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SAFETY HYDRAULIC UNITS FOR SEMI-FINISHED PRODUCTS CLAMPING SYSTEMS IN MACHINE-TOOLS

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Abstract: *This paper introduces a system to increase safety in the operation of the hydraulic units intended for clamping the circular semi-finished products in the case of centre and vertical lathes [1]. It presents the basic diagram, the mathematical models of computation, the results of simulations made in dynamic mode and the practical achievements too. Using this hydraulic system allows decreasing the risk of unclamping the semi-finished products during machining. One of the main elements of those systems is the gas-loaded accumulator. It is the element which assures the necessary energy after the pressure source (the pump) stops.*
Keywords: *gas-loaded accumulator, machine-tools, safety system, mathematical model, simulation*

1. INTRODUCTION.

We shall introduce hereby a hydraulic unit for the actuation of vertical lathe jaws. The unit can be also used for centre lathes or other machine-tools. The operation safety or during accidental stopping is ensured by a gas-loaded accumulator. In the case of lathes, the semi-finished products clamping in devices with jaws poses specific problems.

Among these problems we mention the following two ones:

1. Need for high clamping forces;
2. Ensuring of clamping in case of breakdown too, such as: power failure, breaking of pipes, accidental stopping.

Fig. 1 shows the basic diagram for a hydraulic system of jaws driving.

Notations in this figure are as follows: C - hydraulic cylinder, Ac - gas-loaded accumulator, RD - rotary distributor, PS_1, PS_2, - pressure relays, A, B, P, T - flow paths, D - drain, S_1 - electromagnet, DV - distributor, F - filter, M - pressure gauge, CV - check valve, PCV - unlockable check valve, PV_1, PV_2 - pressure valves, EM - driving electromotor, P_1-P_2 - double pump, p_0 - accumulator preloading pressure, p_1, p_2 - pressures adjusted at pressure valves, p_3 - adjustment pressure of pressure relays, V_0 - accumulator volume.

The real unit was manufactured with DN 6 and DN10 equipment. The electric motor ME drives the double pump P_1-P_2. Afterwards the oil is filtered through F, a filter with clogging sensor. The two pumps are connected by means of check valve CV.

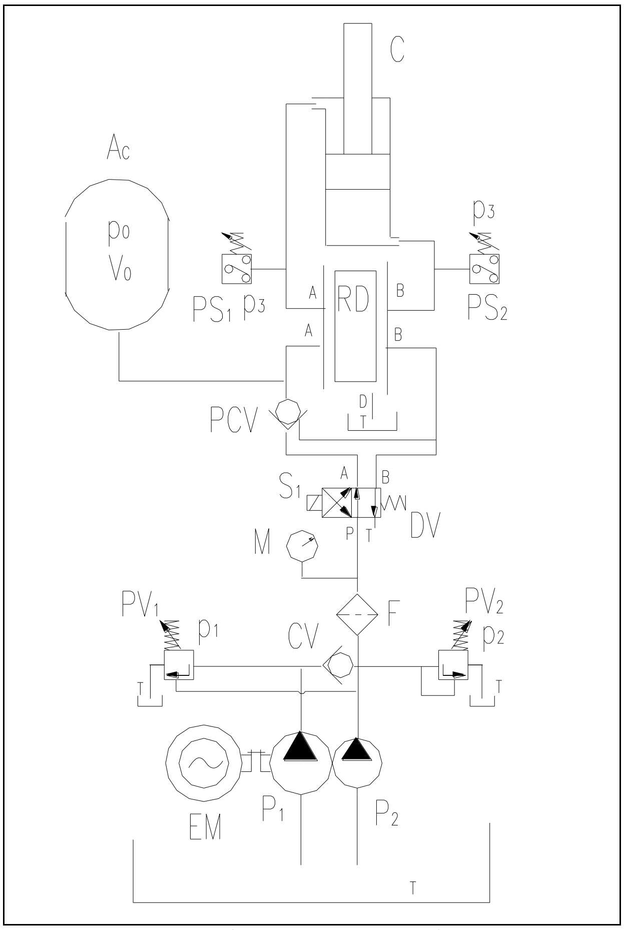

Fig. 1. The basic diagram for a hydraulic system of jaws driving

Pump P_1 is a high flow pump and it will work on its own circuit of maximum pressure of 25 bar, set at pressure valve PV_1.In this very circuit there is also another distributor (not shown in diagram) that operates as a pre-control [2] and makes the coupling and uncoupling. Pump P_2 is a small flow pump and runs with a pressure of 45 bar. This pressure is regulated at pressure valve PV_2.

