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Special knowledge

Producing to plan.

Special knowledge for the lubrication of cutting machine tools





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Welcome to the world of top-class mechanical engineering

Machinery manufacture without machine tools?

Inconceivable! Without machine tools you can't manufacture machines in or for other sectors. Also the demands on cutting machine tools as regards production planning are becoming progressively more stringent, so that customers also expect a lot from machine tool lubricants:

- Stability during the manufacturing process – for highest machine availability
- good production performance – also for future safety and environmental requirements and increasing productivity
- high product availability – always and everywhere.

Klüber Lubrication offers a broad spectrum of top-quality, high-performance products for lubricating machine tools. These lubricants have been developed over long decades of collaboration with numerous OEMs, i.e. the manufacturers of machine tools, spindles and rolling bearings, who recommend them, and indeed use them themselves. On numerous test rigs, Klüber puts all products through their paces.

Still, Klüber is much more than a producer of specialty lubricants: our particular strength, in addition to our products, are our specialists, who with their extensive experience develop the products for your applications, monitor the quality and provide soundly professional consultancy and (in-house) service support.

This brochure showcases our corporate capabilities centered around the lubrication of cutting machine tools, for example the lubrication of machine tool spindle bearings, clamping systems, gears in drilling and milling heads and drive and guide systems – subject to the most critical of operating conditions.

Economic thinking - right from the start

Machining speeds are increasing, machining cycles are getting progressively shorter. There is a further commercial aspect: the life cycles of machine tools are becoming shorter and new business models, e.g. leasing or operator business, come into play.

Thus, an overall and dynamic cost perspective including recurring and subsequent costs (LLC: Life Cycle Costing or TCO: Total Cost of Ownership) that takes into account the entire projected service life is of increasing importance – for both the operators and producers of machine tools. This holds true for an economic and for an ecologic point of view.

Specialty lubricants – mostly on synthetic base oils – not only extend relubrication or replacement intervals, but they can also enable lifetime lubrication while upgrading machinery performance. This is a crucial consideration, meriting due attention in the development phase, since empirical studies have shown that in this early phase of a machine's life-cycle 70–85 % of the total costs have already been determined.

Another important aspect when evaluating the economic efficiency is choosing compatible materials and lubricants and intercompatible lubricants for machine construction. Recurring and subsequent costs, e.g. for maintenance and repair, are subject to this choice.

At Klüber, we are happy to help you select the right lubricant for your application.

The lubrication of spindle bearings

The machining times per workpiece are getting progressively shorter, the cutting performance levels ever higher. This is made possible by higher speeds at the main spindles of the machine tools concerned – with simultaneously constant values for cut width and the feed motion.

Specific requirements for rolling bearings in high-speed spindles are:

- high speed rating ($n \cdot d_m$)
- simultaneous absorption of radial and axial forces
- low friction enabling cool running

The preferred option for this application are angular contact ball bearings with pressure angles of 15 to 25°. Besides the material pairing of steel/steel, increasing use is being made of hybrid bearings with the material pairing of ceramic/steel.

Spindle bearings can basically be lubricated with either oil or grease.

Oil lubrication

The following types of oil lubrication are known: immersion lubrication, drip-feed lubrication and oil mist lubrication, but they are no longer so much in use. High speeds can be achieved by using oil injection lubrication/oil cooling lubrication or minimum oil quantity lubrication. For minimum oil quantity lubrication, the ideal choice is a synthetic oil of original viscosity grade ISO VG 68¹⁾. Another option is oil air lubrication, which enables high speeds, but may prove a costly solution with both equipment and compressed air required. It also raises industrial hygiene issues.

