HYDRAULIC RETURN-CLEARANCE TAKEOVER SYSTEM USED IN HEAVY VERTICAL LATHES. DESIGN AND SIMULATION.

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Abstract: This work presents a hydraulic clearance takeover system which may be used in the design of heavy vertical lathes. The use of this system allows the constructive overlap of the main kinematic chains with the feed chains. This significantly simplifies the manufacturing of such lathes, but also reduces production costs and improves precision.

1. INTRODUCTION

In the case of certain circular feed kinematic chains which equip some vertical lathes, the clearances are introduced especially by the final pinion-wheel transmission [5]. The pinion for such machines belongs to the type pictured in Figure 1.

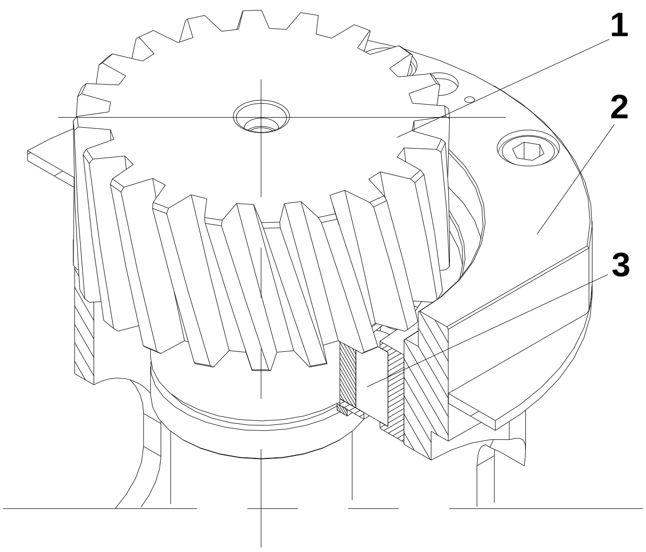

Figure 1. Simple pinion for driving the toothed wheel of vertical lathes.

Pinion 1 is bearing-fitted to cradle 2 with bearings 3. The pinion drives the wheel on the flanks of the teeth corresponding to the direction of rotation. At standstill or at reversal of direction, the contact flanks are changed due to functional clearances, which in turn leads to positioning errors.

2. DOUBLE PINION MECHANIC-HYDRAULIC CLEARANCE TAKEOVER SYSTEM [6]

Starting from the design of the pinion presented under figure 1, a variant which allows the takeover of the return clearance may be produced, only when necessary, i.e. for precise milling and positioning. In vertical lathes, the pinion-wheel mechanism is considered to belong to the main kinematic chain in the case of turning works, and to the circular feed kinematic chain in the case of milling works. Figure 2 presents a diagram of this variant and its operation.

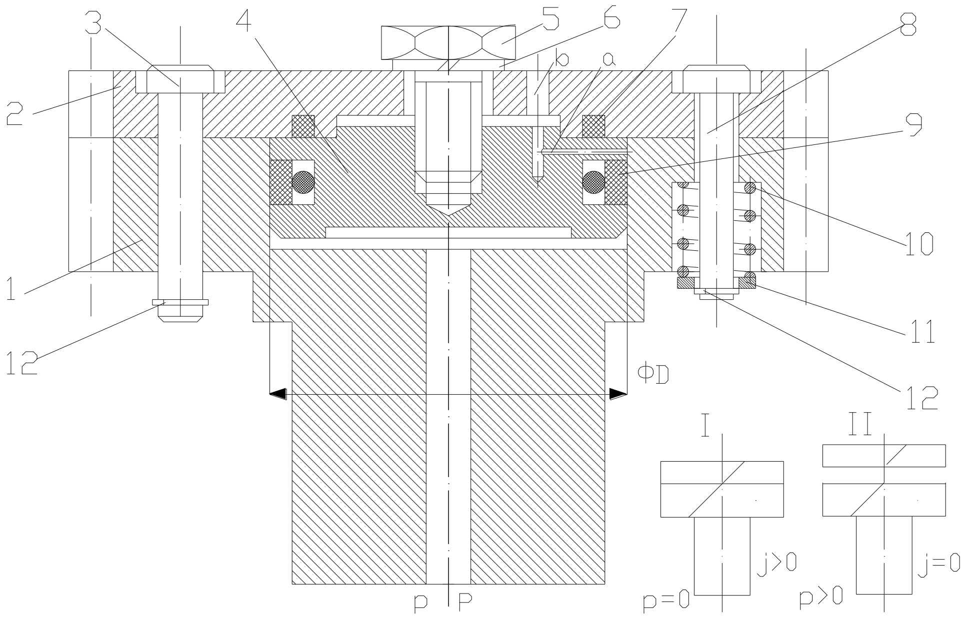

Figure 2. Return clearance takeover system with double pinion with bevel teeth.

