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HIGH PRESSURE COOLER FOR CUTTING TOOLS AND WORK PIECES

Dan PRODAN[1,*], George CONSTANTIN[2], Anca BUCURESTEANU[3]

[1, 2, 3)] Prof., PhD, Eng., Robots and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania

Abstract: *This paper presents a part of the theoretical and experimental researches carried out on the design and realization of a high-pressure cooling installation for turning centers. Besides the general theoretical aspects, adaptable to most of the existing machine tools, the work emphasizes especially those of modern machine tools (CNC), which are processing with high cutting speeds, in the case of series and mass productions. The projected and designed installation is designed for a turning machining center based on a SC14 vertical lathe and allows the tool and the semi-product to be cooled by program control from the outside of the tool and, where appropriate, through the inside of the tool. The authors present some aspects of the necessity and the advantages of using this installation, and also the scheme and its construction.*

Key words*: turning machining center, high-pressure cooling equipment, hydraulic installation.*

1. INTRODUCTION

During the cutting process on machine tools, the heat of the contact tool-workpiece is generated [6, 7]. This heat is absorbed by the tool, the blank and dissipated into environment. By using cooling fluids [3, 4, 9], a large part of this heat is removed. Usually, different fluids can be used for cooling, such as water, emulsions, oil or air. The subject of this paper is the presentation of cooling installations using emulsions [3, 4, 9].

2. HIGH-PRESSURE COOLING INSTALLATIONS

The usual cooling installations work at maximum pressures of 10–20 bar. In these cases, the cooling of the tools is done by directing the coolant to the contact area between the workpiece and the tool with the help of some pipes and connections positioned manually, so that the liquid can take some of the heat. In most cases, the flow is manually adjusted by the operator who is directing it subjective way. The installations usually contain a centrifugal pump [5] and the directing and control devices operating at a maximum pressure of 20 bar [2, 3, 9].

The use of high pressures, which may even exceed 100 bar, has a number of advantages that can be mentioned [8]:

- higher machining security,
- consistent machining process,
- fewer machine stoppages,
- better component quality,
- shorter machining times,
- better utilization of machine capabilities.

In the case of turning, the tool holders are provided with calibrated orifices, which direct the pressure liquid to the cutting area as Fig. 1 shows.

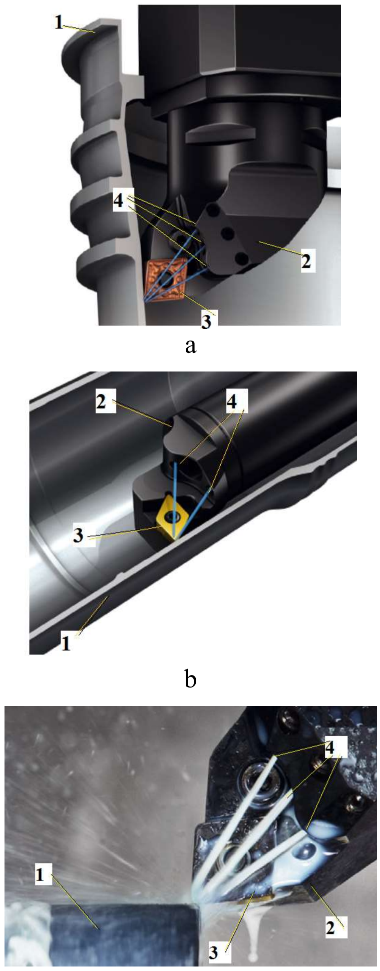


Fig. 1. Tool holders for high pressure cooling systems in turning [7].

