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Quick-Study for Product Design Engineers

Choosing a Grease for Your Design

Choosing a Grease for Your Design

Quick Overview

The grease you choose for your design plays a key role in ensuring that your part performs the way you want it to during durability testing and for lifetime service in the marketplace.

This Quick-Study explores major factors involved in selecting a grease that's formulated to match the load, speed, operating temperatures, available power, and materials of construction specified in your design.

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%)

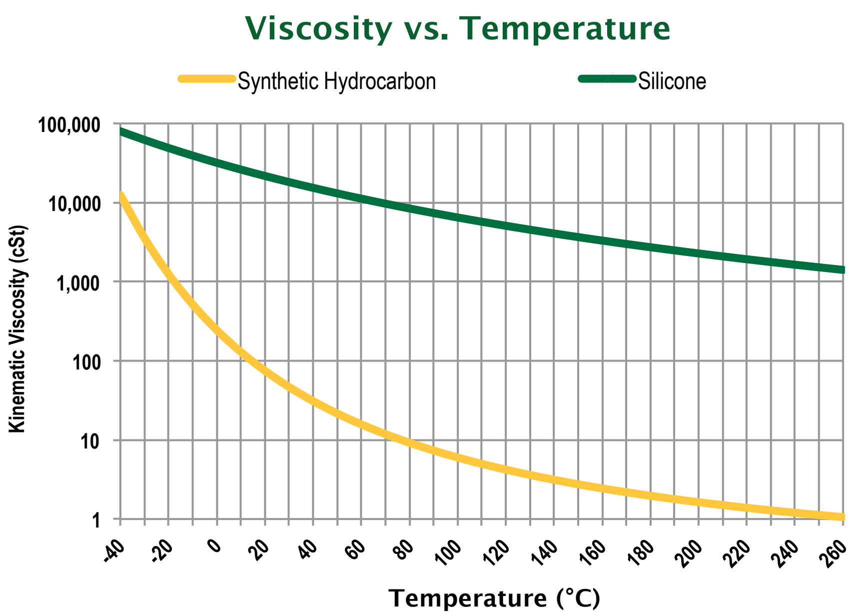
Oils Lubricate. They form a protective film between two surfaces to prevent friction and wear.

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.

First Step: *Choosing the Oil and Its Viscosity*



A Note on Viscosity Index (VI)
The viscosity of an oil gets thicker at low temperatures and thinner at higher temperatures. Viscosity Index indicates how much viscosity changes from –40°C to 100°C. High VI indicates small viscosity change, as in the silicone plot above. Low VI indicates large viscosity change with temperature. High VI ensures more consistent part performance over wide temperature ranges.

Temperature

- Heat generated by a moving part and the ambient operating temperature determine the type of oil you need in your grease. Choose a synthetic oil for temperatures below –30°C and higher than 100°C.
- Temperature changes the viscosity of the oil. The right viscosity ensures the oil does not get too thin to prevent wear at high temperatures or too thick to lubricate properly at low temperatures.

Viscosity and Load

- Heavier loads require higher viscosity oils to form a continuous lubricating film between two surfaces.
- Lubricity additives and solid lubricants can enhance the natural viscosity of the oil and component performance.

Viscosity, Speed, and Power

- High-speed and low-power devices require lighter viscosity oils to reduce drag while still providing the lubricant film needed for lifetime wear protection.

Lubricating Oils: *Capabilities and Costs*

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

Operating Temperature Determines Cost of Base Oil

- As temperature ranges of the base oil expand, cost increases. Don’t “buy” more than you need “as a buffer.” Oil temperature ranges can be considered accurate during the design phase.
- Each additional ingredient (thickener, additives, and solid lubricants) also impacts the cost of the finished grease.

Consider oil blends to increase temperature performance at lower costs

- Mineral oil can be blended with PAOs and esters, but not with other oils.
- Esters and PAGs ***are*** compatible.
- Silicones and PFPEs ***are not*** compatible with other oils.

