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Continuous Lubrication Systems for Machine Tools

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Abstract: *This paper describes some of the results obtained by the authors in the design, simulation and testing of the lubrication units for machine tools. The paper is based on the data collected during the manufacture of a boring and milling machine tool with numerical control (AF 105 CNC). The study includes theoretical considerations, calculations and simulation of unit operation but also explanations on the actual manufacture of the unit. Several machines were built on the basis of this project. The proper selection of the components, the making of calculations and simulation helped to the manufacture of an efficient unit with low noise and reduced heat.*

Keywords: *Lubrication unit, machine tools*

1. Lubrication unit

The unit is meant to lubricate the following mechanisms from the machine housing: two-speed gearbox, nut of the ball screw of the W axis feed kinematic chain [1, 2, 3], guideways of W axis and the boring spindle. Figure 1 shows the kinematic diagram of the AF105 machine housing and the points where the lubrication is required, noted OIL1.1, OIL1.2, OIL3.1, OIL3.2, OIL4.

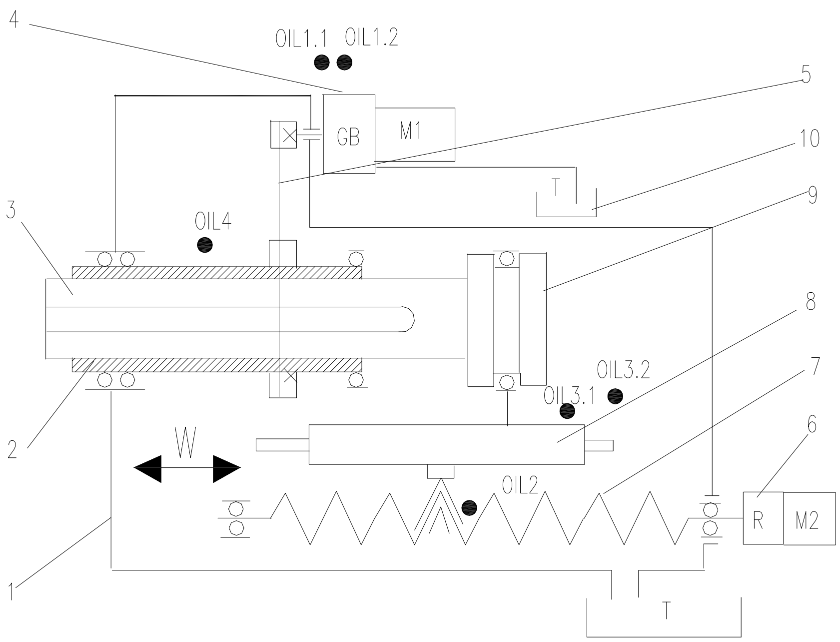


Fig. 1. Kinematic diagram of AF 105 machine housing

The main spindle 2 is supported on bearings related to housing 1 where the boring spindle 3 moves. The main spindle is the last element of the main kinematic chain [1] which also includes the main motor M1 and the GB two-speed gearbox [1, 4]. This one rotates the main spindle by means of the toothed belt 5 [2, 3, 4]. The feed kinematic chain 6 for W axis includes the M2 servomotor, the R reducer and the ball screw 7. This screw actuates the saddle 8 which, thanks to a specific supporting on bearings, moves the boring spindle 3. The oil which will ensure the lubrication is supplied from the tank 10.

The hydraulic diagram of the lubrication unit is shown in Figure 2.