The clamping-unclamping circuit and Ac accumulator are powered by electro-distributor DV and rotary distributor RD. The clamping-unclamping is performed by means of distributor DV. These operations are confirmed by pressure relays PS_1 and PS_2 respectively. They are regulated at 30 bar.

The accumulator used has the volume V_0 and is loaded at a pressure p_0. The unlockable check valve is located on path A (for clamping) and closes on its own if there is no pressure on path B [2]. Clamping –

unclamping cylinder C is powered by rotary distributor RD.

A correct operation of this clamping system involves the following stages: high speed approach to semi-finished product, reaching of semi-finished product, clamping of this one with low speed and great force, maintaining the clamping, rapid unclamping only if commanded.

Clamping is made on path A, while the unclamping is made on path B. The selection of paths is made by distributor DV. If there is a command for the working piece clamping, the two pumps send a totalized flow through the check valve CV at a maximum pressure of 25 daN/cm^2. This phase represents the fast approaching. The contact with the semi-finished product entails the pressure increase. If the pressure is over 25 daN/cm^2 the pump P_1 represses totally through valve PV_1. Pressure increases further up to 45 daN/cm^2, pressure regulated to PV_2. The accumulator was charged with a quantity corresponding to the difference of pressure $p_2 - p_0$.

Therefore the working piece is clamped with a force corresponding to the pressure of 45 daN/cm^2. If motor EM stops, the voltage drops or a loss of oil occurs up to valve PCV; the accumulator makes possible the clamping from 45 daN/cm^2 to p_0, until it is completely discharged through the draining system of the rotary distributor. In fact, the biggest losses occur through this distributor that rotates with more than 200 rpm. The working point for the clamping phase is shown in Fig. 2.

In fig. 2 there are also mentioned: Q_1 – flow of pump P_1, Q_2 – flow of pump P_2.

If the unclamping is commanded, the electromagnet S_1 must be actuated. The oil comes on path B with low pressure. The useful flow is the one resulted from the summation of the two pumps flows. The pressure increases at travel end. This increase is confirmed by the relay PS_2. The cycle can be resumed starting from this moment.

Next it will be calculated the operation time in case of emergency. That means how long the semi-finished product is still clamped by the pressure existing in the circuit with accumulator [3] after a power cut-off. It is considered that the clamping is no more effective if the pressure relay PS_1 does not confirm any more.

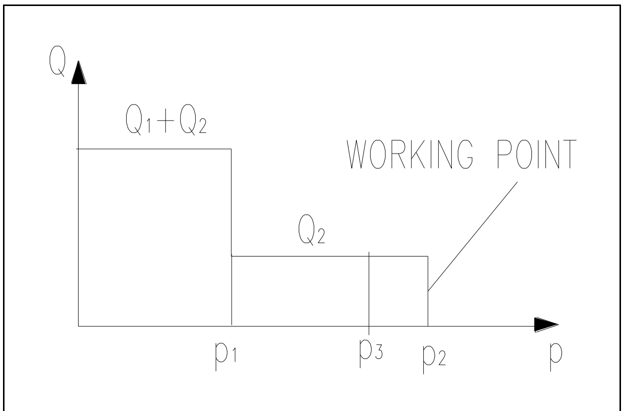

Fig. 2. The working point for the clamping phase

2. SUGGESTED MATHEMATICAL MODEL

It is considered that during a normal operation, at a pressure p there is a loss of flow (especially through the rotary distributor) ΔQ proportional to the pressure, so we can write:

$$\Delta Q = K \cdot p \tag{1}$$

We shall consider the coefficient of proportionality lost flow - pressure, noted K, as being constant, specific to the rotary distributor.

