Essential Lubrication Aspects

Higher productivity and reduced machine tool life cycle costs can be achieved by considering total system efficiency, as Kluber Lubrication explains.

By Stefan Müller
Empirical studies prove that 70-85 percent 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 relubrication and lubricant change intervals or even lifetime lubrication. At the same time, they contribute to significant increases in performance. The following article covers the essential aspects of machine tool lubrication.

Through high operating speeds and hence short cycle times, modern machine tools are expected to increase their overall productivity. 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 dynamic, overall cost analysis. Concepts such as LCC (Life Cycle Costing) or TCO (Total Cost of Ownership) not only consider the purchasing costs of a machine, but also take into account all the costs incurred during the entire envisaged lifetime 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, effective service, and support through well-trained staff on site or through remote maintenance are generally expected.

THE DEVELOPMENT STAGE

As mentioned previously, a high proportion of the total costs to be expected later are already determined during the development stage of a machine. 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 while increasing the 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 fulfill the aforementioned 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 discussion we shall look at selected areas of machine tool lubrication that are essential in mastering even the most critical operating conditions: machine tool spindles, clamping systems, and drilling or milling head gearboxes. Other topics that are not dealt with here, such as the lubrication of industrial gearboxes and linear motion guides, are explained in detail in the relevant brochures available from Klüber Lubrication. For any questions regarding material selection, we refer you to VDI Guideline 3035 “Design of machine tools, production lines and peripheral equipment for the use of metal working fluids” (January 2007).

MACHINE TOOL SPINDLES

In practice, cutting capacity is increasing while the machining time per workpiece is decreasing. This is usually due to higher running speeds of the main machine tool spindle, while cutting depth and feed motion remain the same. Rolling bearings used in high-speed spindles are typically required simultaneously to absorb radial and axial loads and to tolerate high speeds with low friction and heat generation. 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 can basically 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. 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 to provide high wear
protection, and high resistance to water and coolant lubricants. Grease distribution in the bearing is an important issue in this context. An optimized grease distribution operation (running-in) can help significantly to increase a bearing’s performance capacity and its speed factor. If you are interested in further information on this topic or on the determination of the grease fill quantity, please refer to the Klüber brochure on rolling bearing lubrication, “The Element that Rolls the Bearing.” Klüber offers a number of products for spindle bearing lubrication, which are for example also used by the Machine Tool Laboratory of the Technical University in Aachen, Germany.

CLAMPING SYSTEMS

The main task of a lubricant used on a clamping system is to maintain specified and repeatable forces over a wide number of clamping cycles. A lubricant intended for clamping systems must be capable of maintaining the required forces even under the most demanding conditions, such as high temperatures, high pressures, and vibrations. It must also be able to penetrate into the fine gaps of the clamping elements to ensure a uniform distribution of the lubricant. Today’s special spindle bearing greases can cope with extremely high speeds and, due to their consistency, can be used in both horizontally and vertically oriented machine tool spindles. For example, the Forkardt QLC Series-QLC chucks are equipped with a force-feed circulation system to ensure optimum application of the lubricant. The main task of a lubricant used on a clamping system is to maintain specified and repeatable forces over a wide number of clamping cycles. A lubricant intended for clamping systems must be capable of maintaining the required forces even under the most demanding conditions, such as high temperatures, high pressures, and vibrations. It must also be able to penetrate into the fine gaps of the clamping elements to ensure a uniform distribution of the lubricant. Today’s special spindle bearing greases can cope with extremely high speeds and, due to their consistency, can be used in both horizontally and vertically oriented machine tool spindles.
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 scroll, cam, and 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 demand. West Saxonian University in 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 fig. 3 as a function of the clamping cycles.

DRILLING AND MILLING HEAD GEARBOXES

Drilling and milling head gears play a major part in the transmission of high torques and forces from the machine tool main spindle to the cutting tool. The spindle drive gears are operated intermittently and run at high peripheral speeds of more than 20 m/s, depending on the application. The greases used for the lubrication of high-speed gearboxes in drilling and 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 drilling and milling head gearboxes correspond to the previously mentioned demands for machine tool spindle bearings, plus high pressure absorption capacity. Here, too, the advantage of grease lubrication enables simplified design combined with reliable operation.

Gears can be lubricated with the same grease as the spindle bearings, since they often operate in close proximity with one another. The use of one product offers additional advantages: there is no risk of the wrong lubricant being used, and incompatibility reactions are avoided.

Other important issues are the grease distribution and the grease refill, if applicable. The grease distribution running-in operation should be carried out in accordance with the procedure explained in the Klüber 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 in erratic temperature changes or increased power consumption, for example—may affect both the grease and the component. Such operating conditions may arise when the gearbox is warming up after a production standstill, leading to a change in grease consistency and hence the transition to a different lubrication mechanisms, or if the fill level is too high, resulting in 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 correct lubricating mechanism is achieved.

**Fluid lubrication:** fluid greases form a grease sump in which the gear wheels are immersed and supplied with grease. Grease which is flung off the flanks flows back into the grease sump from the housing walls. The grease sump is continuously stirred. However, the churning losses affect the gears’ efficiency. The temperature distribution is almost homogeneous throughout the gearbox due to constant contact with the lubricant.

**Adhesive lubrication:** special greases that are stiffer and show better adhesion may adhere to the housing wall after having been flung off the tooth flanks. As the grease slides off the surfaces very slowly, the tooth flanks are always covered with a sufficient lubricant film. A lubricant channel forms, and therefore power losses are lower than with fluid lubrication. For this type of lubrication, quasi-continuous oil release in the tooth mesh should be ensured, for example through intermittent operation of milling heads allowing a slow backflow of the grease, or "forced back-feed" by means of an external plunger. For high-speed drilling and milling head gears with straight-toothed or helical spur gears, adhesive lubrication has proven a viable lubrication mechanism in real-life applications as well as in tests conducted by FZG [3]. For the lubrication of drilling and milling head gears with a high percentage of sliding friction, such as palloid gears, fluid lubrication has proven most beneficial in practice.

**CONCLUSION**

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

**REFERENCES:**

1) AGMA Standards Collection 2009.
2) AGMAGear Rating Suite, Version 2.2.1, American Gear Manufacturers Association.

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