Grease lubrication

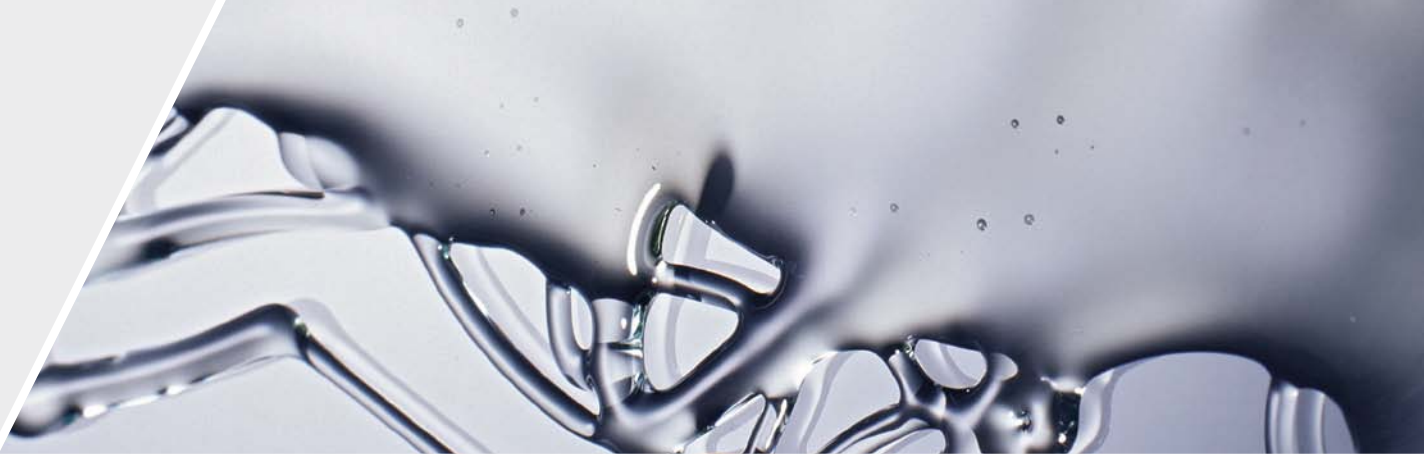
The advantage of grease lubrication is that it enables reliable bearing functions while requiring low construction and assembly efforts for tool spindles. When developing lubricating greases, we at Klüber take increasing speeds into account and test them on our own test bench for spindle bearings. Our greases are of course developed to fulfil lifetime lubrication conditions where possible.

Additional lubricant requirements are:

- effective corrosion protection for long component lifetime.
- good adhesion for high wear resistance.
- high resistance to water and cooling lubricants – particularly for open bearing constructions.

The lubricating greases for high-speed rolling bearings are usually based on low-viscosity synthetic base oils with a variety of different thickeners.

¹⁾ See, for example, "High-speed rolling bearings in machine tools", a reprint from "antriebstechnik" 35 (1996), No. 6



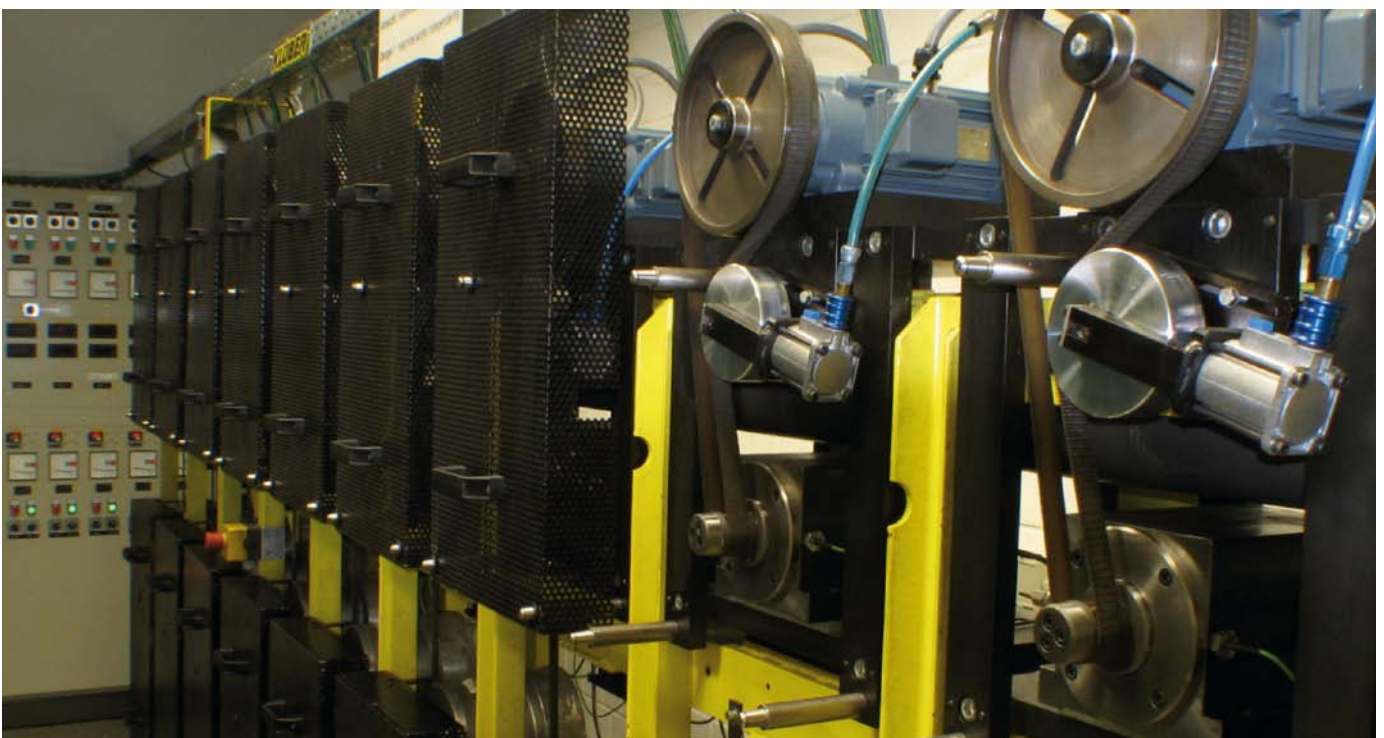
The speed factor ($n \cdot d_m$):