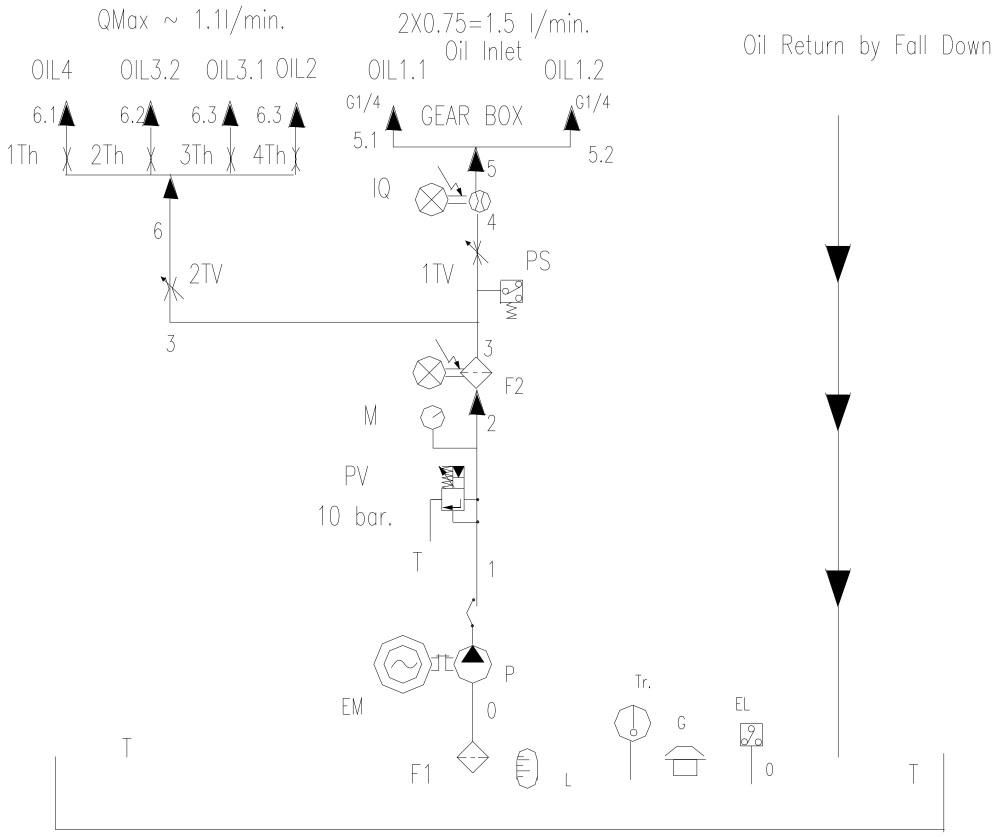


Fig. 2. Hydraulic diagram of the lubrication unit of AF 105 machine housing

The EM electromotor actuates the P gear pump [5, 6, 7]. The maximum operating pressure is regulated by the PV pressure relief valve and is visualized with the help of the M pressure gauge. The purity of the lubrication oil is ensured by the F1 suction filter and the F2 pressure filter. This latter is provided with an electric clogging indicator [6, 7]. The existence of a minimum operating pressure in the CNC machines must be confirmed to allow the corresponding phase of the working program to be carried out. The PS pressure switch was provided to confirm this pressure. The manufacturer of gearboxes recommend that these ones are lubricated at a certain flow rate [5, 4]. The regulation of the flow is made by means of the 1TV throttle valve. The flow rate (1.5 l/min) is confirmed by the IQ flowmeter. The necessary flow summed for the other lubrication points is regulated with the help of the 2TV throttle valve and does not exceed the value of 1 l/min. The following elements are located on the T tank: filling cap G, temperature probe Tr, sight glass L and the minimum level electric indicator EL.

2. Calculation and simulation of the lubrication unit

For the lubrication of the necessary points mentioned above, a constant flow pump will be used. This pump will be driven by a three-phase asynchronous motor which has the sync speed of n = 470 RPM. If the necessary flow is Q_E, the pump capacity will meet the condition:

$$q > \frac{Q_E}{n} \times 1000 \ [cm^3] \quad (1)$$

In the relation above, the Q_E flow is introduced in [l/min]. From the specialty catalogues, the $q_P > q$ is chosen. In this case, the actual available flow is:

$$Q_R = q_P \times \frac{n}{1000} \text{ [l/min]} \quad (2)$$

The maximum operating pressure will not exceed the p_{Max} value imposed. In this case, it is recommended to have p_{Max} = 20 bar.
The required power of the electric motor is determined by means of the relation:

$$P_{EM} = \frac{q_P}{450} p_{Max} \text{ [KW]} \quad (3)$$

The electric motor is chosen from the specialized catalogues. The flange foot motors are recommended [4]. Taking into consideration the operating flow rate, the nominal size DN4 or DN6 is recommended for the devices used.
The tank will have the minimum useful volume V_0, that must verify the condition [5, 6]:

$$V_0 > 5\,Q_R \text{ [l]} \quad (4)$$

In order to verify and to eventually correct the diagram, a simulation in AUTOMATION STUDIO [8] was conducted.
The characteristics in Figure 3 show the desired flow values following up the simulation.

