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HYDRAULIC DEVICE FOR SIMULATION OF PRESSURE SHOCKS

Stanislav LINDÁK*, Radoslav MAJDAN, Ivan JANOŠKO, Miroslav PAP, Mário SZABÓ
Slovak University of Agriculture in Nitra, Slovak Republic

This work is focused on the design of a hydraulic device on which simulations of pressure shocks can be performed. The hydraulic device was constructed to allow simulations of pressure shocks transferred directly in operating conditions because simulation programs for hydraulic accumulators have only theoretical values while simulation on the designed hydraulic device enables obtaining specific readings directly in operating conditions that can be set. At the first control measurement on the hydraulic device, there occurred pressure shocks generated by the hydraulic device itself, these pressure shocks being undesirable in hydraulic circuits. In order to eliminate pressure shocks in the circuit, a diaphragm accumulator was added to the hydraulic device and was used to verify the function of simulating pressure shocks and eliminating undesirable pressure shocks. During the second control measurement on the hydraulic device, a reduction of unwanted pressure shocks was shown with the help of added diaphragm accumulator, thus the function of the hydraulic device to simulate pressure shocks was confirmed, which may also reflect practical application in hydraulic circuits of mobile machines.

Keywords: hydraulic device, simulation, operating conditions, pressure shock, application

There are currently high demands on hydraulic circuits. Their reliability, technical level, effectiveness and safety are paramount and monitored during operation. Every single part of the hydraulic circuit must therefore comply with requirements, standards and function that take in circuits. This work brings the design of circuit for simulation of pressure shocks that may occur in hydraulic circuits of mobile machines. It is also aimed at damping of pressure shocks during operation in the hydraulic circuit. In general, the best way is to reduce pressure shocks at their beginning, thus to correctly assume respective fluid velocities in pipes and to size the system so as to prevent their formation. Under certain operating conditions, pressure shocks are impossible to be completely eliminated by hydraulic circuit design itself. Such being the case, the only option is to install damping elements. One of the methods of installing the damping element is using the hydraulic accumulator. In terms of using the hydraulic accumulator in the circuit, the most important is to know the operating characteristics of the circuit. A correct choice of the hydraulic accumulator type and size for the given circuit enables achieving the proper function of the entire hydraulic circuit. In our case, it is reaching a substantial pressure reduction at the beginning of pressure shock. In addition to the design of device for simulating pressure shocks, there was also designed a particular type of hydraulic accumulator that can dampen pressure shocks in hydraulic circuits using a nominal pressure of 20 MPa, which is a value often used in practice.

All systems containing liquid flowing through pipes may experience pressure pulses at the change of flow rate. This phenomenon is caused by the fact that changes in kinetic energy of liquids are converted into pressure changes. These are then spread in the form of waves in liquids and may cause irreparable damage to installation. The causes leading to formation of pressure shocks include:

- closing and opening of valves;
- shutdown or start of pumps;
- filling or discharging of system;
- mechanical vibration of system and its components.

Simulation programs for circuits with hydraulic accumulator are not completely stable; therefore, a specific application of the hydraulic accumulator is verified in given conditions such as temperature, pressure, flow rate, which the device allows setting. After assembling the designed test device, the course of cyclic pressure load was compared with the course that was determined in advance. For this purpose, there was used a pressure transducer and recording unit Hydac HMG 2020 for recording of measured data (Tkáč, 2010). The choice of the hydraulic accumulator and its subsequent application served for verifying the function of the hydraulic circuit for simulation of pressure shocks, and it also presents a practical application to eliminate pressure shocks in hydraulic circuits of mobile machines.

Material and methods

The simulation of pressure shocks was carried out on the test device that was prepared based on determined course of pressure with given parameters. Values measured on the test device were compared with the interval of values set in advance. The time course of cyclic pressure load, which was set in advance, is shown in Figure 1. This course reflects an increase in pressure from the minimum value to the nominal value of 20 MPa of the hydraulic gear pump. A pressure shock frequency of 1.25 Hz was chosen with respect to operating measurements of pressures in hydraulic circuits of tractors (Kosiba et al., 2010, 2012a, 2012b).

