Proceedings of the International Conference on Manufacturing Systems – ICMaS
Vol. 4, 2009, ISSN 1842-3183
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ADJACENT INSTALLATIONS FOR MACHINE TOOLS. LUBRICATION SYSTEMS FOR CNC MACHINE TOOLS

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Abstract: *The paper presents some aspects concerning the lubrication systems for modern machine tools, especially the CNC one. The calculation methodology and the mathematical models are shown, but also some modern lubrication diagrams and technical solutions, that can be useful for the designers and manufacturers.*

Key words: *lubrication, adjacent installations, machine tools, mathematical models, simulation.*

1. INTRODUCTION

To increase the performances of machine tools and equipments the designers try to increase their efficiencies and powers. Each component of the equipment is calculated, designed and verified with specialized simulation programs. Finally, the component is manufactured. It is necessary to act in optimal conditions in the respective system. This action assumes that components move together with other parts, according to some conditions of speed, force and efficiency. Considering all of these it is important to correctly define the lubrication's function.

First of all, we must define the lubrication medium as a machine part with the following functions:

1. assures the lubrication of surfaces in contact – the lubrication medium is found between surfaces that are in relative motion;
2. improves the heat changes between the surfaces with different temperature between which it flows – as a rule it cools the surfaces in friction motion;
3. cleans the surfaces that it comes in contact with, removing the impurities of the medium and also the impurities obtained during the process;
4. protects the surfaces that it comes in contact with against the corossive agents, usually air and water.

In some cases, the same lubrication medium can be used as a hydraulic medium in action units or command units [1].

In order to obtain the correct lubrication of a machine tool the best medium and the best solution of the shape of lubrication must be chosen. The choice of some solutions other than the optimum ones, usually due to price issues, it can lead to malfunction, causing the crash of the respective machine tool [2].

2. CONTINUOUS LUBRICATION OF BEARINGS

The frictions cannot be cancelled completely no matter the type of bearing and its lubrication. The friction appears between:

- bearing races and balls, rollers, needles;
- bearing races and the bearing cage;
- bearing races and some elements of sealing;
- mobile elements and the lubrication medium.

Table 1

The friction coefficients of the most important types of bearings.

No	Bearing types	Friction coefficient *f*
1.	Radial ball bearing	0.0012 - 0.0016
2.	Radial roller bearing	0.0011 - 0.0014
3.	Taper roller bearing	0.0015 - 0.0025
4.	Barrel-shape roller bearing	0.0015 - 0.0025
5.	Needle bearing without cage	0.0040 - 0.0050
6.	Axial ball bearing	0.0008 - 0.0012

The amount of friction depends on speed and force. The friction coefficients of the most important types of bearings are presented in Table 1.

For the lubrication of machine tools' bearings oil or vaseline is used. The most important criterion in choosing the oil is its viscosity. The bearing's lubrication can be:

- total lubrication – the component elements of the bearing are completely separated by a lubricant layer;
- incomplete lubrication – some surfaces that are in contact can be found.

For each case of oil and bearing two viscosities are relevant:

- the reference viscosity ν_1 – depending on the bearing's size and speed;
- the working viscosity ν – depending on the real used oil.

If :

$\nu > \nu_1$ we have total lubrication;

$\nu \sim \nu_1$ we have normal lubrication;

$\nu < \nu_1$ we have incomplete lubrication.

The usual oil has a mineral origin, doped, with a viscosity of approximately 12 cSt at 70 ^{0}C.

The lubrication with vaseline is usually used at small speeds. It is simpler in terms of manufacturing and it is easier to maintain.

The reference viscosity, optimum value ν_1, is obtained in connection with the d_m, the medium diameter of the bearing, and N [rpm], the bearing speed. The medium diameter is:

$$d_m = \frac{D+d}{2} \,. \tag{1}$$

In the upper relation it is noted: D – the external diameter of the bearing [mm], d – the internal diameter of the bearing [mm]. Diagrams like the one in Fig. 1 can be used as reference.

For example, for the radial bearing 6010 (D = 80 mm, B = 16 mm, d = 50 mm) that works at a speed N = 500 rpm, at 60 ^{0}C, a viscosity $\nu_1 = 31$ cSt is obtained.

The viscosity ν_1 can be obtained analytically, with the following relations:

- if $N < 1000$ rpm

$$\nu_1 = \frac{45500}{\sqrt{N \cdot d_m}} \sqrt[3]{\frac{1000}{N}} \,; \tag{2}$$

- if $N > 100$ rpm

$$\nu_1 = \frac{4500}{\sqrt{N \cdot d_m}} \,. \tag{3}$$

The A.S.T.M. diagram (Fig. 2) is used to determinate the viscosity ν of oil used to lubricate the bearing at operating temperature. The oils have a viscosity index ISO of approximately 100.

