not work
Corrosion	Should be safe	Should be safe	May or may not work	Should be safe	May or may not work	May or may not work	Should be safe	Should be safe	May or may not work	May or may not work	Should be safe	May or may not work	Should be safe
Dropping Point	Should be safe	Should be safe	Should be safe	Should be safe	Should be safe	Don't try it	Should be safe	Should be safe	May or may not work	Should be safe	Should be safe	Should be safe	May or may not work
Fretting	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work	Should be safe	Should be safe	May or may not work	May or may not work	May or may not work	May or may not work	May or may not work
Low Friction	Should be safe	May or may not work	Don't try it	May or may not work	Don't try it	May or may not work	May or may not work	Don't try it	May or may not work	May or may not work	May or may not work	Should be safe	May or may not work
Salt Water	Should be safe	May or may not work	Should be safe	May or may not work	May or may not work	Don't try it	May or may not work	Should be safe	Don't try it	May or may not work	May or may not work	Should be safe	May or may not work
Water	Should be safe	Should be safe	Should be safe	Should be safe	Don't try it	Should be safe	Should be safe	May or may not work	May or may not work	Should be safe	Should be safe	Should be safe	Don't try it
Wear	Should be safe	Should be safe	Don't try it	Should be safe	May or may not work	Should be safe	Should be safe	Should be safe	Should be safe	Should be safe	Should be safe	Should be safe	Should be safe
Worked Stability	Should be safe	Should be safe	May or may not work	Should be safe	May or may not work	May or may not work	May or may not work	Should be safe	Should be safe	Should be safe	May or may not work	Should be safe	May or may not work

● Should be safe ● May or may not work ● Don't try it

Crib Notes on Thickeners

Few compatibility issues between thickeners and plastics…but make sure thickener is compatible with the oil.

- Some thickeners offer special benefits depending on the operating environment, e.g.:
  - Polyurea provides excellent resistance to water and boosts high temperature performance.
  - Calcium Sulfonate boosts corrosion protection and reduces fretting.
  - PTFE lowers friction and resists chemicals.
  - Silica is water- and chemical-resistant, excellent at high temperatures, and barely visible on exposed parts, like sunroof tracks.

Choose the right viscosity for the oil for plastic parts

Kinematic Viscosity
(cSt. @ 25)

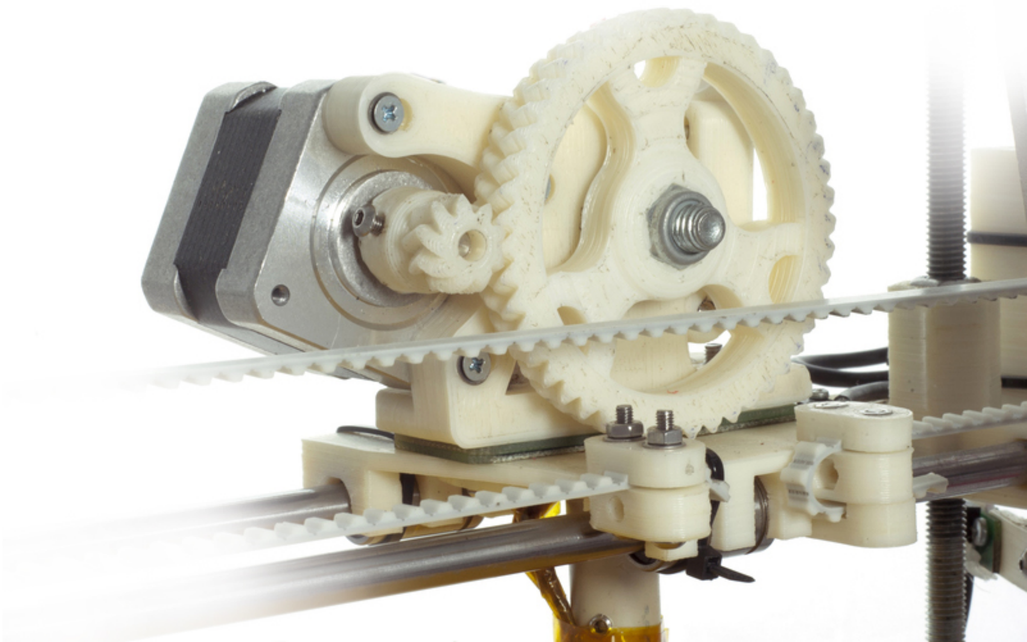



Hot Fudge	20,000
Molasses	10,000
Karo® Syrup	5,000
Honey	2,000
SAE 60 Motor Oil	1,000
SAE 30 Motor Oil	500
SAR 10 Motor Oil	100
Vegetable Oil	50
Water	1

KV is the consistency of a fluid at room temperature, where water is 1 cSt. You'll usually find KV values on a lubricant data sheet.