The accumulator of volume V_0, initially charged at pressure p_0, contains oil at pressure p, in the proximity of pressure p_2. It will be discharged until reaching pressure p_0; then the supplied flow becomes 0. The discharge is isothermally made, according to the relation:

$$V_0 \cdot p_0 = V \cdot p \tag{2}$$

In relation (2), V is the gas volume at the pressure existing when the discharge begins. The volume of oil available between the pressures p and p_0 is:

$$\Delta V = V_0 \cdot \left(1 - \frac{p_0}{p}\right) \tag{3}$$

The rotary distributor losses will have an average value:

$$\Delta Q_{p \to p_0} = K \cdot \frac{p + p_0}{2} \tag{4}$$

From the relations above we get:

$$\Delta Q_{p \to p_0} = \frac{\Delta Q}{p} \cdot \frac{p + p_0}{2} \tag{5}$$

ΔQ loss, on the drainage path shown in fig. 1, can be determined experimentally. In these circumstances it may be:

$$\Delta V = \Delta Q_{p \to p_0} \cdot t = \frac{\Delta Q}{p} \cdot \frac{p + p_0}{2} \cdot t \tag{6}$$

According to the relation above, the discharge time of the accumulator t, if there are not other significant losses, will be:

$$t = \frac{\Delta V \cdot 2p}{\Delta Q \cdot \left(p + p_0\right)} \tag{7}$$

For the unit described above, we obtain t ~ 3 min. So, even in total absence of pumps flow, the working piece is clamped for more than 3 minutes.

3. SYSTEM STUDY BY SIMULATION [4]

At the present moment, the design of such systems is facilitated by the existence of special programs for calculation of electro-hydraulic units in dynamic mode.

For the values mentioned above, in the phase of clamping start, we obtained the feature pressure depending on flow as per fig. 3.

One can notice that after 3 s approximately, the clamping was done and confirmed by the pressure relay PS_1 (30 bar). After about 60 s, the maximum value of 45 bar has been reached, and the accumulator has been properly charged.

Next, to determine the period of time when the clamping is done by accumulator only, we simulated, starting from second 62, a loss of pressure source (because of burst pipes, power failure, etc.).

In fig. 4 is shown pressure dynamics from maximum value (p_2) up to minimum acceptable value (p_3). According to fig. 4a and 4b we can see that in the absence of pressure supply the pressure drops from 45 to 30 bar in an interval of about 124 s.

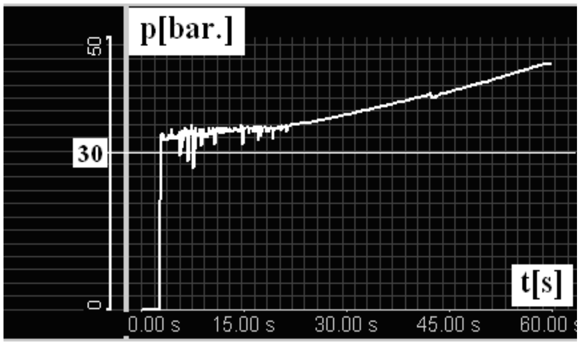

Fig. 3. The feature pressure - flow in the phase of clamping start

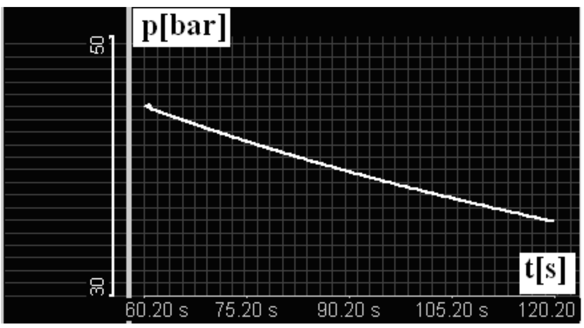

Fig. 4a. Pressure dynamics from maximum value (p_2) up to minimum acceptable value (p_3)

