Getting a Grip on Gearbox Friction

It is well understood that friction is a fact of life. Any mechanical device with components in relative motion must cope with both the beneficial and detrimental aspects of friction in all of its forms. With regard to gearboxes, four specific types of friction must be accounted for in order to understand their potential impact on gearbox efficiency. These include friction that stems from the meshing of gear sets, bearing friction, seal friction and viscous friction, which occurs due to lubricant action. Knowing the relative impact of these friction variables–in addition to understanding no-load torque and thermal considerations–will help you select the most efficient gearbox for your next application.

Four kinds of gearbox friction.

Friction values and their relative weights will vary depending on the specific style of gearbox selected. For planetary gearboxes with involute, zero helix angle gears, *gear mesh friction* is the smallest portion of overall gearbox friction. *Rolling bearing friction* that results from the motion of planet gear bearings as well as input and output bearings is the second largest friction variable. *Seal friction* is next: Input and output bearing seals and shaft seals can contribute significantly to the overall friction load. Seals are essential to keeping lubrication in and contamination out, but can add to the friction load. Static seals have no impact on efficiency, but dynamic seals that contact rotating parts such as the shaft generate friction and heat, resulting in efficiency losses.

It is important to recognize that these first three types of friction are only minimally dependent on the revolutions per minute (rpm). However, the fourth type of friction–that which results from the churning and mixing of lubricant–greatly depends on rpm speed. At very low rotation, *viscous friction* is almost negligible. Once the gearbox begins to turn, viscous friction increases significantly as rpm speeds up. For example, at a typical input of 200 rpm, viscous friction is the largest contributor to overall friction.

Methods to minimize gearbox friction.

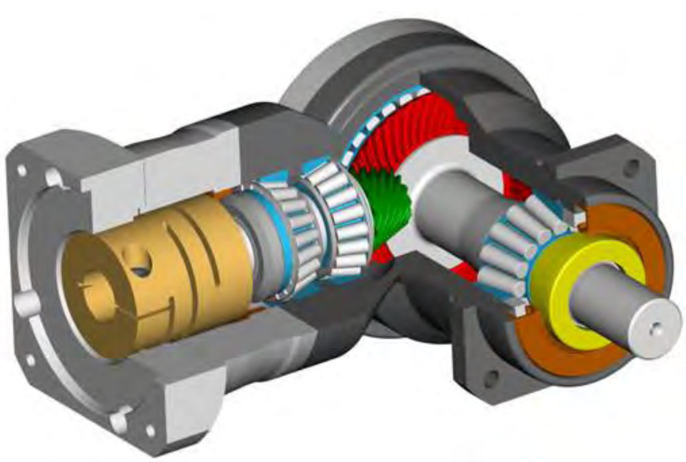
Several strategies exist to minimize gearbox friction. For example, removing some of the seals will likewise remove the friction generated by these bearing seals and/or shaft seals. However, this approach will increase the probability of leakage, which can lead to other problems including gearbox damage and failure. Another method of reducing friction is to use a smaller quantity of lubricant and/or a lower viscosity (thinner) lubricant to reduce the viscous friction that is generated. However, using insufficient lubricant can shorten the gear life due to increased tooth wear. Well designed gearboxes are constructed with all of these factors in mind, achieving the correct balance between acceptable friction levels and gearbox longevity.

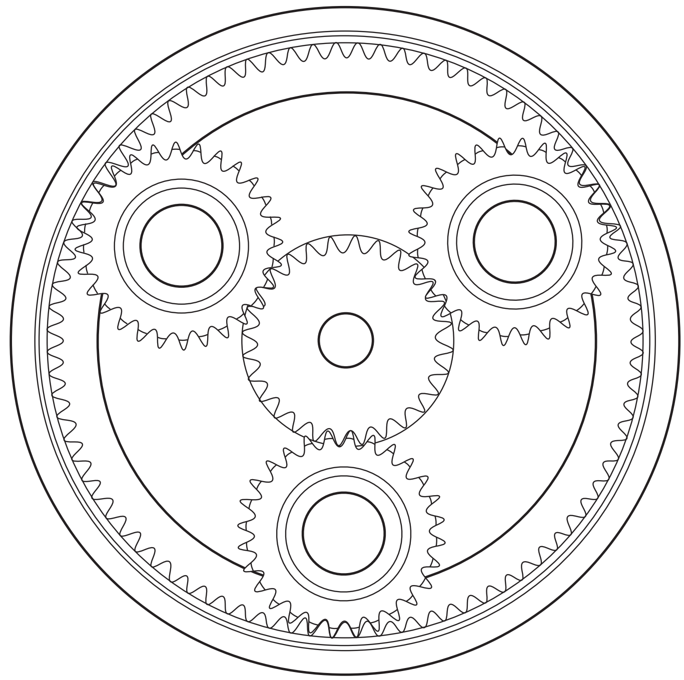
No-load torque values.