The main pinion 1 and secondary pinion 2 are coupled with bolts 3. They are introduced in pressed form in pinion 2 and slide in pinion 3. The piston 4 is fitted on pinion 2 with the screw 5 and the safety washer 6. Element 7 ensures the sealing between pinion 2 and piston 4. The sealing between piston 4 and pinion 2 is ensured by element 9. The pinions are maintained in close contact by the pre-tensioned springs 10. They are guided by bolts 8. The pressure due to the pre-tensioning is taken over by washers 11. All the bolts are secured with elastic rings 12.

In the turning phase, pinions 1 and 2 work on the same wheel flank. If milling is performed, oil at p pressure is introduced through the P conduit. The pressurized oil actuates piston 4, with diameter D, pushing it upwards. The two pinions have bevel teeth. For this reason, the pinions will work on different flanks of the driven wheel, thus taking over the clearance. The potential losses are recovered on the a, b path.

If the bevel angle of the teeth in relation to the vertical is β, the following relations may be considered:

$$F_A = p \cdot \frac{\pi \cdot D^2}{4} \tag{1.1}$$

$$F_N = \frac{F_A}{\sin\beta} \tag{1.2}$$

$$F_T = F_A \cdot ctg\beta \tag{1.3}$$

In relations (1.1) – (1.3) the following has been documented: F_A - axial force, F_N - normal teeth force, F_T - tangential force. Force F_A is dimensioned so as to ensure the permanent takeover of the clearance, regardless of the instantaneous value of the reduced torque at pinion level.

The solution presented under figure 2 represents an invention patent of the authors from 2011 [6].

3. HYDRAULIC CLEARANCE TAKEOVER PLANT

The hydraulic diagram recommended for such clearance takeover systems is presented under Figure 3 [4].

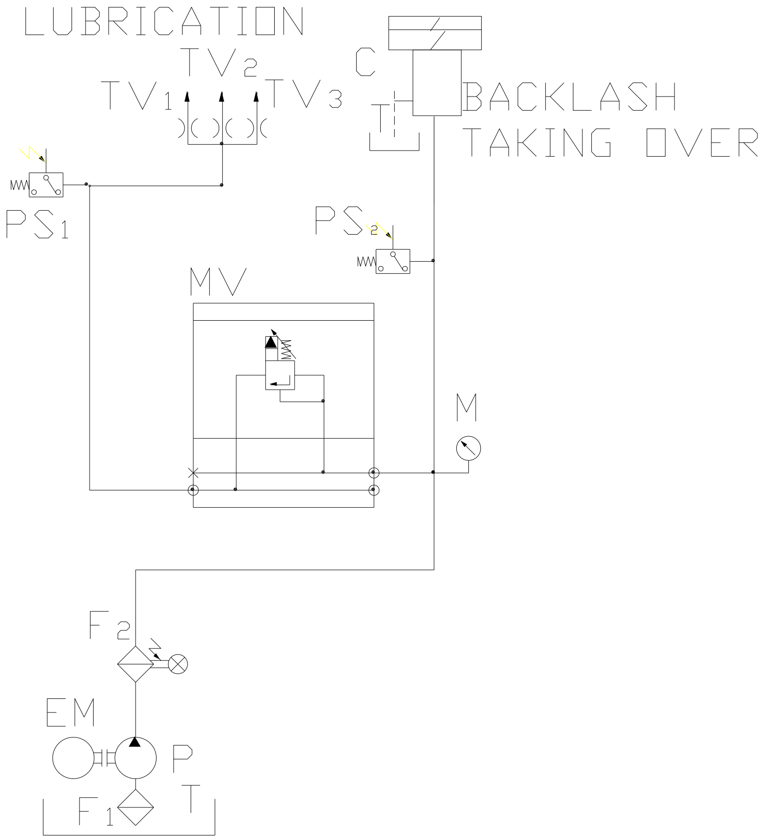

Figure 3. Hydraulic diagram of the system.

Pump P, driven by the electric motor EM, sucks-in air through the strainer (filter) F1 from tank T. The maximum plant pressure is adjusted by means of the pressure valve (maximal valve) MV and is displayed on the pressure gauge M. The oil purity is ensured by the pressure filter F2. The existence of clearance takeover pressure in cylinder C is confirmed by the pressure relay PS2. The return of the pressure valve also ensures the lubrication of the specific linkages of such a transmission. The lubrication adjustment is performed by the throttle valves TV1, TV2 and TV3. The lubrication is confirmed by pressure relay PS1. The electromotor EM is switched on by the START command of the machine and works as long as the rotation takes place.