[*] Corresponding author: Splaiul Independenței 313, district 6, 060042, Bucharest, Romania
Tel.: 0040 21 402 9174;
Fax: 0040 21 402 9724
E-mail addresses: *prodand2004@yahoo.com* (D. Prodan), *george.constantin@icmas.eu* (G. Constantin), *ancab66@yahoo.com* (A. Bucuresteanu)

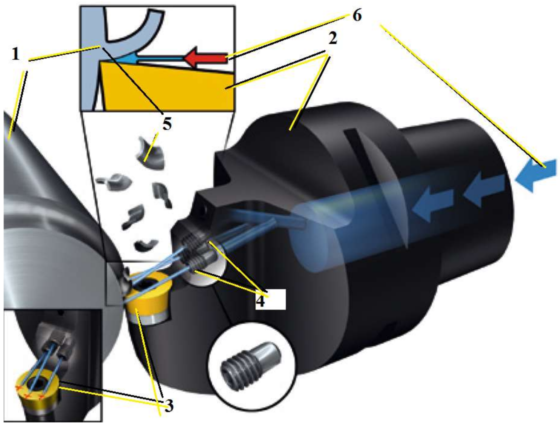


Fig. 2. Turning with high-pressure coolant [7].

For the processing of the blank 1, the plate 3 is attached on the tool holder 2. Through the holes 4 the high-pressure cooling liquid is brought in the cutting area. For these cases, the recommended pressure is 70 bar [8].

In this case, due to this pressure the cooling fluid behaves like a wedge (hydraulic wedge) that penetrates beneath the forming chips on the shearing plane helping to break it as Fig. 2 shows.

In Fig. 2, besides the previously used notations, we can meet also 5 – chips, 6 – high-pressure cooling system.

The flow rate that ensures good cutting in this case has the expression:

$$Q_U = C_D n \frac{\pi d^2}{4} \sqrt{\frac{2p_1}{\rho}}. \quad (1)$$

In relation (1) it is noted: Q_U – useful flow, C_D – throttling constant (0.7–0.8), n – number of holes, d – hole diameter, p_1 – pressure at which the orifices are fed, ρ – density of the cooling liquid.

The cooling liquid velocity at the exit of the holes will be:

$$v = C_D \sqrt{\frac{2p_1}{\rho}}. \quad (2)$$

It is recommended that the pump flow rate Q_P to check the relationship:

$$Q_P > Q_U. \quad (3)$$

The tank will have a minimum volume $V_{\min}$ that can be obtained with relation [2]:

$$V_{Min} = 5Q_P. \quad (4)$$

In relation (4) the flow rate is expressed in [l/min] and the volume in [liters].

After setting the pump, if necessary, the power of the electric drive motor is checked with:

$$P_{EMP} \geq \frac{p_{Max} Q_P}{450}. \quad (5)$$

In the above relationship we have noted: P_{EMP} – power of the pump drive [kW], $p_{\max}$ – maximum pressure in the system [bar], Q_P – pump flow rate [l/min]. At present, most manufacturers of such pumps provide the complete characteristics: speed, flow, pressure and power, and this last verification is not necessary.

3. HYDRAULIC SCHEME OF THE INSTALLATION

The designed and accomplished installation is destined to serve a vertical turning center [1, 6, 7], which processes parts specific to aviation industry.

For processed parts, classic cooling is also required at a pressure lower than 10 bar, but in some phases cooling is required at a pressure of 70 bar.

The basic element of the installation is the high pressure pump. This must supply a maximum flow Q_P = 30 l/min at maximum pressure $p_{\max}$ = 70 bar. The chosen pump Hydra-Cell is made by Wanner Engineering and is shown in Fig. 3. The pump is served by an adjustable pressure valve supplied by the same manufacturer [2, 5].

Pump 1 works immersed in the coolant. The maximum pressure is adjusted by means of the pressure valve 2. The pump is a special construction [5] with pistons that work in an oil bath. Its level is viewed with the level indicator 3. The pump selection was performed according to the diagram in Fig. 4.