Bearing $n \cdot d_m$ value is determined by the speed of the bearing at standard operating conditions n in $[\text{min}^{-1}]$ multiplied by the mean bearing diameter d_m in $[\text{mm}]$.

The speed factor of a lubricating grease depends largely on its base oil type, viscosity, thickener type, and of course the bearing type used. Under high-speed bearing operating conditions it is important to achieve a constant oil supply at a defined rate within the bearing combined with optimum lubricant adhesion to the bearing surfaces if successful lubrication is to be achieved.

For Klüber Lubrication spindle bearing greases, the maximum speed factors for use in deep groove ball bearings are specified. They should not be lower than the speeds to be expected in a given application.

Please contact Klüber Lubrication for further assistance in this respect.



Test bench for the determination of speed factors in spindle bearings at Klüber Lubrication München KG

Application of grease lubrication

Depending on the bearing type, size and its intended application, initial lubrication can be made at the bearing manufacturer. Rolling bearing manufacturers have developed their own initial lubrication techniques for the application of grease. The chosen technique normally involves a central lubricating system conveying the grease from its original container to the filling station, from where it is applied to the bearing via nozzles.

How much grease does the bearing need?

For lifetime lubrication, the required grease quantities are determined in accordance with the bearing free space.

According to the GFT worksheet 3²⁾ bearing free space can be determined by means of the formula below. Deviating from the GFT worksheet, the formula uses volume units instead of weight units.

This helps to avoid calculation errors due to the different densities of greases

$$V \approx [\pi/4 \times B \times (D^2 - d^2) \times 10^{-9} - G/7800] \text{ m}^3$$

wherein

V = bearing free space

d = bearing bore diameter [mm]

D = outer bearing diameter [mm]

B = bearing width [mm]

G = bearing weight [kg]

Due to different bearing types, cages and designs, the a.m. formula only provides a rough estimation. We therefore recommend to consult the bearing OEM about the exact bearing free space. Once the bearing free space has been determined, the required grease quantity is calculated as a percentage of the available free space. The correct quantity is important to ensure proper lubrication of all contact surfaces.

Overlubrication can be just as detrimental as underlubrication: if overlubricated, bearings can develop higher starting and running torques and high-speed bearings may overheat.

We generally observe:

low operating temperatures = long service life of both the grease and the bearing. The diagram on the next page provides an overview of the required grease quantities as a percentage of bearing free space for various speed factors in [mm x min⁻¹].

In addition to the speed factor, bearing type, environmental factors and grease quantity, compatibility with any elastomer seals and the position of the bearing should also be taken into account.

Running-in

Running-in is particularly required in high-speed precision bearings.

