

HYDRAULIC INSTALLATIONS FOR HEAVY MACHINE-TOOLS

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Abstract: This paperwork presents the most frequent applications of the hydrostatic drives on heavy machine-tools and tries to modularize them. The focus is on CNC heavy machine-tools that have been manufactured after year 2000. Hydraulic drives are used for heavy duty machine-tools when a high power density is required, especially for the auxiliary kinematic chains: locking, toolholder or workpiece clamping/unclamping, balancing of vertically moving loads, compensation of geometric errors etc.

Keywords: heavy machine-tools, hydrostatic drives

1. INTRODUCTION

The machine-tools approached within this article are: heavy horizontal lathes (NL) and vertical lathes (VL), gantry milling machines (G), horizontal boring mills with or without quill (AF or AFP) and some special heavy machines (SMU).

At present, the hydraulic installations designed for these machines belong to some systems that are not involved directly in the driving of the generating kinematic chains [1], such as the main and the feed kinematic chains. The hydraulic drive which is characterized by a high density of power and by the capability to develop high forces seems to be at present irreplaceable in some of the specific applications. Some of these applications are going to be presented hereinafter.

2. CLASSIFICATION OF THE HYDRAULIC DRIVING SYSTEMS USED ON HEAVY MACHINE-TOOLS

For the machine-tools mentioned above, the hydraulic drives are often met under the working conditions shown within the Table 1.

No matter the function they meet, the hydraulic systems that are used can be presented as shown in Figure 1.

The source of hydraulic power is the pump HS, that can have a constant (PCF) or variable (PVF) flow [2]. It provides a flow Q and it is subjected to a pressure p . Usually, the pressure and the flow have the values shown in the Table 1. In order to accomplish the function, at the level of the final element which usually is a linear hydraulic motor (HM or C), the values of the used flow Q_u and working pressure p_u , are adjusted within the hydraulic system HI by the control and distribution equipment [2]. The adjustment can be made initially or during the operation, usually by means of the Control Equipment. In some cases, there are provided position or speed transducers T1 which close the loop for the automatic systems. The adjustment can be made also through the pressure control loop, if variable flow pump with pressure regulator and specific transducers T2 are used.

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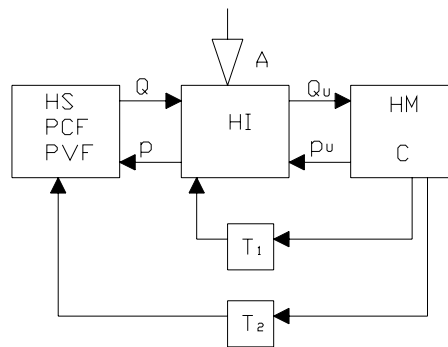


Fig. 1. The hydraulic system.

Table 1. The hydraulic systems for heavy machine-tools.

No.	FUNCTION	Working pressure at source [bar]	Required flow at source [l/min]	Working mode	Machine-tools	Remarks
1.	Toolholder clamping/ unclamping	60 - 160	6	Intermittent or continuous	All	Most of them has hydraulic unclamping and mechanical clamping
2.	Locking and Unlocking on axes	30 - 210	2 - 10	Intermittent or continuous	All	CNC machine-tools have hydraulic locking and unlocking on axes
3.	Switch of speed range at the gearbox	30 - 50	10 - 16	Preferably intermittent	All the machine that have not typified gearbox with electric switching on and off	
4.	Backlash compensation	15 - 60	2 - 16	Continuous	Majority	For the axes provide with pinion-rack or pinion-crown gear mechanisms
5.	Indexers drive	30 - 80	6	Intermittent	VL, G	Only if the crossrail movement is not a working axis
6.	Weight balancing on vertical direction	30 - 120	10 - 120	Continuous	All	Preferred solution to all CNC machine-tools
7.	Compensation of geometric errors	> 100	2 - 10	Continuous	AFP	It could be correlated with the balancing
8.	Hydrostatic bearing	50 - 60	6 - 60	Continuous	AFP, G VL (with table over 5000 mm)	Excepting the VL, it is about hydrostatic system on feed kinematic chains. For large VL it is on main for turning and on feed for milling

3. HYDRAULIC EQUIPMENT USED FOR HEAVY MACHINE-TOOLS

In most cases, the used pumps are driven by 3-phase electric motors with 1470 rpm speed at 50 Hz. The types of pumps frequently used on heavy machine-tools are presented in Table 2.

Table 2. The types of pumps frequently used on heavy machine-tools.

No.	Pump type	Flow [l/min]	Usual pressure [bar]	Adjustment possibility	System type	Remarks
1.	Gear	max. 30 - 40	max.200	No	All	Usually with external teeth. Lowest price.
2.	Vane	max. 100	max.160	Yes	Balancing. Rare, others	Those with pressure regulator are to be preferred. Price is acceptable
3.	Axial piston	max. 200	max. 320	Yes	Balancing	Those with pressure regulator and tilting disk are preferred. Price - highest.
4.	Radial piston	max. 2 - 5	max. 600	No	Lockings	Rarely met installations.

The gear pumps are the most often used – in 85 – 90% of the cases, one of the reasons being their low cost. If the pressures and flows required are high, then the lost power is around 4-5 kW, and thus, the pumps with regulator – usually those vane and simple action – are preferred [3]. The main types of hydraulic equipment used for machine-tools are shown in Table 3.

Table 3. The main types of hydraulic equipment.