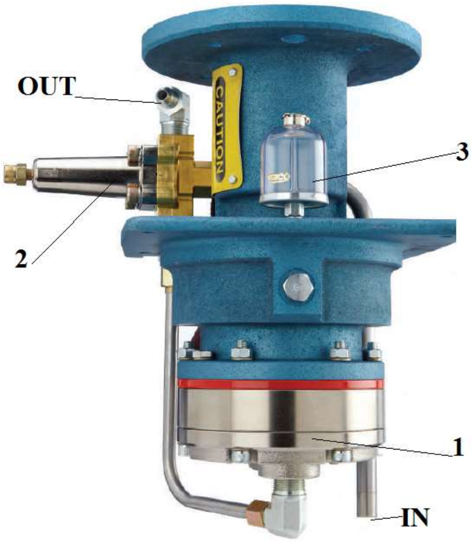


Fig. 3. High pressure pump (1 – body; 2 – pressure valve; 3 – level indicator; IN – liquid intake; OUT – liquid evacuation) [Wanner Engineering].

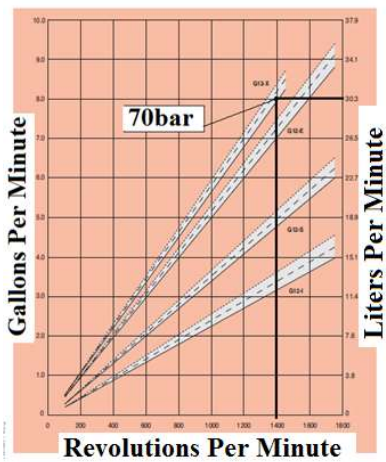


Fig. 4. Diagram for pump selection [5].

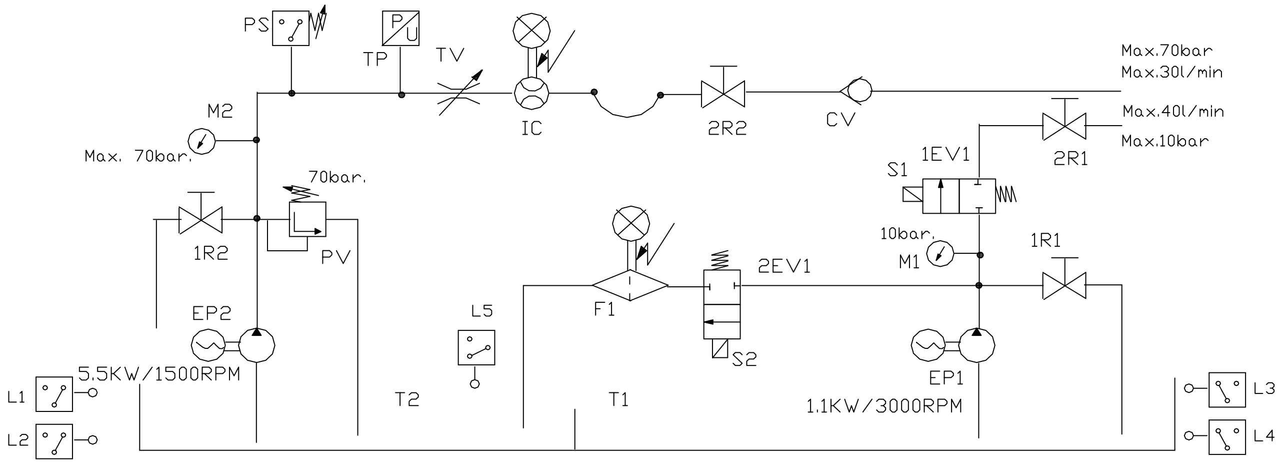


Fig. 5. Hydraulic scheme of the cooling system (EP1 – low pressure electric pump; EP2 – high pressure electric pump; PV – pressure valve; T1 – low pressure pump tank; T2 – high pressure pump tank; 1R1,2R1 – low pressure valves; 1R2,2R2 – high pressure valves; F1 – filter; M1, M2 – pressure gauges; PS – pressure relay; TP – pressure transducer; 1EV1, 2EV1 – electrovalve; S1, S2 – electromagnets; CV – directional valve; L1, L2, L3, L4, L5 – electric level indicators).