Check oil compatibility with plastics

A Guide to Oil-Plastic Compatibility

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

● (Green) Should be safe ● (Yellow) May or may not work ● (Red) Don't try it

Some oils and plastics don't mix

- PAO is safe with nearly all plastics, but they may or may not work with PPE, PP, or PVC.
- Silicone and PFPE are safe with any plastic.
- PAGs and esters don't mix with polycarbonates, polyphenylene oxides and sulfides, polysulfones, polypropylene, and polyvinyl chlorides.

Check oil compatibility with elastomers

A Guide to Oil-Elastomer Compatibility

Elastomer		Mineral	PAO	Ester	PAG	Silicone	PFPE
Polyacrylate Rubber	ACM	🟢	🟢	🟡	🟡	🟢	🟢
Vamac	AEM	🟢	🟢	🟡	🟡	🟢	🟢
Polychloroprene	CR	🟢	🟢	🔴	🔴	🟢	🟢
Ethylene Propylene Diene Monomer	EPDM	🔴	🔴	🟡	🟢	🟢	🟢
Fluoroelastomers	FKM	🟢	🟢	🟢	🟢	🟢	🟢
FluoroSilicone Rubber	FVMQ	🟡	🟡	🟡	🟢	🔴	🟢
Hydrogenated NBR	HNBR	🟢	🟢	🟡	🟡	🟢	🟢
Butyl	IIR	🔴	🔴	🔴	🔴	🟢	🟢
Nitrile (Buna N)	NBR	🟢	🟢	🟡	🟡	🟢	🟢
Buna S	SBR	🔴	🔴	🔴	🔴	🟢	🟢
Silicone	VQM	🟡	🟡	🟡	🟢	🔴	🟢
Natural Rubber		🔴	🔴	🔴	🔴	🟢	🟢

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

Some oils and elastomers don't mix

- Silicone is safe with all elastomers, except fluorosilicone rubber.
- PAO is safe with most elastomers, except EPDM, Butyl, Buna S, and Natural Rubber.
- PFPE oils are safe with all elastomers.

Step 2: *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

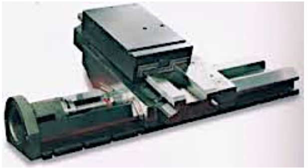
- Aluminum <80°C.
- Barium Complex and Lithium <135°C.
- Aluminum Complex, Calcium Complex, Calcium Sulfonate, and Lithium Complex <175°C.
- Extreme-temp thickeners include Polyurea (<200°C), PTFE (<275°C), and Amorphous Silica (<300°C).

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.*

The Stick-Slip Phenomenon

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 perceived quality of the part.



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

Every day 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

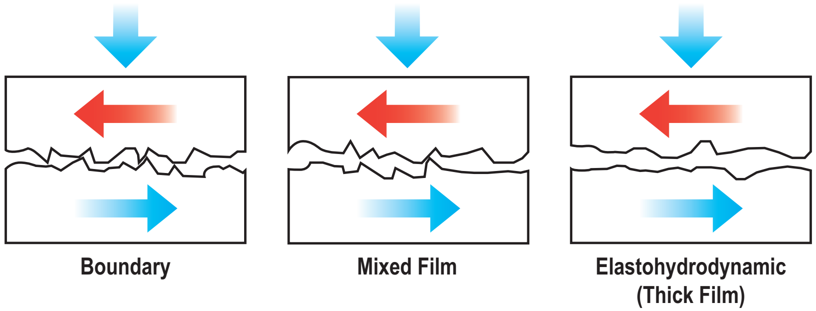
- Hydraulic cylinders, lathes, and other components where something needs to slide smoothly and noiselessly on a slideway.
- Stick-Slip occurs when static friction ("stick phase") is greater than kinetic friction ("slip phase").