In the adjustment phase, the following are established: the efficient clearance takeover pressure and the flow rates necessary for the lubrication. In the design phase of such a plant, the operation may be simulated by means of dedicated software.

4. OPERATION SIMULATION OF THE HYDRAULIC CLEARANCE TAKEOVER SYSTEM

Based on the diagram from Figure 3, a simulation of the system has been performed for a pump with a flow rate Q = 6 l/min, at an MV pressure level of 60 bar.

Figure 4 shows the evolution of pressures (p) recorded by the pressure relays PS1 and PS2.

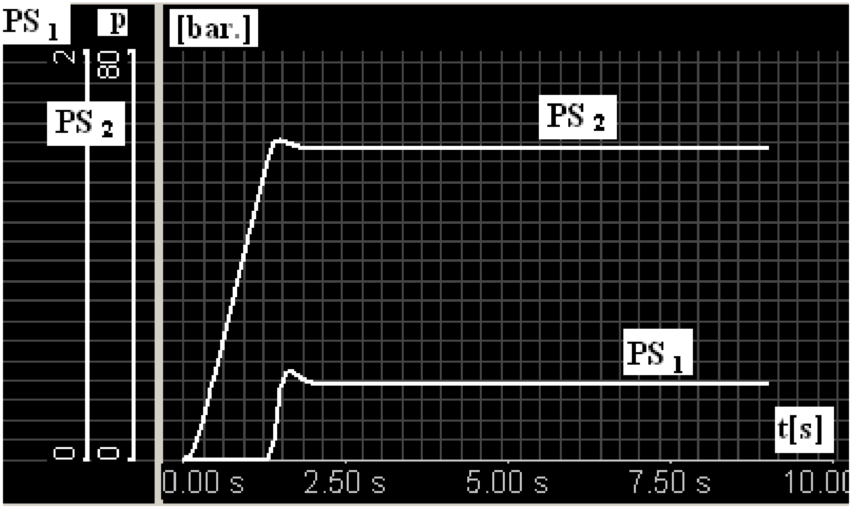

Figure 4. Evolution of pressures.

Is it noticed that after less than 3 seconds from the start, the pressures are stabilized both on clearance takeover (PS2 ~ 60bar) and on lubrication (PS1 ~ 0.4 bar).

For the lubrication flow rates, it was considered that the throttle valvesTV1, TV2 and TV3 have been opened by 18%, 13% and respectively 8% of the maximum areas. In such conditions, the flow rates (Q) for the three adjustments are presented in Figure 5.

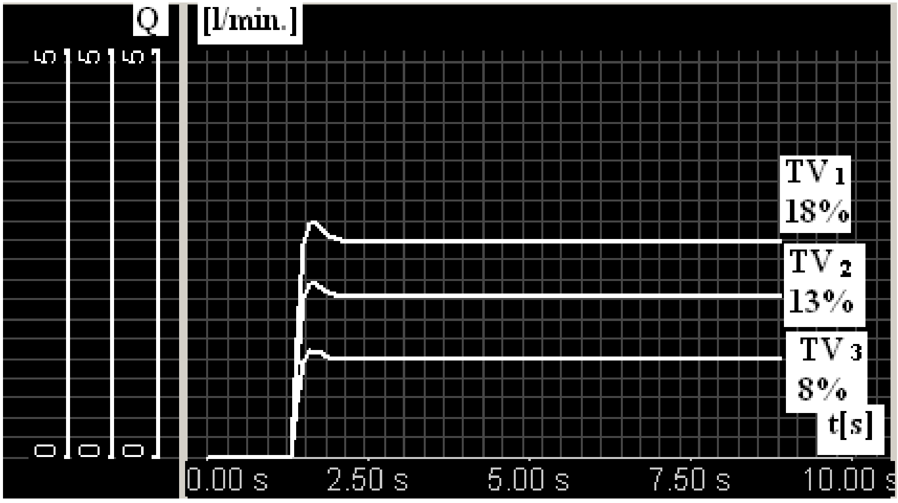

Figure 5. Evolution of the lubrication flow rates.

After a short period of less than 3 seconds, the adjusted flow rates ensure the lubrication of the specific linkages, bearings, other gears, etc. [2], [3].

5. USE OF THE HYDRAULIC CLEARANCE TAKEOVER SYSTEM

The above system is recommended for heavy vertical lathes [3], [1], fitted with clearance-free gearboxes [4], designed for turning, milling and drilling applications [2]. By using such a system, the main kinematic chain for turning may be transformed into a circular feed kinematic chain at modern machine with digital operation, exclusively by operating the hydraulic clearance takeover system.