Running-in may also considerably increase the performance of a bearing. Rolling bearing manufacturers have their own empirical values in this respect, which means that their running-in methods may differ.

2) Gesellschaft für Tribologie, worksheet 3, "Wälzlagerschmierung", May 1993.

3) Brochure by FAG Aircraft/Super Precision Bearings GmbH, "Super Precision Bearings", 2001, p. 147.



For instance, the department responsible for spindle bearings at Schaeffler KG recommends the following for its spindle bearings type B, HS and HC:⁹⁾

a) Rotating speed = $0.5 \cdot n_{max}$

Five intervals of 20 s running time and 2 min rest period

b) Rotating speed = $0.75 \cdot n_{max}$

Five intervals of 20 s running time and 2 min rest period

c) Rotating speed = n_{max}

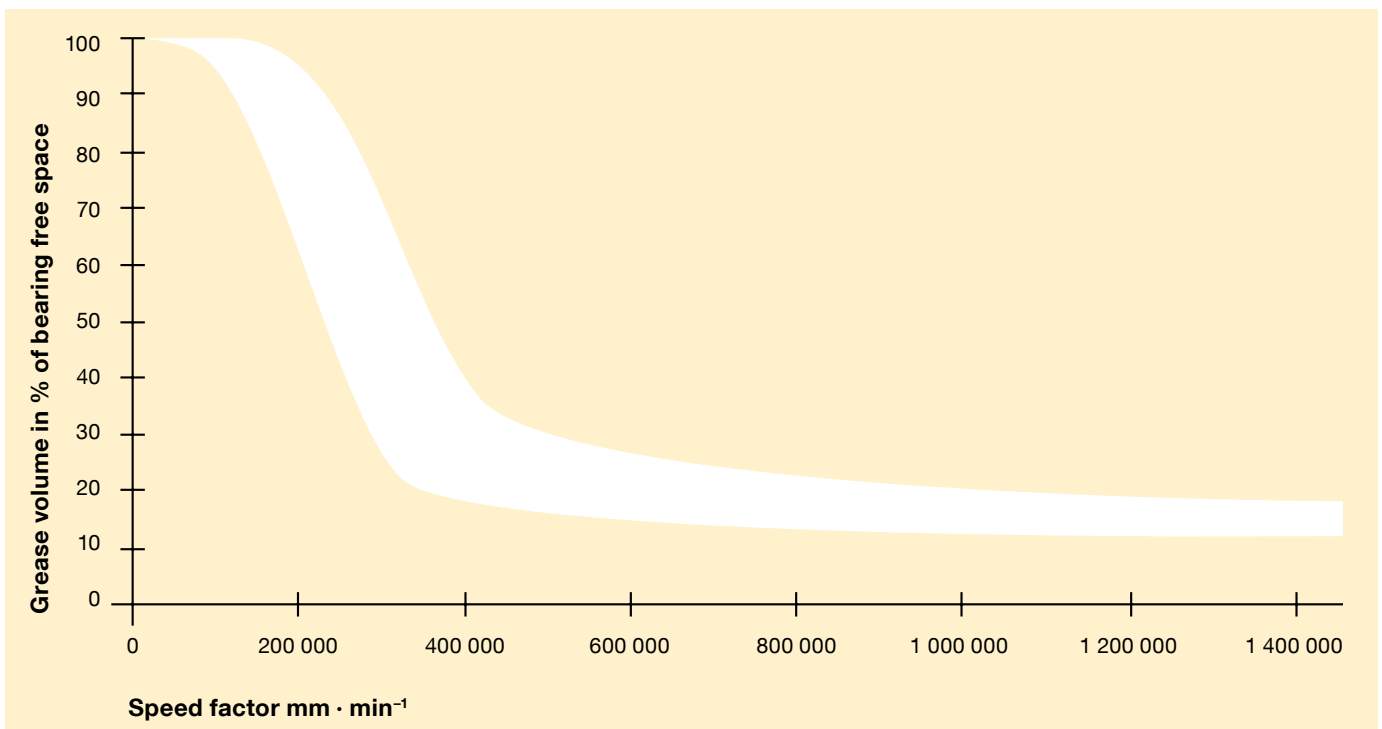
Five intervals of 20 s running time and 2 min rest period

Ten intervals of 30 s running time und 2 min rest period

Ten intervals of 1 min running time and 1 min rest period

According to this recommendation, the intervals featuring longer running time and shorter rest period should be implemented in a way that a steady-state temperature be reached at n_{max} . For indirectly driven spindles, the temperature should not exceed 65 °C.