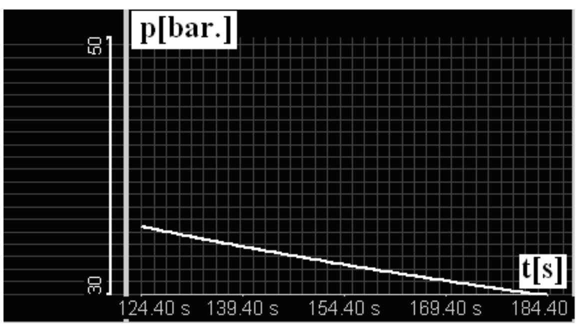

Fig. 4b. Pressure dynamics from maximum value (p_2) up to minimum acceptable value (p_3)

In conclusion, we can say that the semi-finished product is clamped in conformity with the imposed safety conditions for two minutes. It is enough time to stop the main spindle [5], without supplementary interventions or by using brakes.

For the previous calculation and the simulations above, we took into consideration a loss of flow of 1.5 l/min at the rotary distributor. It is obvious that the simulation in dynamic mode offers results closer to reality. After manufacturing the unit, the measurements done showed us that the real discharge time is about two minutes.

4. EXPERIMENTAL ACHIEVEMENTS

Fig. 5 shows a rotary distributor, used for railways wheels vertical lathes. This is the distributor used in the diagram of fig. 1.

The paths A and B make the clamping – unclamping of the semi-finished products. Any loss is recovered through the drain D. The distributor is placed on the hydraulic motor C that drives the jaws.

Fig. 6 shows a hydraulic cylinder and its inputs. The rotary distributor 1 is assembled on the linear hydraulic cylinder 2, A and B are corresponding holes. The entire assembly is fastened to the faceplate of fig. 7.