Stick-Slip Solutions

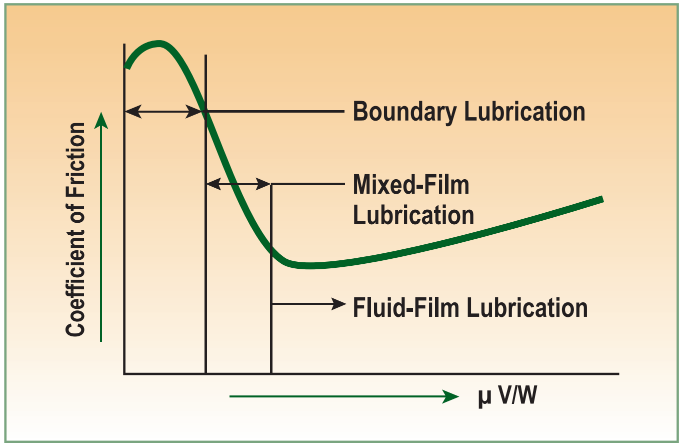
- Increase the viscosity of the base oil.
- Oil additives can improve oil lubricity.
- Solid lubricants may help to reduce intermittent static friction build-up and the accelerated wear and noise it causes.

Frequent Start-Stop Components

Lubrication Regimes
(Type of Lubrication from Start to Stop)



Representation of Stribeck Curve
(Correlation of Friction Losses to the 3 Regimes)



How Greases Work

- Load and speed release oil from the thickener, which creates a fluid film to reduce friction between two surfaces.

3 Phases of Lubrication from Start to Stop

- **Boundary:** Two surfaces mostly in contact, even though an oil is present.
- **Mixed:** Two surfaces partly separated by oil.
- **EHD:** Two surfaces separated by a thin fluid film.
- Note: The thickness of the fluid film determines the lubrication regime.

Focus on Additives for Boundary Regime

- Friction and wear is highest at start-up, when oil does not completely separate two surfaces.
- Extreme pressure additives fortify the oil during boundary lubrication.
- Solid lubricants like MoS_2, graphite, and PTFE added to the thickener provide an additional, non-abrasive "cushion" between two surfaces during start-up in the boundary regime.

Fretting Wear and Fretting Corrosion

Fretting wear is also known as vibrational wear. Because virtually all machines vibrate, fretting is likely to occur:

- In joints that are bolted, pinned, press-fitted, keyed and riveted.
- Between components not intended to move.
- In oscillating splines, couplings, bearings, clutches, spindles and seals.
- In base plates, universal joints and shackles.

"Fretting wear has initiated fatigue cracks, which often result in fatigue failure in shafts and other highly stressed components."

Fretting wear is caused by thermal expansion, contraction, or nearby motion

- Small amplitude vibrations cause the microscopic asperities on "stationary" metal parts to rub against each other and "break off," which produces wear debris that impedes performance.
- Close-fit metal parts are especially susceptible, but fretting is also known to deform plastics.

Fretting corrosion is the oxidation of fretting wear debris

- Fretting wear continually exposes fresh layers of metal surface to oxygen, producing abrasive metal oxides that further accelerate substrate wear.

Lubricants Retard Wear and Corrosion

- Metal deactivator additives help reduce fretting wear, but will not likely stop fretting altogether.
- In most fretting situations, the lubricant acts as an oxygen barrier. It prevents oxygen from reaching the fretting surface, reacting with wear debris, and producing abrasive oxides.

Add some color to the grease?

Four reasons to consider adding color to a grease

- **High Speed Manufacturing.** A UV dye enables in-line quality inspection with IR vision systems.
- **Manual Assembly.** Grease with color aids visual inspection by line workers.
- **Color-coding.** Colors help to ensure the right grease is chosen from inventory.
- **Market Perception.** Color doesn't matter with sealed components, but if the grease is exposed, its color may influence buyer perception.

3 ways to change the color of a grease

- **Dyes.** For your choice of color, use a dye. There are a rainbow of colors! Dyes rarely affect grease performance.
- **Additives.** Some oil additives add color to a grease, though it's not their primary function. Make sure the color change doesn't have a negative impact on market perception.
- **Solid Lubricants.** Like oil additives, solid lubricants like MoS_2 or graphite blackens the grease. PTFE will lighten the color of a grease.

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