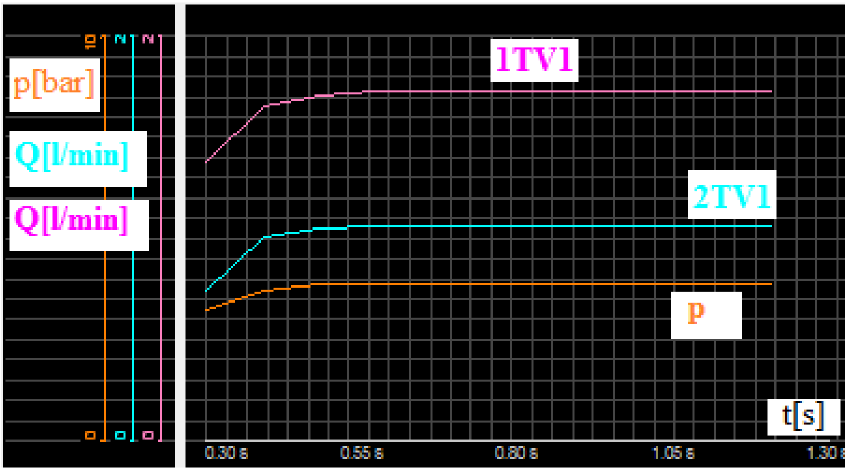
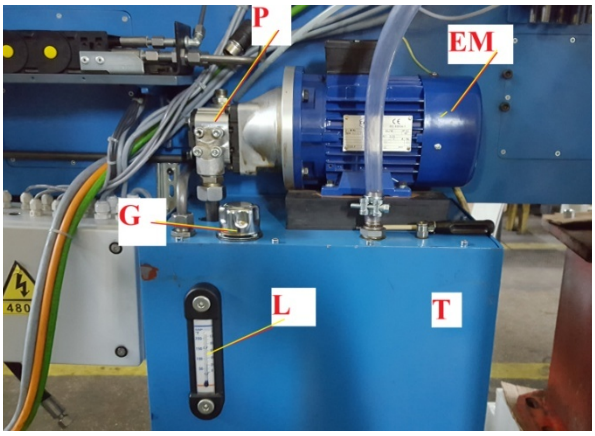


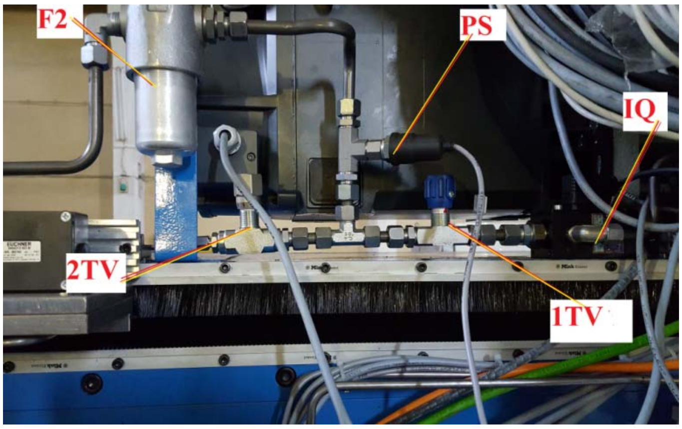
Fig. 3. Results of the simulation

We observe from the characteristics of Figure 3 that after less than 1s the pressure reaches the value of 4 bar for the regulated flow rates. Thus, downstream the 1TV1 throttle valve (at the gear box) a flow rate equal to 1.67 l/min is obtained. Downstream the 2TV1 throttle valve, a flow valve of 1.1 l/min is obtained.
Studying the results of the simulation and observing that less than 10% of the throttle valves regulation capacity was used, we considered that the designed diagram met the requirements and the manufacture was started.

