Worm Gears—Higher Energy Efficiency and Less Strain on Resources

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Introduction

The concepts of sustainability and energy efficiency are gaining importance in power transmission engineering. More than ever, manufacturers are looking for ways to reduce raw material consumption and attain a lower energy consumption and hence a better CO_2 balance. This can be done by making machines more efficient, extending the lifetime of components as well as maintenance intervals. The added benefit of such measures is a reduction of operating costs.

Gear Lubricants

The increase of gear efficiency harbors a frequently overlooked potential for increasing the efficiency of a machine as a whole. A very direct and effective way of increasing power transmission efficiency—which goes along with excellent wear protection—is a changeover from mineral-oil-based to synthetic lubricants. Synthetic lubricants based on polyalphaolefin, ester or polyglycol oils, for example, have proven to reduce energy costs and in addition extend the service life of gears. The possible extent of efficiency increase, however, depends on the type of gears: while gears featuring a low percentage of sliding friction, such as spur or bevel gears, offer a relatively low potential, gears with a high percentage of sliding friction enable considerable improvements.

A particularly positive effect can be noted when worm gears are switched over to polyglycol oil: their efficiency has been increased by up to 35 percent. In addition, their lifetime can be extended tenfold. A conversion to synthetic oils offers an enormous potential for savings especially in facilities where a large number of gears are operated—for example in logistics centers, filling stations, breweries or airports. The example in the sidebar illustrates how several million euros can be saved at a large airport.

Tribological factors are decisive in attaining the maximum performance of a machine and its components. When choosing a lubricant for a gearbox or machine, therefore, design engineers should be aware of the characteristics of the various types of lubricants and know how to use them. While, as a rule, synthetic special lubricants tend to be more expensive than mineral oils in terms of the sales price, they pay off after a short time when taking into account efficiency, oil change intervals, oil consumption and the longer lifetime of lubricated components. With such lubricants, gear manufacturers offer their customers the added benefit of lower operating costs.

Tested and Proven

Applied to the effect a lubricant provides in worm gears, the aspects of sustainability and energy efficiency can be translated into the wear behavior and the efficiency of a gearbox. Reduced wear means longer service life of components, which has a consequential effect on the exploitation of resources as less raw material is required to make new components to replace the old ones. Higher gear efficiency has a direct effect on the amount of energy consumed.

On a worm gear test rig developed by Klüber Lubrication specifically for the purpose, the influence gear oils have on the wear and efficiency behavior in heavily loaded worm gears is examined under real-life conditions. Both the speed and the torque of the worm can be measured on this test rig. This is correlated to the worm wheel output torque to calculate the total efficiency of the gear unit. Wear on the worm wheel is measured by determining the weight loss and the abrasion of the tooth flanks occurring during operation. Various temperature values are also measured in the standard version of this test, namely oil sump temperature, mass temperature of the worm shaft, casing temperature and ambient temperature.

Minimizing Wear

A hint that polyglycol oils offer the best wear protection to worm gears is already included in DIN 3996 on the design of cylindrical worm gears. They can help to extend the lifetime of a worm gearbox significantly compared with a mineral oil. The examination of the wear behavior of various polyglycol gear oils made by Klüber Lubrication performed on Klüber's worm gear test rig shows that with these high-performance gear oils wear is even lower than what DIN 3996 stipulates that gear designers should assume for gears lubricated with polyglycol products.

Figure 1 shows that the use of a high-performance polyglycol oil made by Klüber Lubrication rather than a standard polyglycol oil enables an even more significant reduction of wear. Consequently, the worm wheel survives longer with the same load, or the output torque can be increased without dimensional changes. Additional benefits for machine operators are cost savings due to longer maintenance intervals, a lower risk of equipment failure and minimized downtime.

