

Producing to plan

Special lubricants for machine tools contribute to achieving higher productivity and a reduction in life cycle costs

Empirical studies prove that 70 to 85 per cent of the expected life cycle costs of a machine are determined during its development stage. Synthetic lubricants constitute a valuable contribution in the quest to minimize these costs, as they provide extended re-lubrication and lubricant change intervals or even lifetime lubrication. At the same time, they contribute to significant increases in performance. The following article covers essential aspects of machine tool lubrication.

Through high operating speeds, modern machine tools are expected to increase overall productivity and reduce cycle times. Machine tool manufacturers and operators not only demand high product and process reliability as well as availability, they also assign more and more importance to a dynamic, overall cost analysis. Concepts such as LCC (Life Cycle Costing) or TCO (Total Cost of Ownership) do not only consider the purchasing costs of a machine, but also take into account all the costs incurred during the entire envisaged life time of a machine.

These include, for example, expenditure for maintenance and service, spare parts, compressed air, energy, lubricants and tools, but also potential follow-up costs which might arise through the operation and disposal of a machine. These economic factors are increasingly accompanied by ecological demands aimed at reducing the potential environmental hazards posed by machine tools to a minimum. Last but not least, worldwide availability and effective service and support through well-trained staff on site or through remote maintenance are generally expected.

The majority of the total costs are determined in the development stage

Empirical studies prove that around 70 to 85 per cent of the total costs to be expected later are already determined during the development stage of a machine.¹⁾ In this context, lubricants, whose importance is often underestimated, also become a focal point of interest, as it has been shown that in many instances special synthetic lubricants provide extended relubrication and lubricant change intervals or even lifetime lubrication whilst increasing performance of production machinery at the same time. Klüber Lubrication, a global player in the lubricant sector, offers a wide range of high-quality, high-performance special lubricants for the lubrication of machine tools to fulfil the afore-mentioned extensive requirements. Klüber

products are developed in close cooperation with OEMs (manufacturers of machine tools, spindles and rolling bearings), who recommend and use these lubricants themselves.

In the following, we shall look at selected areas of machine tool lubrication which are essential in mastering even the most critical operating conditions: Machine tool spindles, clamping systems and assembly aids, as well as milling head gearboxes. Other topics which are not dealt with here, such as the lubrication of industrial gearboxes, corrosion protection or the entire subject of “linear motion” are explained in detail in the relevant brochures available from Klüber Lubrication. For any questions regarding material selection, the author would like to refer you to VDI Guideline 3035 "Design of machine tools, production lines and peripheral equipment for the use of metal working fluids" (draft January 2007).

Lubrication of machine tool spindles

In practice, machining time per work piece is decreasing, thus increasing cutting capacity, usually due to higher running speeds of the main machine tool spindle, whilst cutting depth and feed motion remain the same. High speed factors and the simultaneous accommodation of radial and axial loads are typical requirements made on the rolling bearings used in high-speed spindles. Angular contact ball bearings with pressure angles of 15 to 25° prevail in this segment. Apart from the standard material combination steel/steel, hybrid bearings made of ceramics and steel are increasingly used in this field. The bearings are usually unsealed and can be lubricated with oil or grease.

If oil lubrication is desired, immersion, drip-feed or oil mist lubrication may be used, although none of these methods are state of the art. In the rare cases where oil lubrication is encountered today, higher speeds can be obtained by using oil injection or minimum quantity lubrication. With oil minimum quantity lubrication, optimum results are obtained using a synthetic oil of ISO VG 68.²⁾

Another oil lubrication method is oil spot lubrication, whose major disadvantage is the cost for compressed air provision.

In the grease lubrication of high-speed rolling bearings, greases consisting of a low-viscosity synthetic oil and a suitable thickener are used. The main advantage of grease lubrication is the simplification of design combined with reliable operation, resulting in increased productivity and reliability. The main requirements made on lubricating greases are:

- Effective corrosion protection to obtain prolonged component service life
- Good adhesion and pressure absorption to provide high wear protection
- High resistance to water and cooling lubricants

Grease distribution in the bearing is an important issue in this context. (If you are interested in further information on this topic, please refer to the Klüber brochure on Rolling Bearing Lubrication.)

Klüber offers a number of products for spindle bearing lubrication, which are also used by the Machine Tool Laboratory (Werkzeugmaschinenlabor – WZL) of the Technical University (RWTH) in Aachen, Germany.