Rotating speed in [min^{-1}]



Grease volume as a function of the speed factor in %

The lubrication of clamping systems

Lubricant and chuck have to be perfectly matched, because their paramount task is to establish constant defined clamping forces – and this over a high number of clamping cycles. If the clamping force weakens, tools or workpieces may become detached. This holds true for all types of chucks – be they scroll chucks, cam chucks or spiral chucks.

The specific requirements for the lubricants used in clamping systems are:

- consistent clamping forces for all chuck types
- protection against frictional and fretting corrosion (tribo-corrosion) at frictional or positive connections
- good resistance to water and media, e.g. to cooling lubricants

From a tribological point of view, pastes have proven to be effective for the fulfillment of these requirements as they provide a very adhesive, thin coating layer while ensuring sufficient lubrication. Pastes normally consist of low-viscosity base oils with various thickeners and additional solid lubricants.

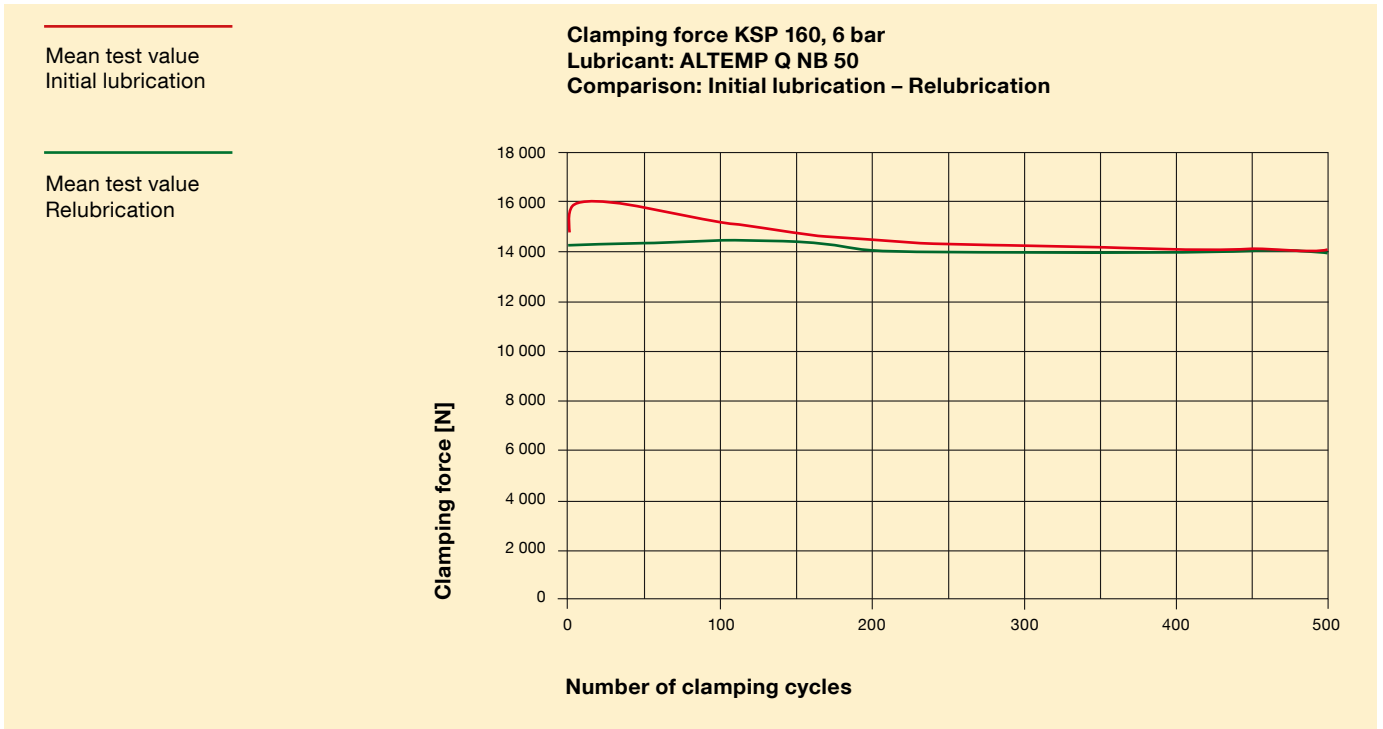


The Klüber paste ALTEMP Q NB 50 can basically also be used when installing frictionally engaged connections such as annular-spring and clamping-sleeve connections, and positive connections such as bearing seats, profile guides, etc.