Maximum Efficiency

Maximum energy efficiency of a gear unit means that it produces the highest possible output power for a given input power. The energy lost in the process manifests itself in the form of heat, for example in bearings, O-ring seals or gear wheels. As gear efficiency increases, its temperature will go down. This has a number of positive effects: a decreasing temperature not only extends the oil life, but the service life of seals as well. This in turn reduces the risk of leakage. Another benefit is that fans or air conditioners in production facilities might be switched off, which is another contributor to lower energy costs and a better CO_2 balance (Fig. 2).

According to DIN 3996, the efficiency of gears in mesh is influenced by, among other factors, the oil's basic friction

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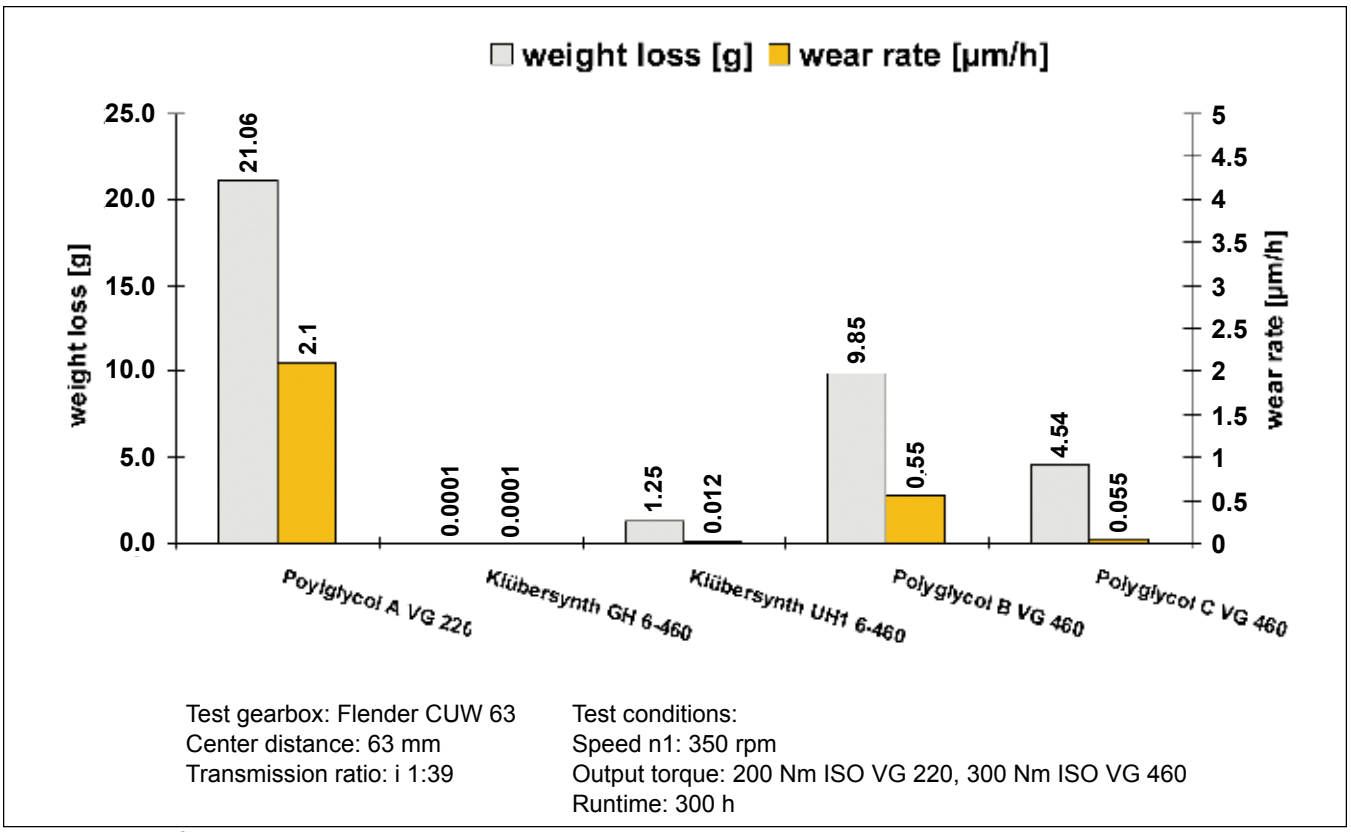

Test gearbox: Flender CUW 63
Center distance: 63 mm
Transmission ratio: i 1:39

Test conditions:
Speed n1: 350 rpm
Output torque: 200 Nm ISO VG 220, 300 Nm ISO VG 460
Runtime: 300 h

Fig. 1—Tests performed on Klüber Lubrication worm gear test rig: weight loss and wear rates measured.