Light or Heavy?

- Oils with a kinematic viscosity of 100 centistokes at 25°C (the consistency of SAE 10 motor oil) or higher are less likely to penetrate, crack, or craze plastic.
- Lighter loads require lower-viscosity oils to prevent viscous drag. Heavier loads require higher-viscosity oils to maintain a lubricant film from start to stop.



Using additives in greases for plastic parts

Commonly Used Grease Additives

Antioxidants

Antiwear/Anti-scuffing additives

Anti-weld/Solid lubricant additives

Dyes

Extreme pressure additives

Friction reducers

Rust and corrosion inhibitors

Tackifiers/polymers

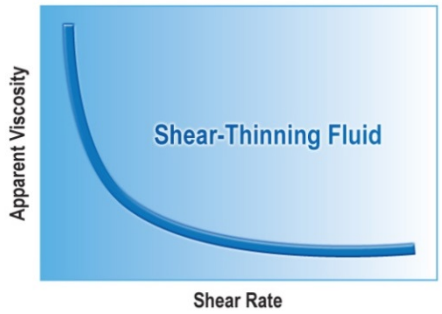
VI improvers

Crib Notes on Additives

- PTFE is safe with all plastics. They're especially good at reducing friction on start-up.
- MoS_2 and graphite require testing. Either additive may penetrate and weaken plastic.
- Extreme Pressure (EP) and anti-corrosion additives, often used for metal-on-metal, aren't needed in greases formulated for plastic parts.

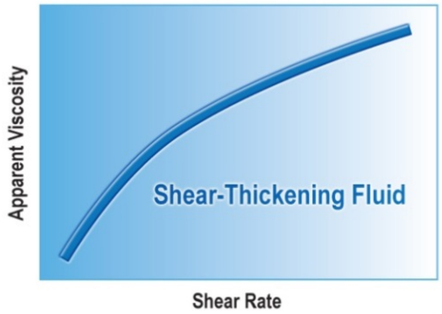
Check Apparent Viscosity of the grease for shearability at high and low temperatures

Thixotropic Grease: Shear-Thinning
Viscosity Decreases with Shear



The viscosity of a grease changes when sheared.
Apparent Viscosity, reported in centipoise,
gives a design engineer an indication of the "shear quality" of a grease at specific temperatures.
(Water is about 1 cP. Wood putty is about 1 million cP.)

Dilatant Grease: Shear-Thickening
Viscosity Increases with Shear

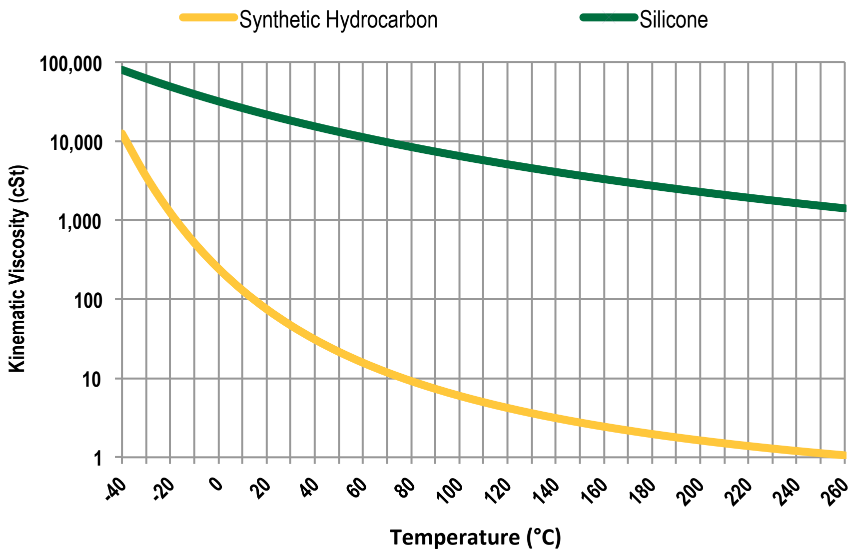


Apparent vs. Kinematic Viscosity

- **Kinematic Viscosity** is a characteristic of the base oil. The viscosity of oil may change with temperature or compression but, typically, ***is not affected*** by shear.
- **Apparent Viscosity** is a characteristic of the grease. The viscosity of grease ***is affected*** by shear. It will become thinner – or thicker.
- **Thixotropic greases** become less viscous when sheared, like butter stirred at room temperature.
- **Dilatant greases** become more viscous when sheared, like water and flour stirred at room temperature.