The construction of the device for simulation of pressure shocks is based on the concept of a device intended for lifespan tests of hydraulic gear pumps (Tkáč et al., 2005; Petranský et al., 2004a; 2004b; Škulec et al., 2001).

The hydraulic gear pump manufactured by Jihostroj Aero Technology and Hydraulics was used in the test device

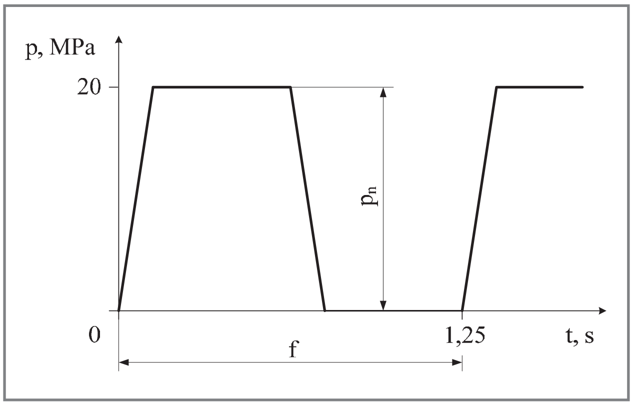

Figure 1 Time course of cyclic pressure load

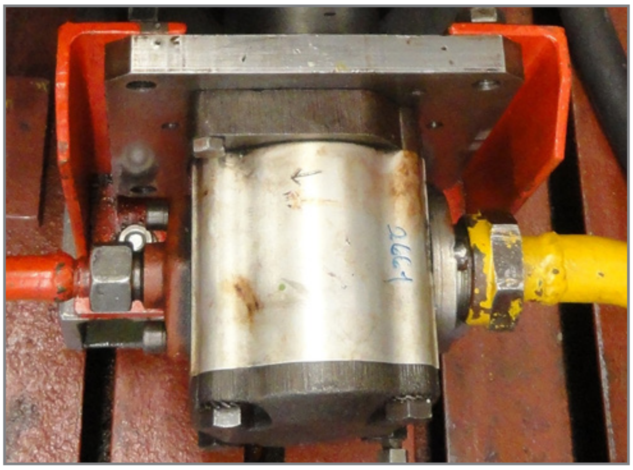

Figure 2 UD 25 hydraulic gear pump
Source: Jihostroj, 2007

(Figure 2). The UD 25 hydraulic gear pump is equipped with a pressure compensation of axial float, which is directly implemented by facial sealing in bearing fronts. It is used in small and medium-sized farm and building machinery. The technical parameters of the UD 25 hydraulic gear pump are shown in Table 1.

The diaphragm accumulator 210 SBO – 0.32 E1 by Hydac Ltd. (Figure 3) was added to the circuit. Nitrogen was used as gas filling in the accumulator, its volume is 0.32 l, operating temperature was set to 50 °C, the minimum working

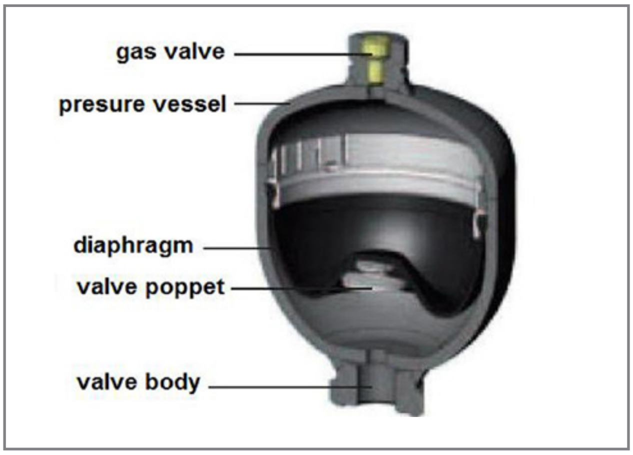

Figure 3 Diaphragm accumulator of SBO 210 – 0.32 E1 type
Source: Hydac, 2012

pressure 4 MPa and the maximum working pressure 25 MPa. The hydraulic accumulator was selected according to operating conditions of hydraulic circuits and the hydraulic accumulator was designed using the program by Hydac Ltd.