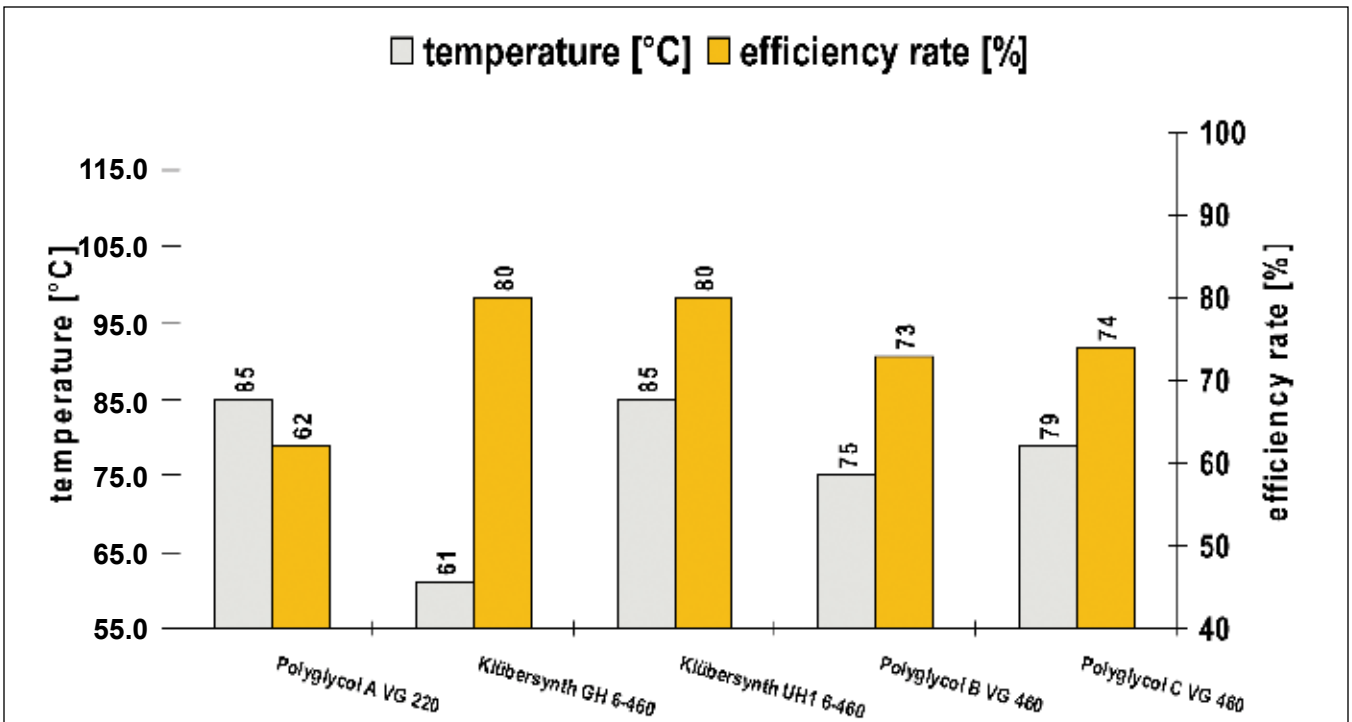

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Fig. 2—Tests performed on Klüber Lubrication worm gear test rig: temperatures and efficiency rates measured.