The lubrication with oil is preferred for higher speeds and temperature. The oil allows the cooling and can be easily changed. It must be filtrated fully at at least 40 µm.

The type of lubrication is chosen according to the product $N \times d_m$, where: N – bearing speed [rpm], d_m – medium diameter of the bearing [mm].

As a rough guide Table 2 can be used.

For natural flow the necessary oil amount can be determined using the diagram from Fig. 3.

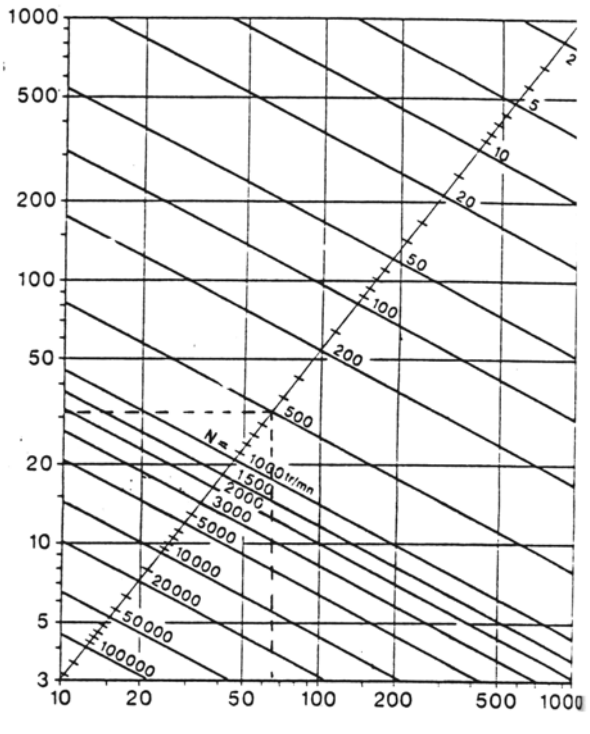

Fig. 1. Diagram used for obtaining the reference viscosity.

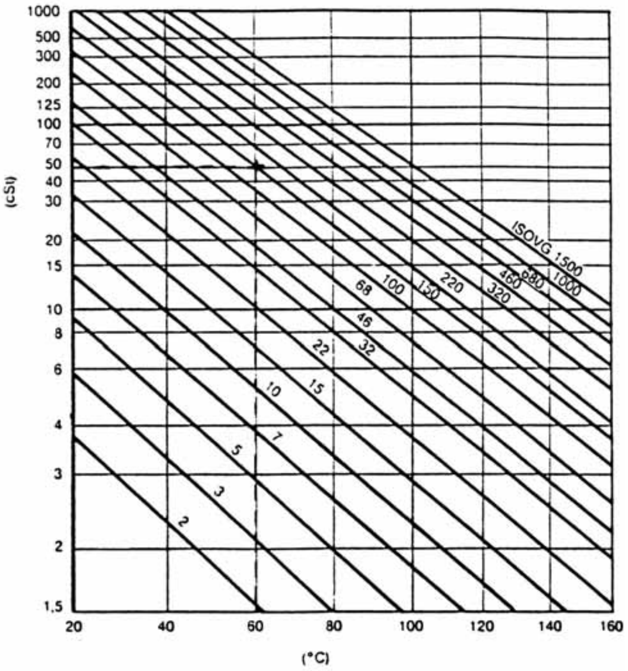

Fig. 2. The A.S.T.M. diagram.

Table 2

The guide for chosing the type of lubrication.

Lubricated system	$N \times d_m$
Oil box	< 300 000
Natural flow	< 400 000
Drop-feed lubrication	< 500 000
Constrained flow	< 750 000
Oil mist (air and oil mist)	< 1 000 000
Injection with oil*	< 1 300 000
* Injection is made at a minimum speed of 15 m/s; this speed is necessary to overcome the air vortexes generated by the high speed.	

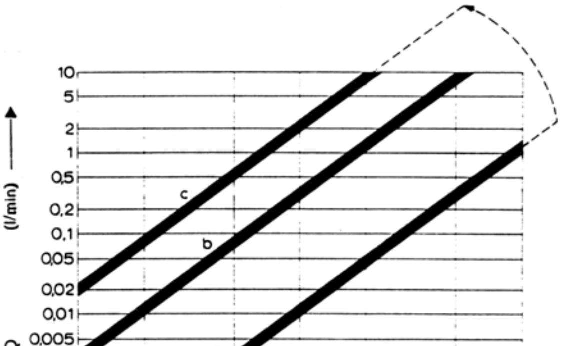

Fig. 3. The diagram for determining the necessary oil amount.