Lubrication of clamping systems and assembly aids

The main task of a lubricant used on a clamping system is to maintain specified and repeatable retention forces over a wide number of clamping cycles. Reduction of the clamping force may cause loosening of the tool or workpiece. In summary, the requirements made on the lubricants applied in machine tools are as follows: They should maintain constant clamping forces in all types of clamping chucks, such as key bar, plane cam and plane spiral chucks, and, at the same time, offer adequate protection from tribocorrosion in frictional and positive connections. Good water and media resistance, for example to coolants, are a further requirement to be met. The Westsächsische Hochschule Zwickau (West Saxonian University of Zwickau, Germany) has tested Klüber products for the lubrication of clamping systems. One of these was ALTEMP Q NB 50, whose clamping force curve is shown in Figure 1 as a function of the clamping cycles. The maximum speed of the clamping jaws in the test was 0.52 m/min.

In principle, these pastes can also be used for the assembly of frictional connections, such as annular spring or adapter sleeve connections, and for positive connections, such as bearing seats or profiled guideways. Screw tightening torque and disassembly, even after prolonged service life, can be optimized by using a suitable lubricating paste. An unstable friction coefficient would drastically affect the preload of torque controlled assembly tools.

The altering tribological behaviour of Klüberpaste ME 31-52 was examined as a function of time and temperature in accordance with VW-TL 52112. The result is illustrated in Figure 2. The friction coefficients of this Klüberpaste, as determined in the “Screw Test”, highlight the excellent tribological performance of this special lubricant.

Lubrication of drilling and milling head gearboxes

The greases used for the lubrication of high-speed gearboxes in milling heads consist of low-viscosity, synthetic oils and a suitable thickener. The actual lubricating effect depends on the consistency of the grease, the viscosity grade of the base oil and the grease’s oil release properties, all of which need to be adapted to the relevant application. The specific

requirements made on lubricating greases for milling head gearboxes correspond to the demands for machine tool spindle bearings as indicated on page XX. Here, too, the advantage of grease lubrication consists in simplified design combined with reliable operation.

Other important issues are the grease distribution and the grease refill, if applicable. The grease distribution run should be carried out in accordance with the procedure explained in the Klüber Rolling Bearing brochure. Depending on the application, the grease fill should be 70 to 90 per cent of the free space. It is important to ensure that grease does not escape through bore holes or other orifices.³⁾

Fluctuating operating conditions, which result, for example, in erratic temperature changes or increased power consumption, may affect both the grease and the component. Such operating conditions may arise, for example, when the gearbox is gradually heating up after a production standstill, which causes alterations between lubrication mechanisms due to grease consistency variations or if the filling level is too high, resulting in a quasi-forced fluid lubrication due to the pumping effect of the gearing.

It is essential that such fluctuating operating conditions are avoided by selecting the correct lubricant and that, depending on the filling level and other factors, the suitable lubricating mechanism is reached:

a) Fluid lubrication

Fluid greases can form a highly viscous grease sump in which the gear wheels are immersed and supplied with grease. Grease which is centrifuged off the flanks flows back into the grease sump from the housing walls. The grease sump is continuously stirred. However, the churning motion causes relatively high power losses. The temperature distribution is well-nigh homogeneous throughout the gearbox due to the consistent contact with the lubricant.

b) Adhesive lubrication

Adhesive greases may adhere to the housing wall after having been flung off the tooth flanks. The gear wheels run dry and are covered only with a very thin grease layer. Hence, the temperature distribution is not homogeneous. Power loss, however, is much lower under these circumstances.

There should be the possibility of quasi-continuous oil release at the tooth meshing, for example through intermittent operation of milling heads allowing a slow backflow of the grease.

This article illustrates the tremendous potential special lubricants offer for optimizing machine tool operation. The function and performance of spindles, milling heads and clamping systems improve dramatically when carefully selected lubricants are applied. These lubricants may contribute considerably to achieving reliable and cost-effective machine tool operation.

Remarks:

¹⁾ VDI Guideline 2884: Purchase, operating and maintenance of production equipment using Life Cycle Costing (LCC), December 2005

²⁾ High-speed Rolling Bearings in Machine Tools, Special print from "Antriebstechnik" 35 (1996), No. 6

³⁾ See also: "Comparative Examination of Gear Lubrication with Universal Greases"; Project F1207 and Report No. 2691 of April 2002, Gear Research Centre (Forschungsstelle für Zahnräder und Getriebebau - FZG) of the Technical University of Munich, Germany

Captions

Figure 1 – Grease/Bearing

Today's special spindle bearing greases can cope with extremely high speeds and, thanks to their consistency, can be used in both horizontally and vertically aligned machine tool spindles.

Figure 2 – Clamping chuck

Power chuck of the Forkardt QLC Series – QLC chucks are equipped with a force-feed circulation system to ensure optimum application of the lubricants.

Figure 3 – Milling head

Grease-lubricated milling head gearboxes achieve extremely high running speeds

Fig. 1

Clamping force as a function of the clamping cycles

Fig. 2

Altering of the tribological behaviour as a function of time and temperature

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