Table 1

Functioning cycle chart

Nr.	PHASE	EP1	EP2	S1	S2	M1	M2	PS	TP	IC
1	STOP	–	–	–	–	–	–	–	–	–
2	Max 40 l/min Max 10 bar	+	–	+	–	0–10	0	0	0	0
3	Max 30 l/min Max 70 bar	+	+	–	+	0–5	30–70	+	5–70	5–70

The elements that make up these pumps are made of stainless steel, ceramic matrix and rubber. Screw pumps [2, 5] can also be used for such installations.

The hydraulic scheme of the whole installation is shown in Fig. 5.

The installation provides flow rates of up to 40 l / min and a maximum pressure of 10 bar or maximum flow rate of 30 l/min at a maximum pressure of 70 bar, according to the cycle chart in Table 1.

If working at low pressure, only the EP1 electropump is started and the electrovalve 1EV1 (S1+) is activated. The flow and pressure are adjusted by means of the 1R1 and 2R1 valves [3].

For cooling at over 30 bar, both electropumps are started and the 2EV1 (S2 +) electrovalve is activated. The EP1 electropump ensures the passage of the liquid through the F1 filter to the high pressure pump reservoir by means of electrovalve 2EV1. This works at the pressure set on the PV pressure valve. The flow rate is adjusted using the TV throttle. Its value is read using the flow indicator. The minimum pressure (30 bar) is confirmed by the PS pressure relay. The pressure value at all times is indicated by the TP pressure transducer. Keeping the liquid column after the machine is switched off is provided by the SS valve. The level indicators L1–L5 maintain the required levels in the two pools. The F1 filter provides the filtering requirements of the pump shown in Fig. 3.

4. SIMULATION OF THE OPERATION OF THE HIGH-PRESSURE COOLING SYSTEM

Before the installation assembling and after the necessary components were set up, simulation of the operation of the installation was carried out using the AUTOMATION STUDIO program [10].

It took into account the characteristics of the pump, throttle valve and pressure chosen, but these data were correlated with the number of holes of toolholders used and their diameters.

The pressure valve was set at a maximum pressure of 70 bar. According to the relation (1), for the tool with a single cooling hole of diameter $d = 1$ mm, it is necessary to set the value of 5.2 l/min at the throttle. For this adjustment, the flow and pressure evolution at the pump level after the pressure valve adjusted to 70 bar is shown in Fig. 6.

For the considered adjustment, at the exit of the cooling hole in the tool holder the flow and the pressure evolve as Fig. 7 shows.

Following the simulations, it has been established that the projected installation meets the flow and pressure requirements specific to the tool holders used.

5. HIGH-PRESSURE COOLING INSTALLATION FOR THE TURNING CENTER

The installation is shown in Fig. 8, keeping the notations used in the hydraulic scheme in Fig. 5.

The total volume of T1 and T2 tanks is 420 liters. They are separated by a plate that only allows the filtered liquid to be discharged from T2 to the unfiltered liquid from T1. The electro pump EP1 is centrifugal [5] and provides a maximum flow of 40 liters / min. It is used for pressure cooling up to 10 bar. The EP2 is a special construction with pistons [2, 5] and can work at a maximum pressure of 70 bar. Electrovalves 1EV1 and 2EV1 work only at low pressure and are controlled at 24

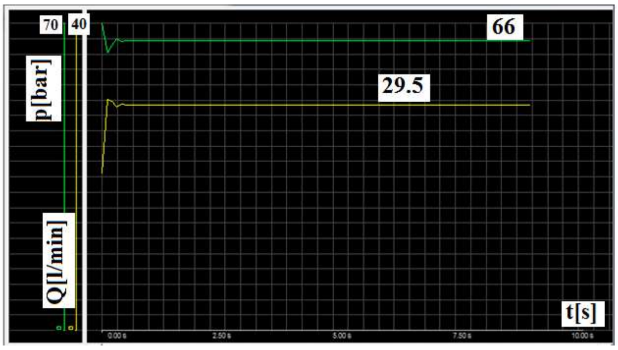


Fig. 6. Evolution of pump flow and pressure in time.