In Zwickau, the German University “Westfälische Hochschule” tested ALTEMP Q NB 50 in clamping trials. In numerous clamping trials, the clamping force has proven to be very consistent as data variance was very low.

Suggestion:

You can reduce friction between the moving parts of the clamping system already by applying only a very thin, extensive layer of paste with a brush or a lint-free piece of cloth.



Clamping force as a function of the clamping cycles using ALTEMP Q NB 50. Maximum traverse speed of the clamping chucks on Fritz Schunk GmbH's KSP 160 clamping force block (tandem clasper) was 0.52 m/min.

The lubrication of gears in drilling and milling heads

Gears in drilling and milling heads play a major role when it comes to the transmission of load and torque from the machine tool main spindle to the cutting tool. They are operated in cycles and run, depending on the type of application, at high peripheral speeds of more than 20 m/s.

The special requirements regarding these components are therefore:

- reliable operation and long component service life
- high peripheral speeds
- high acceleration

In most cases, the a.m. components are spur, bevel or spiral bevel wheel gears (pallid gears).

Special requirements regarding lubricants are:

- effective corrosion protection for long component lifetime
- good adhesion and pressure absorption for high wear resistance
- high resistance to water and cooling lubricants

The lubricating greases for high-speed gears in drilling and milling heads are usually based on low-viscosity synthetic base oils with a variety of different thickeners. The crucial factors for the particular application concerned are the initial consistency and how it changes when loaded, the Klüber viscosity grade (see info box) and the oil release capacity.

The advantage of grease lubrication is the low outlay required for design and installation of the drilling and milling heads while retaining the reliability of the gear functions involved.

Gear lubrication for drilling and milling heads will sometimes utilise the same grease as for spindle bearing lubrication because rolling bearings and gear wheels are rarely accommodated in separate spaces. Using the same or a compatible product can provide additional advantages. The risk of mixing products or using incompatible lubricants is eliminated.

Klüber viscosity grades		
Viscosity grade	Apparent dynamic viscosity (mPa s)	Explanation
EL	≤ 2 000	Dynamically, ultra-light lubricating grease for very low torques, e.g. smooth running grease.
L	2 000–4 000	Dynamically, light lubricating grease for low torques or high speeds in rolling bearings, e.g. high-speed grease.
M	4 000–8 000	Dynamically, medium-heavy lubricating grease for standard requirements within the total application range of grease lubrication.
S	8 000–20 000	Dynamically, heavy lubricating grease for high load applications or liquids, e.g. extreme pressure or sealing grease.
ES	≥ 20 000	Dynamically extra heavy lubricating grease for applications requiring high torques or securing effects, e.g. grease for valves and fittings or optical grease.



We would like to point out the importance of running-in and possible refilling up to the required level. We would suggest to perform running-in as described in the chapter on spindle bearing lubrication.

Suggestion:

The degree of grease fill is about 70–90 % of the available free space, depending on the particular application. It is important to ensure that the grease does not leak from boreholes, gaps or similar apertures.