3. CONTINUOUS LUBRICATION OF GEARS

The easier method to determine the necessary oil viscosity is proposed by Chabert. If is noted with v_t the maximum tangential velocity from the gear [m/s] and with ν_{60} the cinematic viscosity of used oil at 60 ^{0}C, it can considered:

$$\frac{100}{\sqrt{v_t}} < \nu_{60} < \frac{200}{\sqrt{v_t}} \,. \tag{4}$$

There are some more accurate analytical methods such as UNITED and DIN 51509. They are based on the calculation of some coefficients depending on force, the gear's dimensions etc. Using these coefficients and the maximum tangential velocity the recommended viscosity at a certain temperature is calculated. The value of these coefficients is corrected in relation to the real acting temperature.

For worm gears, the following relation can be verified:

$$\frac{25}{\sqrt{v_g}} < \nu_{100} < \frac{50}{\sqrt{v_g}}, \qquad (5)$$

where v_g – the tangential velocity of the worm [m/s] and ν_{100} – the viscosity at 100 ^{0}C.

It is difficult to find an optimum oil for gears due to the great number of influencing factors and lubrication producers. For this reason, it is recommended to consult the oil and vaseline producers when new machines are designed [3].

4. PARTICULARITIES OF CONTINUOUS LUBRICATION SYSTEMS USED TO CNC MACHINE TOOLS

When CNC machine tools are used, the lubrication systems must be permanently confirmed to the control system. Every interruption in action must be noticed and notified, in order to fix the problem. In some cases, the damage can lead to stopping the machine. In order to confirm the lubrication, pressure relays and/or flow indicators are used.

The pressure relays, as shown in Fig. 4, confirm the existence of static pressure in a part of the circuit, in the range of 0.1 bar to 25–30 bar. The pressure relays have a simple and reliable structure. They are adjusted to an unique pressure or in a certain range of pressure by the producers.

It presents the disadvantage of confirming the existence of pressure even if the lubrication is not achieved; for example, in the case of obstructing the circuit after the mounting place, but before the lubrication point.

The flow indicators confirm the oil flow on a part of the circuit; they certainly confirm the lubrication if the circuit after flow indicators is not accidentally broken (if a pipe is broken or a sleeve is opened). The flow indicators are more expensive than pressure relays.

An example is presented in Fig. 5 [4].

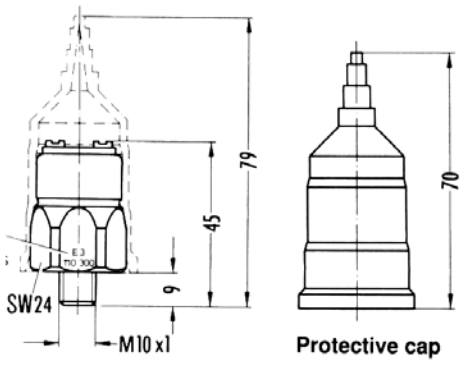

Fig. 4. The pressure relay.

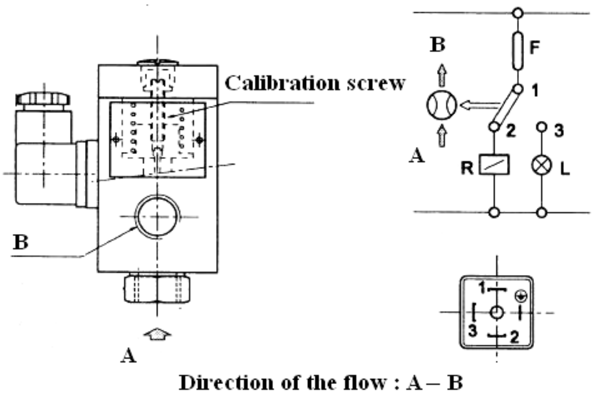

Fig. 5. The flow indicator.

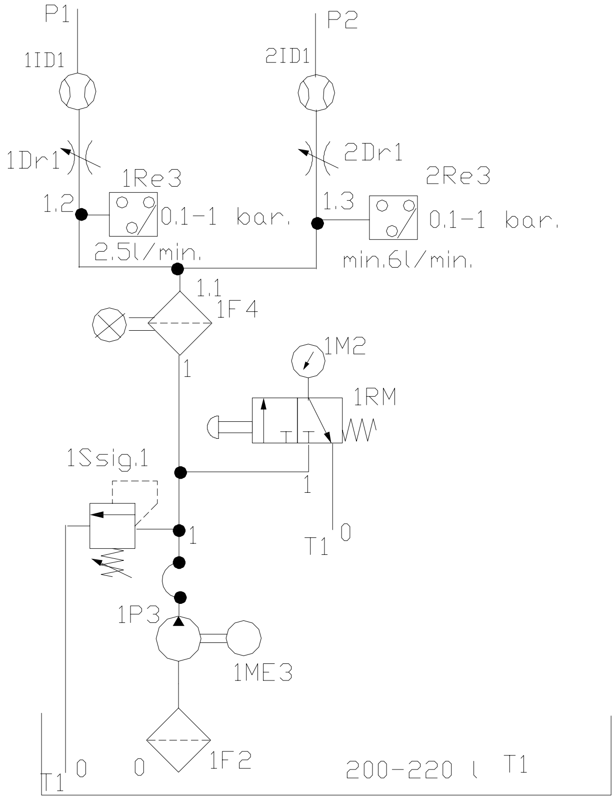

Fig. 6. The lubrication unit of a machine tool.