Figure 6 sows the kinematic diagram of the main/feed kinematic chain for such a machine.

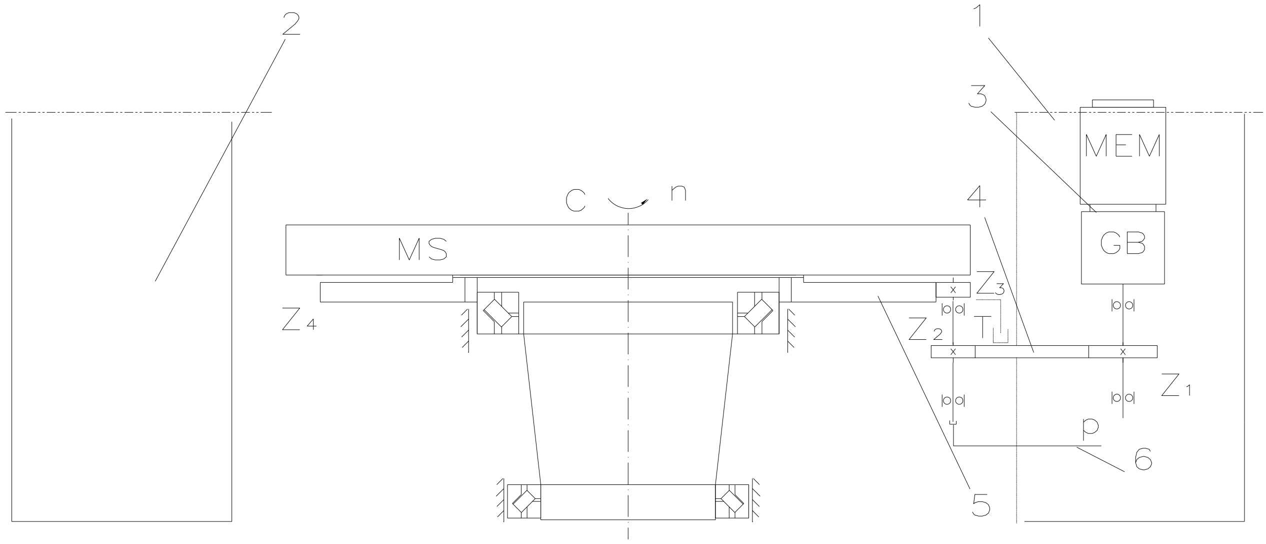

Figure 6. Principle kinematic diagram.

In Figure 6 the following notation was made: 1, 2 - struts, 3 - main electric motor and integrated gearbox, 4 - clearance-free toothed belt, 5 - pinion transmission with clearance takeover and toothed wheel, 6 - hydraulic plant, Z_1, Z_2 - toothed belt rollers, Z_3 - pinion with clearance takeover, Z_4 - toothed wheel, MEM – main electric actuator motor, GB - gearbox, MS - main shaft, C - digitally operated axle, n - main shaft speed.

The rotation movement is brought from the MEM main electric motor by means of the GB gearbox (clearance-free), toothed belt transmission and the pinion-wheel linkage at the main shaft with adjusted speed n. In the case of turning works, this is the main kinematic chain [1]. In such a situation, the clearance takeover system is not actuated. For milling and drilling works, the clearance takeover system is activated, and n speed becomes feed speed [1], controlled and correlated with other movements by means of the CNC equipment. Only one motor is used for the main kinematic chain and for the circular milling chain, by means of a single gearbox (feed). Presently, separated gearboxes and feed boxes are used.

6. CONCLUSIONS

The clearance takeover system is made-up mainly from two pinions working in the same body, they are united by bolts on which one of them slides, the clearance is taken over due to the relatively axial movement of two sectors with BEVEL teeth. The two pinions work both with the actuated clearance takeover system (milling, drilling) and when the clearance is not taken over (turning). Presently, in vertical pinion lathes, the turning wheel is separated from the double pinion wheel mechanism for milling.

Only one motor may be used for the main kinematic chain and for the circular milling chain, by means of a single gearbox (feed). Presently, separated gearboxes and feed boxes are used, each with its own engine.

The use of the hydraulic clearance takeover system leads to the constructive simplification of the machine, but also to a precision increase, due to the significant reduction of transmissions used.

The use of simulation software may lead to a more thoughtful design of the hydraulic clearance takeover plant and the lubrication systems for other machine linkages and components (bearings, other transmissions, even the wheel/pinion mechanism).

Furthermore, the solution proposed by the authors may be equally used both in the design of new vertical lathes and in the modification and fitting of the existing vertical lathes with such a system, which would allow to use them for a much wider range of technological applications which would have otherwise required the transfer of the parts to other dedicated machine-tools.

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