Spindle drive

Bevel wheels/spur wheels

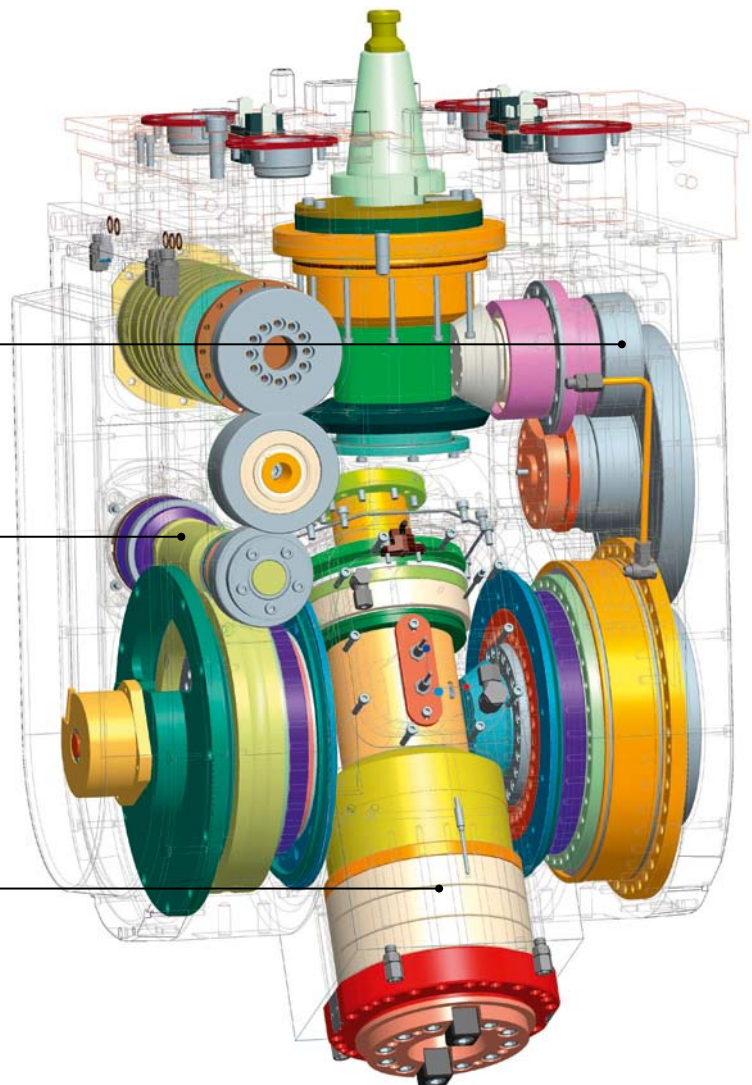
Grease: ISOFLEX TOPAS NB 52

Worm

Grease: ISOFLEX TOPAS NB 152

Milling spindle

Grease: ISOFLEX TOPAS NB 52



Example for an intercompatible product system for the lubrication of a mechanical milling head (© HEADTec GmbH, Chemnitz)

Changing, unsteady operating states, manifested in abrupt changes in temperature or power consumption levels, for example, may have adverse effects on both the grease and the component.

These may occur if

- after standstill there is an abrupt change from one lubrication mechanism to another, due to the slow warming of the gear unit and the resultant alteration in the consistency of the grease
- the transmission of torque and power and hence the load and consistency of the grease vary significantly
- the system is being run with too much grease, producing forced fluid lubrication caused by the pumping effect of the intermeshing gears

It is therefore crucial to choose the right lubricant. It helps to fulfill the requirements concerning the component and to avoid unsteady operation states and – depending on the degree of filling – to achieve the requested lubricating mechanism:

a) Fluid lubrication

A sump of grease in which the wheels are immersed and supplied with grease is formed. The grease spun off from the flanks splashes against the wall of the housing and flows back into the grease sump, which is thus thoroughly mixed. The temperature distribution is well-nigh homogenous due to the continuous contact provided. The splashing, however, can reduce gear efficiency.

b) Adhesive lubrication

The grease is spun off from the flanks and remains stuck to the wall of the housing. The gear wheels dig their way out and leave a cavity in the grease. There should be a possibility to transport the grease back to the intermeshing tooth flanks, e.g. by the alternating operation of cutter heads allowing a slow backflow of grease. The slowly moving grease covers the tooth flanks with a sufficient lubricating layer. The grease structure remains while losses are lower than in the case of fluid lubrication.

For high-speed drilling and milling head gears, adhesive lubrication has emerged in practice and in the relevant studies on gear lubrication at TU Munich as a generally suitable method.

The lubrication of drive and guide systems

Increasingly, linear motion guides rather than conventional guide ways are used in modern machine tools for the positioning of workpieces and tools. They are mostly driven by ball screws. Linear motion guides are built as flat tracks or profile rails with either recirculating balls or rollers.