No.	Equipment type	DN [mm]	Control/ Adjustment	System type	Remarks
1.	Pressure adjustment valve	6 - 32	Manual	All	
2.	Pressure reducing valve	6 - 10	Manual	Hydrostatic bearing, balancing, other functions	It gives flow loss
3.	Proportional reducing pressure valves	6	Electric(+10V)	Errors compensations	Controlled by CNC. They require special filtration.
4.	Directional control valves	6 - 10	Electric 24V cc.	All	Electromagnets with 100% load.
5.	Check valves	6 - 32	-	All	Opening at minim pressure
6.	Unlockable check valves	6 – 10	-	Switching of the speed, toolholder clamping/unclamping	Modular with opening at minim pressure
7.	Throttles	6 - 32	Manual	Hydrostatic bearing, accumulators discharge, speed range change speed adjustment, indexing of flows	Way or plate type, with or without check valve
8.	Flow regulators	6 - 10	Manual	Hydrostatic bearing and rarely for feed kinematic chain	Plate type with 2 or 3 ways
9.	Pneumatic-hydraulic accumulators	-	-	Locking/unlocking systems, balancing, discharging, wherever pre-control systems are provided [2].	Within the range 0.5-10 L, with safety block and observing the international standards.

Table 3. Continuation.

No.	Equipment type	DN [mm]	Control/ Adjustment	System type	Remarks
10	Pressure switch	-	Manual	All	Assembling on the way or plate. It confirms a control. Those with reduced hysteresis are preferred.
11.	Filters	-	-	All	Electric confirmation of the clogging for the pressure and return filters.
12.	Pipes, hoses, plates	6 - 32	-	All	Special steel pipes, pressure hoses and plates according to the equipment used.
13.	Tanks	-	-	All	Typified tanks can be used for small volumes, up to 10 L. Larger tanks – welding construction – are preferred for larger volumes.

The selection of the optimum linear hydraulic motor is done by the mechanical and hydraulic designers. The selection of the hydraulic equipment is to be done by the hydraulic designer [4, 5]. The selection is based on technical criteria, but also on economic grounds. The cost of the hydraulic installations depends on the size and complexity of the machine tool and varies within 1000 and 100,000 Euro.

4. HYDRAULIC SYSTEMS FOR HEAVY MACHINE-TOOLS

Roughly, there are two ways to approach the design of the hydraulic installations of the heavy machine-tools:

- V1 - a reduced number of pumps, even just one HS, to ensure the required functions, with adjustments specific for each one, HI1-HIn and the driven working elements FW1-FWn;
- V2 – distribution of the functions on several pumps HS1-HSn, usually making the pressure adjustments required for each of the systems HI1-HIn, which operate the working elements FW1-FWn.

The diagrams in Figure 2 show these two variants.

Table 4 presents the advantages and disadvantages of the two variants.

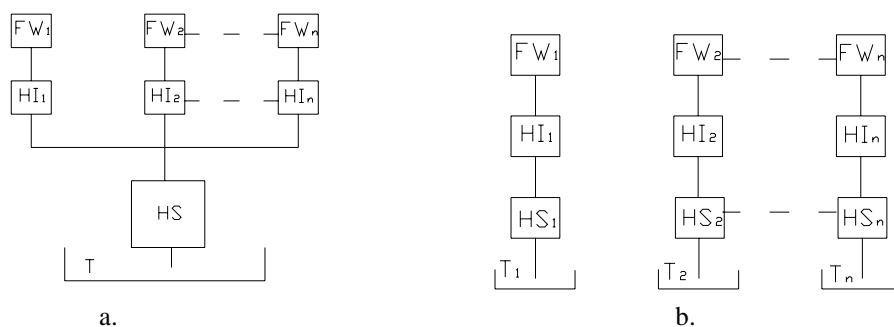


Fig. 2. The ways to approach the design of the hydraulic installations of the heavy machine-tools.

Table 4. The advantages and disadvantages of the two variants.

No.	Advantages	Disadvantages
V1	A reduced number of pumps and electric motors. Less tanks. Noise concentrated in a limited area.	A higher number of adjusting components. Interconditionings. The pump and the electric motor dimensioned to the maximum values of flow and pressure which leads to a low efficiency. Equipment with different DN on each system. The pump will operate continuously. Any intervention should be made only after the full stop of the machine [6].
V2	A reduced number of adjusting equipment. The pumps and the electric motors dimensioned for each function. The required interventions can be made without the full stop of the entire installation. Each installation has its suitable DN. Only the requested pump operates.	A larger number of pumps and electric motors. More tanks. The power supply (motors) system is more developed.

Of course, there are cases where intermediate variants are adopted, where the functions are grouped on the optimum source. The design of the installation results by grouping the functions, but also taking into consideration the location on the machine. An optimal cooperation between the mechanical designer and the hydraulic one could lead to a reduced number of working pressure values on the machine and therefore to a simplification of the installation and a decrease of the costs [4]. The paperwork presents a summary of the authors' theoretical and practical research in the field of these machine-tools. An upcoming paperwork will present some examples of modularization of the hydraulic installations intended for the heavy duty machine-tools: compensation of geometric errors, balancing systems, toolholder clamping/unclamping etc.

5. CONCLUSIONS

The hydraulic drives are successfully used to accomplish various functions on heavy machine-tools. These functions are: toolholder clamping/unclamping, working axes locking/unlocking, switching of the speed range in the gearbox [5], backlash compensation, indexers actuation, vertical balancing of the weights, geometrical errors compensation and hydrostatic bearing. These functions can be brought together on the same schematic, as previously shown. When putting into practice, the constructive particularities of the machine should be taken into consideration to avoid too long hoses and cable carriers. By increasing the working pressure, the size of the hydraulic equipment is reduced, and consequently the price. When dimensioning the hydraulic equipment components it is recommended to use specialized software of simulation under dynamic condition.

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