Apparent Viscosity as a Design Tool

Viscosity vs. Temperature



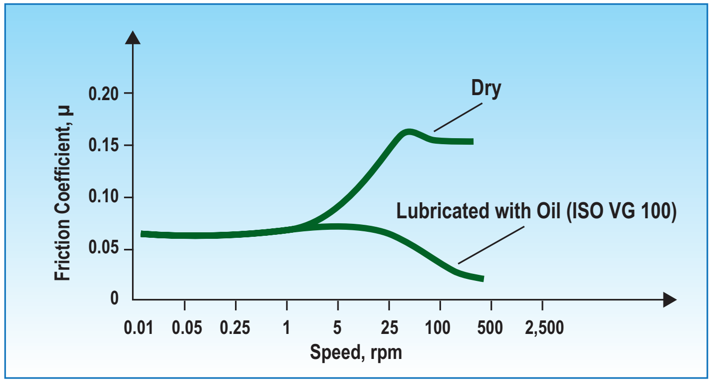
A Note on Viscosity Index (VI)
High VI indicates less viscosity change with temperature, as in the silicone plot above. Low VI indicates large viscosity change as in the SHC plot above.

Check the Viscosity Index

- The viscosity of an oil gets thicker at low temperatures and thinner at higher temperatures.
- Viscosity Index (VI) is a dimensionless number indicating how much viscosity changes from –40°C to 100°C.
- Higher VI means less change with temperature and more consistent part performance over wide temperature ranges. VI can be found on most data sheets.
- Knowing the speed, load, operating temperature range of the part, and the grease's viscosity profile makes it easier to specify the viscosity and Viscosity Index needed for a mechanical system to operate reliably.
- Knowing a grease's viscosity also helps in evaluating its pumpability, pourability, ease of handling, and suitability for dipping or coating operations — important production and assembly considerations.

Lubricating plastic gears and bearings, even "no-lube" plastics, boosts part performance and life

Lubricating Internally Lubricated Plastics



Lubrication reduces friction between a PTFE sleeve bearing and a steel shaft.

Even lightly loaded, low speed components with "no lube" plastic (i.e., plastic internally lubricated with an oil or solid lubricant) will last longer and run more quietly with an "external" lubricant than without one, as seen in the graph above. Consider life and performance requirements.

Source: Machine Design

Oil or Grease?

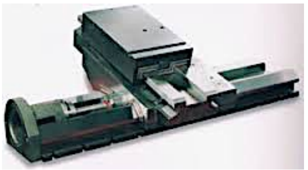
- Light oils have been the norm, especially in small, low-torque, low-horsepower plastic gearboxes and bearings. Oil requires proper sealing and oil/seal material compatibility. Leakage is a persistent concern.
- Soft, thixotropic, even pourable greases are now replacing oils in low-torque plastic gearboxes and bearings. They flow like oil during operation and then slump into the gear teeth mesh or bearing races after operation, resuming their original gel-like consistency and serving double-duty as sealants.
- Adding tackifiers improves the ability of grease to adhere to plastic without impairing flow.
- **Production Caution:** There is no guarantee that a grease formulated for virgin plastic will also work with regrind plastic. More likely than not, it won't.

"No Lube" and Glass-filled Plastic

- Don't add PTFE to the grease if plastic is infused with PTFE. Together, they increase friction.
- For glass-filled nylon, choose a higher-viscosity oil to ensure lubricating film is not affected if wear exposes abrasive fiberglass.

Plastic slides? Watch out for Stick-Slip

Stick-Slip is a spontaneous jerking motion that can occur while two objects are sliding over each other. Stick-Slip not only increases wear; it's often noisy, which impacts the perceived quality of the part.



Design Note
Lubricants don't work very well when placed between two ultra-smooth, polished surfaces.

Everyday examples of Stick-Slip you've probably heard

- Jerky motion of windshield wipers.
- Loose drive belts.
- Music from bowed instruments or a "glass harp."

Parts Typically Subject to Stick-Slip

- Precision-motion or other components where a part needs to slide smoothly and noiselessly on a slideway.
- Stick-Slip occurs when static friction (the "stick phase") is greater than kinetic friction (the "slip phase").

Stick-Slip Solutions

- Increase the viscosity of the base oil.
- Oil additives can improve oil lubricity.
- Solid lubricants may help to reduce intermittent static-friction build-up and the accelerated wear and noise it causes.

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