Airports Offer Enormous Potential for Savings

A large airport may utilize more than 20,000 gear units, for example in conveyor belts and escalators. Approximately 15,000 of them may be spur- and bevel gears with a mean power of 5 kW, and another 5,000 worm gears with a mean power of 15 kW. With some 4,000 operating hours a year and a utilization rate of 40 percent, total power consumption is at approximately 240 GWh. Replacing a mineral oil with a polyglycol special oil will increase the efficiency of all gears by roughly 5.25 percent on average. The power saved thus totals 12.6 GWh—this is the annual power consumption of approx. 3,000 private households. 12.6 GWh equals 12,600 MWh. Based on Germany's average mix of energy sources encompassing fossil fuels, nuclear power and renewables, that's equivalent to the emission of more than

8,500 tons of CO_2*. Based on an energy price of 9.5 cents per kWh, more than a million Euros can be saved this way.

* Source: CARMA (*www.carma.org*), 2008

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coefficient. Consequently, oils with a low friction coefficient offer potential for increasing gear efficiency. Similar to their wear characteristics, polyglycol oils show a lower friction coefficient than other base oils. Suitable additives can help to further improve the friction coefficient of a polyglycol. Diagram X shows a comparison of various polyglycol oils. The basic friction coefficients determined for Klübersynth GH 6 and Klübersynth UH1 6 are clearly below the figures to be assumed for polyglycol oils according to DIN 3996 (Fig. 3).

The described effects of higher efficiency make themselves strongly felt in the energy balance of facilities operating several hundred gearboxes. This is shown in detail in the example of a large airport (see sidebar).

Conclusion

The changeover from mineral-oil-based to synthetic gear oils is a simple and highly effective way of minimizing wear and improving energy efficiency. The extent of optimization possible depends on the individual gear type. Best results are obtained where polyglycol oils are used in worm gears. Additional potential for improvement is offered by polyglycol oils based on special formulations and containing specific additives. Such lubricants enable even longer gear and machine life as well as a lower energy consumption for a given output power.

The result is savings both in terms of financial resources and raw materials. Besides these savings, operators enjoy the benefit of a much better CO_2 balance in their operations.

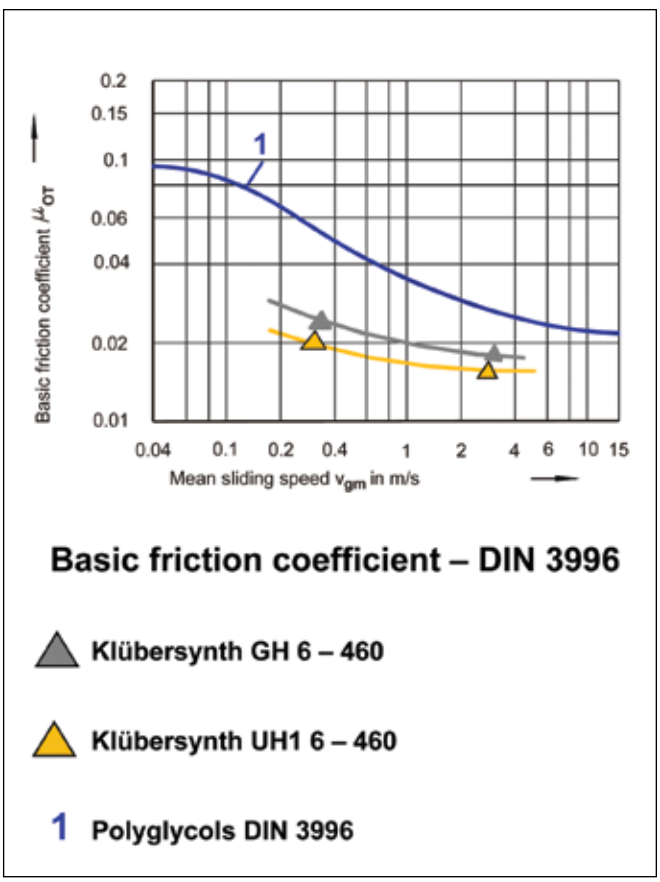

Fig. 3—A low basic friction constitutes a design advantage in worm gears.