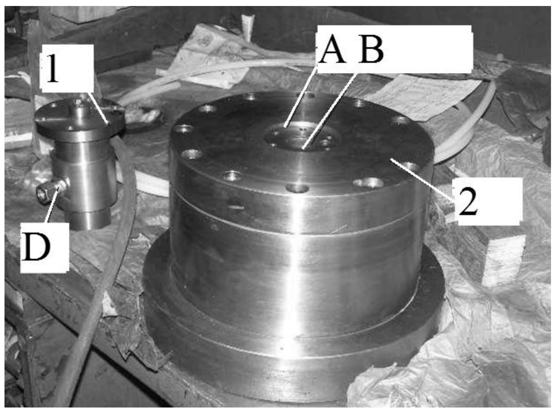

Fig. 5. Rotary distributor

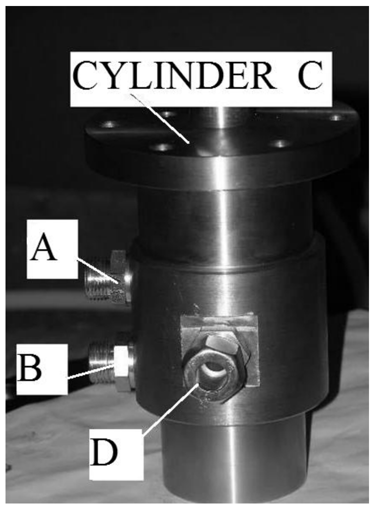

Fig. 6. Clamping-unclamping hydraulic cylinder

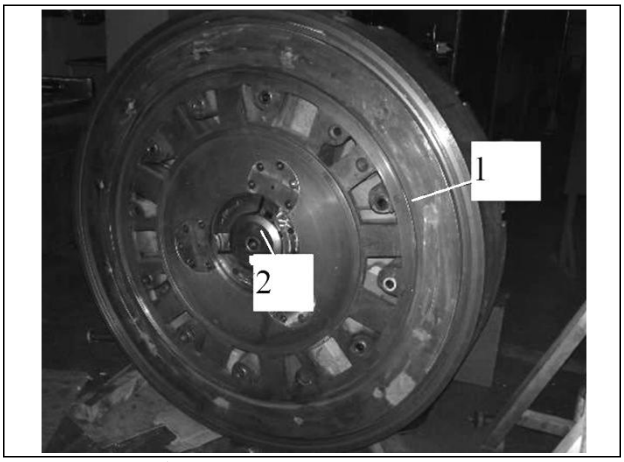

Fig. 7. Faceplate of vertical turning lathe

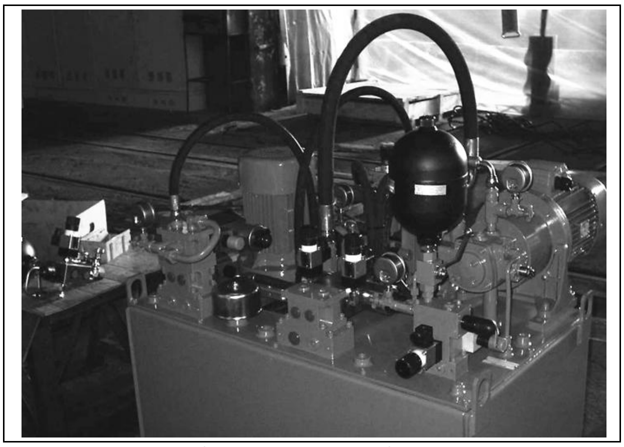

Fig. 8. Hydraulic unit for driving the semi-finished product clamping-unclamping

Faceplate 1 receives the rotation movement from a toothed belt transmission and the linear hydraulic motor is fastened to flange 2, which enables its rotation together with the distributor piston. Its body is fixed.

The unit shown in fig. 8 was made according to the diagram in fig. 1. The unit includes, on the same tank, the ram counterbalancing system.

Fig. 9 shows the complete schema of the installation.

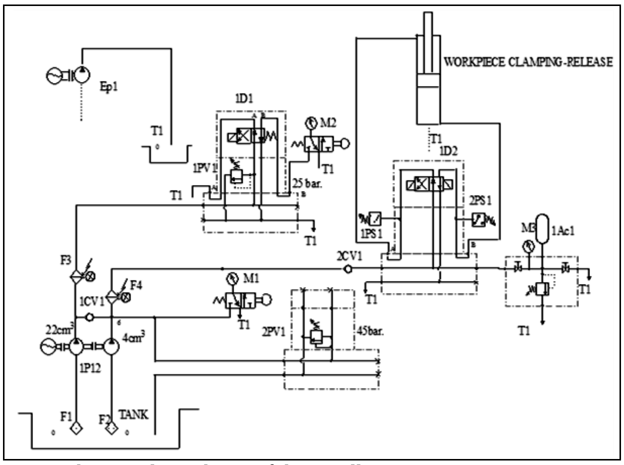

Fig. 9. The complete schema of the installation

There is a double pump 1P12 on the tank that works all the time. The distributor 1D1 connects and disconnects the high flow pump (22 cm^3/rot), which works at 25 bar, pressure regulated by the pressure valve 1PV1. The small flow pump works at 45 bar, pressure regulated by the pressure valve 2PV1.

The distributor 1D2 selects the operation of clamping-unclamping of the jaws. Uncoupling the high flow pump is made by the pressure relays 1PS1 and 2PS1. At the end of the phase, the jaws are kept in position (clamped or unclamped) by the gas-loaded accumulator 1Ac1 [3].

The check valves 1CV1 and 2CV1 close parts of the circuit. The oil enters in the double pump through the filters F1 and F2 and it is filtered in the circuit by the pressure filters F3 and F4.

The pressure in different parts of the circuit could by check on the manometers M1, M2 and M3. Any loss in the rotary distributor is recovered by the electro-pump Ep1.

5. CONCLUSION

The existence of the accumulator is compulsory for the systems of clamping and blocking. It can provide the coverage of potential losses.

The calculation of such a system requires knowledge of some coefficients, such as the coefficient of proportionality K above. Usually these coefficients will be determined experimentally.

The calculation method presented can be an important basis for pre-sizing or verification. The accumulator sizing depends on a series of objective factors but also on designer's "courage", we must admit it. A closer relationship between theoretical and experimental results can be achieved by means of simulation.

Those clamping systems of the semi-finished products are recommended whenever it is required a strong, reliable and fast clamping.

Following the trend of integrated conception of the machine tools [6], those clamping-unclamping systems can be typified for different classes of machines.

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