Maximum allowable pressure ratio: $p_0 \leq 0.9\, p_1$

Boost pressure for the given hydraulic accumulator type: $p_2 / p_0 = 8 : 1$

For selection of the hydraulic accumulator, it is important to choose a correct equation used to calculate its parameters. The choice is dependent on the duration of hydraulic accumulator charging and its emptying. Whereas in our case, the cycle time period was less than 1 minute, the change in gas state takes place so rapidly that heat exchange with the environment cannot take place. This change of gas state is called adiabatic and is expressed by Equation (1):

$$p \times V^{K} = p_1 \times V_1^{K} = \text{const.} \tag{1}$$

where:
p – pressure, MPa
V – volume, m^3
K – adiabatic exponent; for diatomic gases such as nitrogen, the exponent is K = 1.4

Table 1 Technical parameters of UD 25 hydraulic gear pump (Jihostroj, 2007)

Parameter		**Unit**	**Value**
Speed	rated	min^{-1}	1,500
	maximum		3,000
	minimum		500
Pressure at the inlet	maximum	Pa	0.05
	minimum		0.03
Pressure at the outlet	rated	MPa	20
	maximum continuous		23
Nominal volume (geometric volume) V_G		cm^3	25
Nominal input		kW	14.2

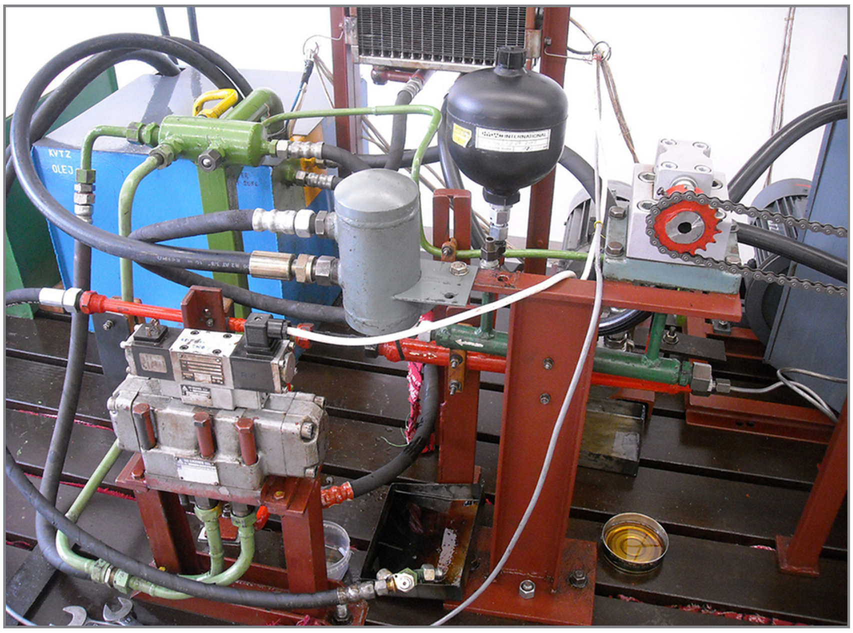

Figure 4 Diaphragm accumulator in hydraulic circuit

Figure 5 Portable data recorder HMG 2020
Source: Hyquip, 2013

The diaphragm accumulator, which was selected for the given circuit using the program, was then connected into the hydraulic circuit (Figure 4).