The lubrication indicators are made for a great range of discharges; the range is enough for specified requirements for attended machine tools.

It is recommended to use both types of units to confirm the lubrication, especially in the case of heavy machine tools with important lubrication points (gears boxes, great bearings or bearings that work at great speeds) [5].

In Fig. 6, the lubrication unit of a machine tool is presented, which requires a controlled lubrication in two points P1 and P2. The necessary discharges are 2.5 l/min and, respectively, 6 l/min.

The pump 1P3 delivers a discharge of 12 l/min. The pressure valve 1S adjusts the maximum pressure. The value of pressure is read using the manometer 1M2, after acting the cock 1RM. The filter 1F4 assures the necessary purity of lubrication (10 µm). To divide the discharge the valves 1Dr1 and 2Dr1 are used. The pressure

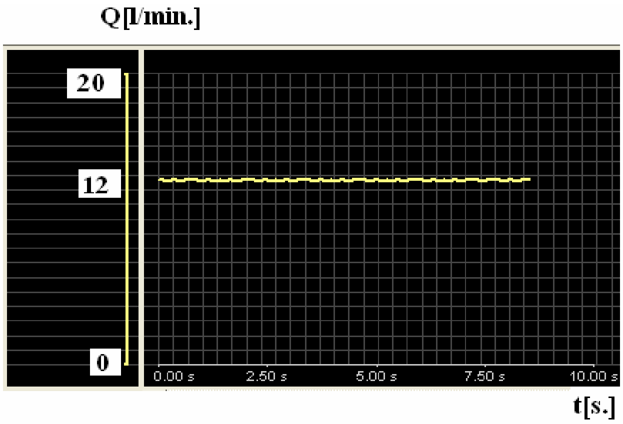

Fig. 7. The characteristics of the discharge of pump 1P3 (gear pump with constant discharge).

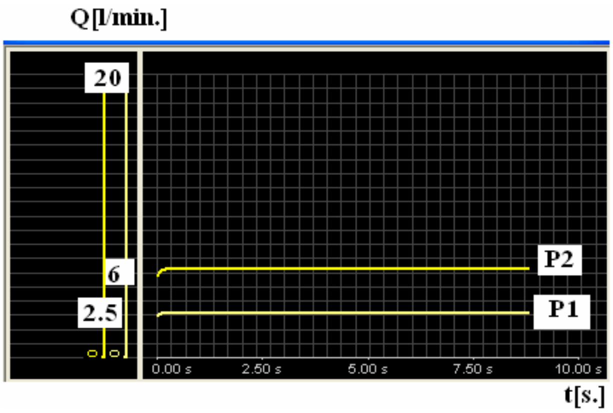

Fig. 8. Two discharges used for lubrication in points P1 and P2.

relays 1Re3 and Re3 notice every static pressure greater than 0.1 bar. The flow indicators 1ID1 and 2ID1 confirm the oil flow towards the lubrication points.

5. SIMULATION OF CONTINUOUS LUBRICATION SISTEMS

In order to manufacture the lubrication unit, it is necessary to choose the specific components and after that it is necessary to verify their functioning inside the system. It is recommended to use specialized simulation programs [6].

After the simulation schema is made and all the characteristics of the components are introduced, its functionality can be tested using different simulations of the adjustments: opening valves, the capacity pump, adjusting pressure etc.

In Fig. 7, the characteristics of the discharge of pump 1P3 (gear pump with constant discharge) are presented.

This discharge, supplied to the unit, is divided in two discharges used for lubrication with 2.5 l/min and 6 l/min in points P1 and P2 (see Fig. 8). The excess is overfilled using pressure valves.

The simulation allows the determination of the capacity of adjustment of the system; the final adjustment is done according to the working conditions imposed by the topic.

6. CONCLUSIONS

The lubrication units for CNC machine tools must be considered base components. They are designed and manufactured like the others mechanical, hydraulic and electrical components. The lubrication units cannot be seen as some additional components of machine tools. Their action is an integrated part of the whole system: machine tool, program and technology. Actually, the specialized firms deliver components that are requested by designers and producers of machine tools. The right choices of these components must be made using the mathematical model and simulation programs.

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