When it comes to calculating overall gearbox efficiency, it is important to understand that no-load friction torque is highly dependent on rpm speed. This is because in certain applications, the starting torque–or *breakaway torque at the input*–can have a noticeable impact on overall efficiency values. Be sure to ask your gearbox supplier about these breakaway torque values, which are often stated as Nm values in specification documents. For example, Neugart supplies values for both breakaway torque at the input as well as *back driving torque at the output* shaft. At zero rpm, these values are negligible for churning losses. However, when rpm speed begins to increase as gearbox motion begins, the adhesive force of the cold lubricant grease must be overcome and breakaway torque values will begin to increase accordingly.

Understanding thermal limits.

Friction is responsible for generating heat within the gearbox. If friction is independent of rpm, the generated heat will be proportional to the speed. However, this is not the case. Because a large portion of the overall friction is viscous friction and depends on the rpm, heat generation will increase exponentially with rpm.





Load distribution over several meshing areas.

Gearbox operating temperature must be carefully monitored and controlled in order to avoid damage and premature failure. Excessive temperatures can lead to seal damage, lubricant thinning and reduced component lifetimes. Gearbox manufacturers should provide recommended maximum operating temperatures in their specification sheets. For example, Neugart's *recommended maximum gearbox operating temperature* is 90°C. Closely related to this value is the rpm at which the recommended maximum operating gearbox temperature sets in, which can be determined by tests. Neugart refers to this value as *maximum recommended input rpm* for a defined ambient condition, which includes ambient temperature, airflow around the gearbox, and other environmental conditions. A related value, the *listed maximum peak rpm*, is only allowable for a very short time to avoid damage to the gearbox.

Efficiency calculations.

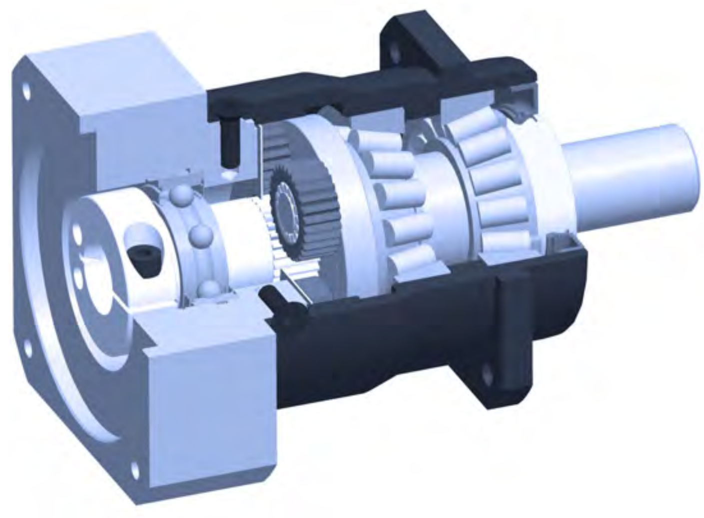
Simply stated, friction-torque × rpm is equivalent to the energy losses of the running gearbox. Therefore, friction losses determine gearbox efficiency. One frequent misconception is to assume that gearbox efficiency is a constant value. This is not true. Because friction losses are not constant, but instead vary depending on operating conditions (such as rpm load) and ambient conditions (such as temperature and humidity), efficiency fluctuates as well.

Note the definition of efficiency and its correct physical interpretation:

- Efficiency = energy output from the gearbox/ energy input into the gearbox
- Efficiency = (energy input into the gearbox – gearbox energy losses)/energy input into the gearbox
- Efficiency = 1 – gearbox energy losses/energy input into the gearbox

From the above definitions, it follows that:

1. If the gearbox is running without load (no useful energy output):
   Energy input into the gearbox = gearbox energy losses --> efficiency = 0
2. With increasing load, efficiency increases to a nominal operating point (described mainly by load and rpm). The efficiency value at this "nominal point" is defined by the manufacturer as *nominal efficiency*.
3. Gearbox efficiency is dependent on both load and rpm.



Technical assistance and advice.

Friction is an extremely complex topic involving many variables. However, specifying the most efficient gearbox for the intended application is not rocket science. With a grasp of application details and a basic understanding of how the four main types of friction affect gearbox efficiency and performance, the task of choosing a suitable gearbox is manageable. For more specific technical advice, contact your system integrator, a knowledgeable distributor or a reputable gearbox manufacturer. The engineering team at Neugart is ready to assist at any time.

For more information on Neugart gearboxes, visit **www.neugartusa.com**