Special component requirements are:

- high degree of precision
- high degree of reliability
- smooth running
- high speeds
- high acceleration causing high loads

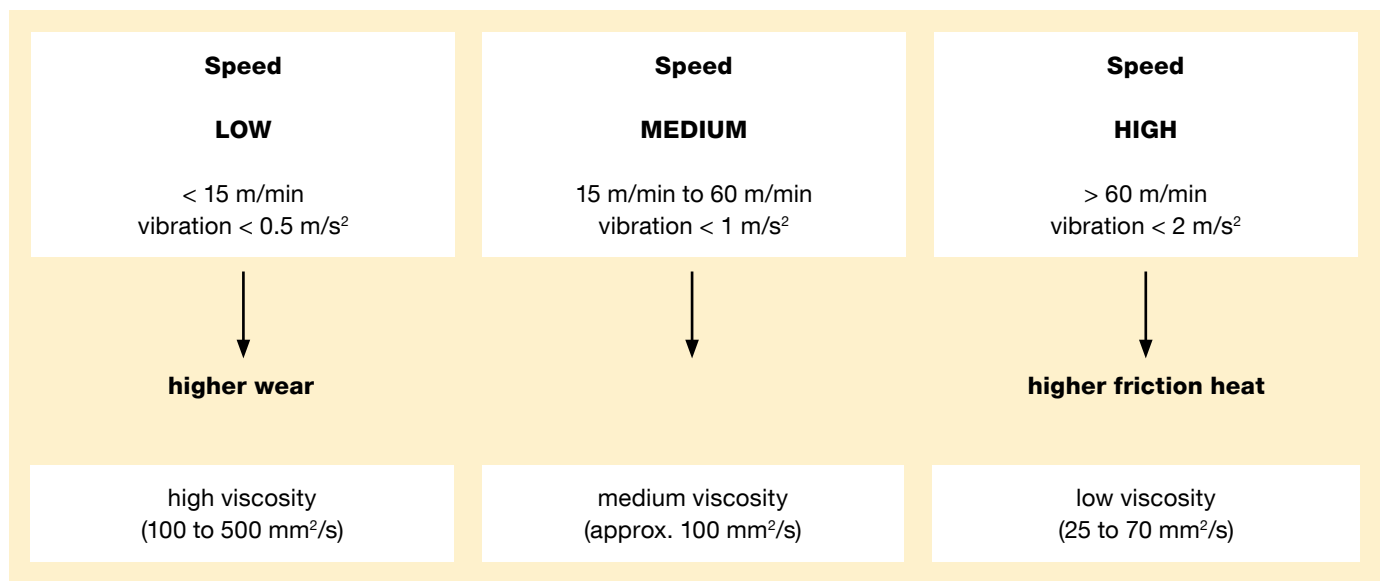
Consequently, there are high requirements regarding lubricants:

- good corrosion protection and demulsifying ability for high media resistance
- good noise damping for health and safety at work
- wear protection also for minute movement and low friction for a smooth start-up
- additional sealing ability in case of soiled environments
- good compatibility with plastics/elastomers and other lubricants



Klüber has the right lubricant for the wide size range of linear guides.

Speed-viscosity ratio



Overview of tried-and-tested base oil viscosities for various linear speed conditions.

There are different lubricants for each of these complex requirements – depending on speeds and loads, different base oil viscosities are needed. Properties like good metal adhesion, resistance or damping can be achieved through the use of thickeners. For this reason, there are customised lubricants for each special application.

Most OEMs take care of initial greasing themselves. Relubrication is effected by the operator via automatic centralised grease lubrication systems or automatic lubricant dispensers using smooth grease lubricants. It is therefore essential to have compatible lubricants for initial greasing and relubrication.

Suggestion:

It is recommended to clean the guide or lead screw with a lint-free piece of cloth. About 50 % of the initial lubricant quantity is required for relubrication. Frequent relubrication with small lubricant quantities is the preferred lubrication strategy.



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Klüber Lubrication – your global specialist

Innovative tribological solutions are our passion. Through personal contact and consultation, we help our customers to be successful worldwide, in all industries and markets. With our ambitious technical concepts and experienced, competent staff we have been fulfilling increasingly demanding requirements by manufacturing efficient high-performance lubricants for more than 80 years.



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