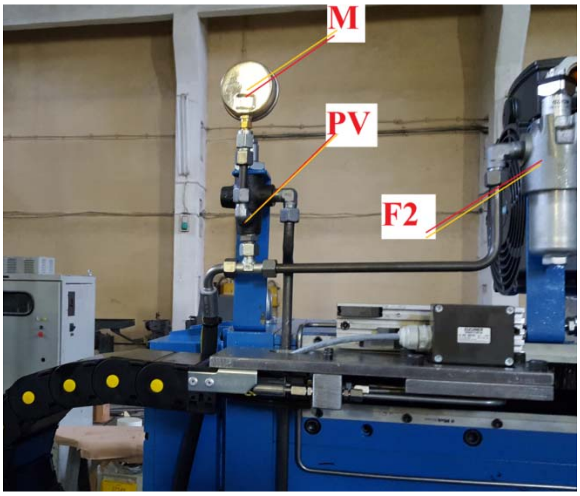
3. Presentation of the unit

Due to constructive reasons, the manufactured tank has a useful volume V_0 = 30 l. The electric motor, the pump and a part of the components were assembled on the tank. Their location – keeping the same notations as in Figure 2 – is shown in Figure 4.
The lubrication points are presented in Figure 5 together with some of the elements of the kinematic diagram in Figure 1.
After making the unit, this one was adjusted. During the operation, the real pressure is 5-6 bar, the flow rate downstream the 1TV1 throttle valve, measured at gearbox output, is 1.6 l/min. The flow rate, regulated at the 2TV1 throttle valve output, cannot be measured because the discharge is freely made and the oil is recovered by falling.



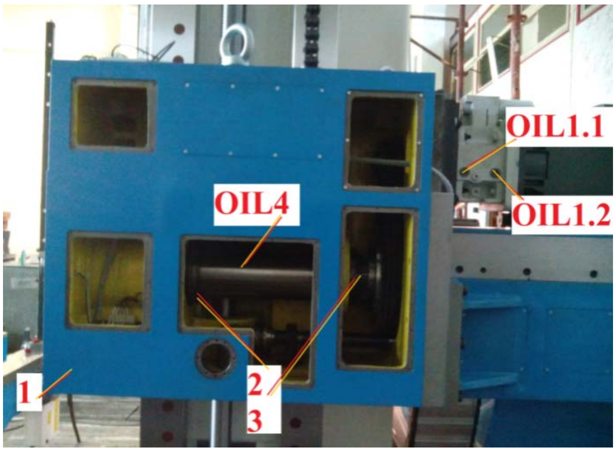


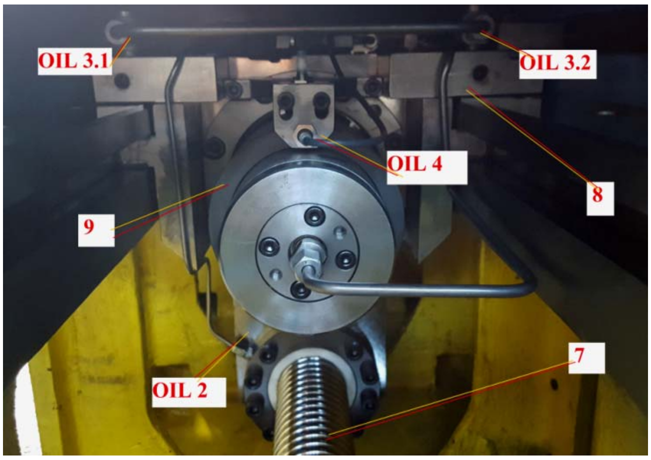
a. b.



c.

Fig. 4. Presentation of the unit





a. b.

Fig. 5. Presentation of the lubrication points

4. Conclusions

The lubrication units belong to the category of subsidiary systems of the machine tools.
These ones include a pump (usually a constant flow one) and the equipment for measurement and control. Generally, the operating pressure does not exceed 20 - 25 bar. The adjustment of the flow rates, in the case of the permanent flow lubrication, is made using fixed or adjustable throttle valves.
In the case of the numerical control machines, the minimum pressure is confirmed by pressure switches.
If standard gearboxes are used, it is important to comply with the recommendations of the manufacturers regarding the value of the necessary flow. The existence of the recommended flow is confirmed by means of flowmeters. These ones and the pressure switches as well shall be calibrated periodically.
By using simulation programs in the design phase of the lubrication units, one can study the behavior of the elements in the diagram and also its operation. It is also possible to determine the capacities for regulation of the flow and pressure.
The results of the simulations are indicative ones; therefore, they must be compared with the results obtained experimentally.

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