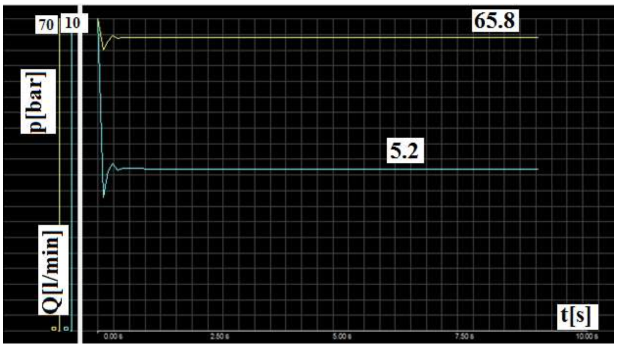
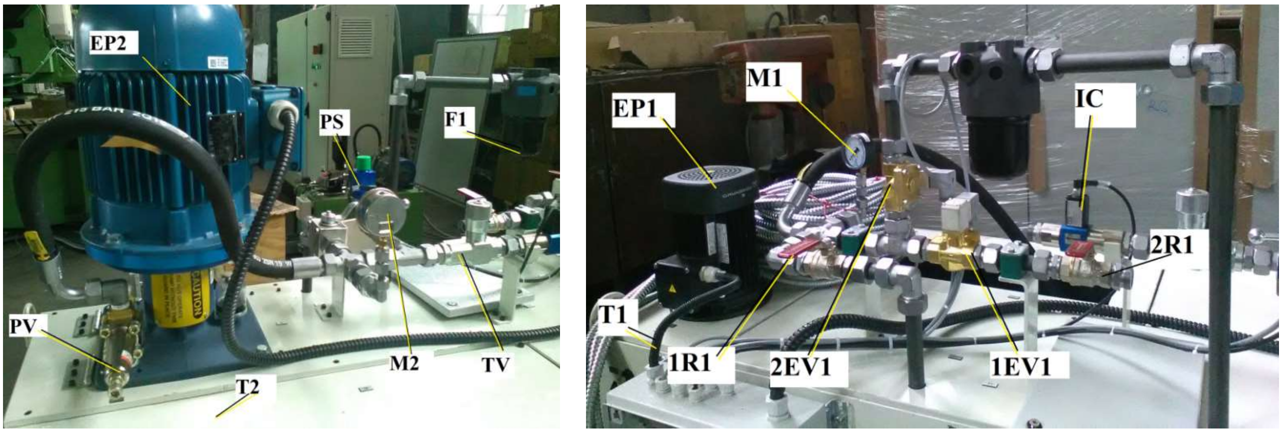


Fig. 7. Evolution of tool flow and pressure in time.



a b

Fig. 8. The cooling installation.

Fig. 9. Airplane turbine elements processing on a turning center.

V DC voltage. The installation can serve different types of machine tools [1, 6, 7] using tool holders and tools for high-pressure cooling operations.

The mounted installation serves a turning center, which processes airplane turbine elements. Figure 9 shows the cooling at a maximum pressure of 70 bar for a single hole of the tool holder used in these machining operations.

The installation can also serve other machine tools [1, 6, 7, 9] such as milling machining centers, grinding machines, etc.

6. CONCLUSIONS

Modern machine tools are designed for high-speed cutting, with high precision and high productivity. Cooling of tools and work pieces is done in these cases with special installations that work at high pressures and flows, controllable by CNC machine equipment. The liquid used in addition to cooling also ensures that the forming chips break by the effect of hydraulic wedge.

Cooling installations in this case include special equipment (pumps, valves, transducers, etc.) that are not normally required for cooling installations working at pressures of up to 10 bar.

The cooling fluid must be filtered according to the requirements of the equipment and tool holder-tool used.

For processes that do not require high pressure, it is recommended also that the plant to include the necessary equipment for these cases.

Due to the high pressure and flow rates, there are liquid vapors and even a specific haze in the work area. These must be recovered by a specific suction-recirculation system that has to be adapted to the machine housing system.

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