In the measuring chain of the test device, there was used a pressure sensor of HDA 3800 type by Hydac. This pressure sensor is used to measure the pressure course in the hydraulic circuit. The sensor has a measuring range of 0–60 MPa and an accuracy of 2 %. Sensor signal was transmitted through the adapter to the input of the HMG 2020 unit.

The HMG device was connected to a laptop MicroBook 825d, by which the measurement process was controlled using the HMGDESK program. The program allows following in on-line mode the course of measurement in graphical form and a simultaneous recording of time courses of selected variables. The measurement of pressure course in the hydraulic circuit was performed based on the knowledge published by Drabant et al. (2005) and Vitázek (2005).

Microsoft Excel was used for the evaluation and processing of measured data files recorded by the HMG 2020 device and by the HMGDESK program.

Results and discussion

The device for simulation of pressure shocks consists of components found in most of the hydraulic circuits. It is a hydraulic gear pump (HG) and electro-hydraulically operated directional control valve (RV). In this hydraulic circuit, the electro-hydraulically operated directional control valve is used to block the output flow of the hydraulic gear pump. Pressure shock occurs in this way, which causes an increase in pressure above the nominal value of 20 MPa set on a pressure relief valve (TV2). The circuit further contains a pressure relief valve (TV1) and auxiliary components such as a filter and cooler. The positional change of the electro-hydraulically operated directional control valve is provided by a control block, part of which is a cycler, too.

After selecting the appropriate type of hydraulic accumulator, required values resulting from the given circuit are entered into the ASP 5.0 program by Hydac Ltd. (Figure 7), which evaluates them and chooses the appropriate size and parameters of the hydraulic accumulator for the given circuit.

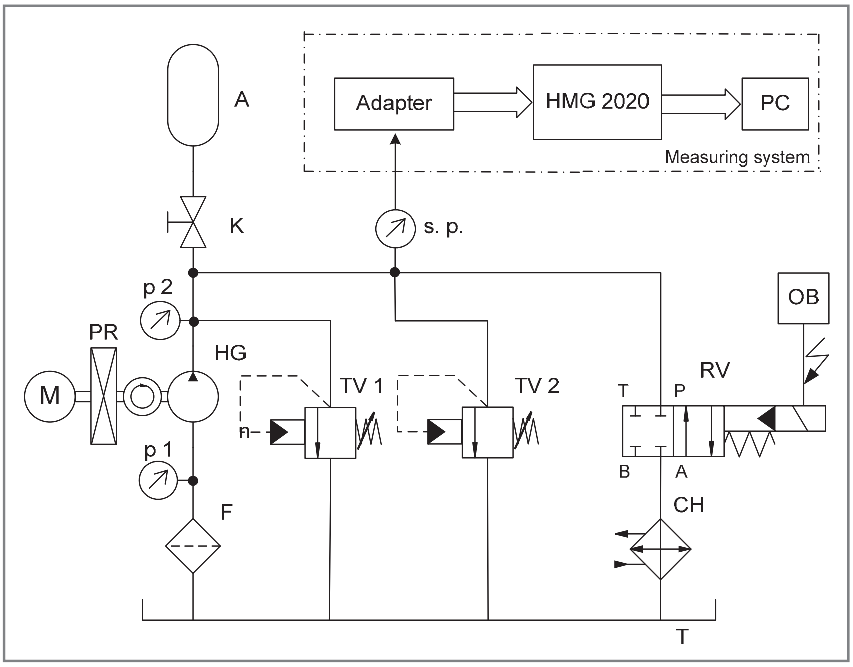

Figure 6 Hydraulic device for simulation of pressure shocks
M – electric motor, n1 – speed sensor, HG – hydraulic gear pump, TV1 – pressure relief valve, TV2 – pressure relief valve to adjust the nominal output pressure of the hydraulic gear pump, p1 – pressure gauge of output pressure, p2 – pressure gauge for vacuum, RV – electro-hydraulically operated directional control valve, CH – cooler, OB – control block, K – shut-off valve, A – hydraulic accumulator, T – tank, F – filter

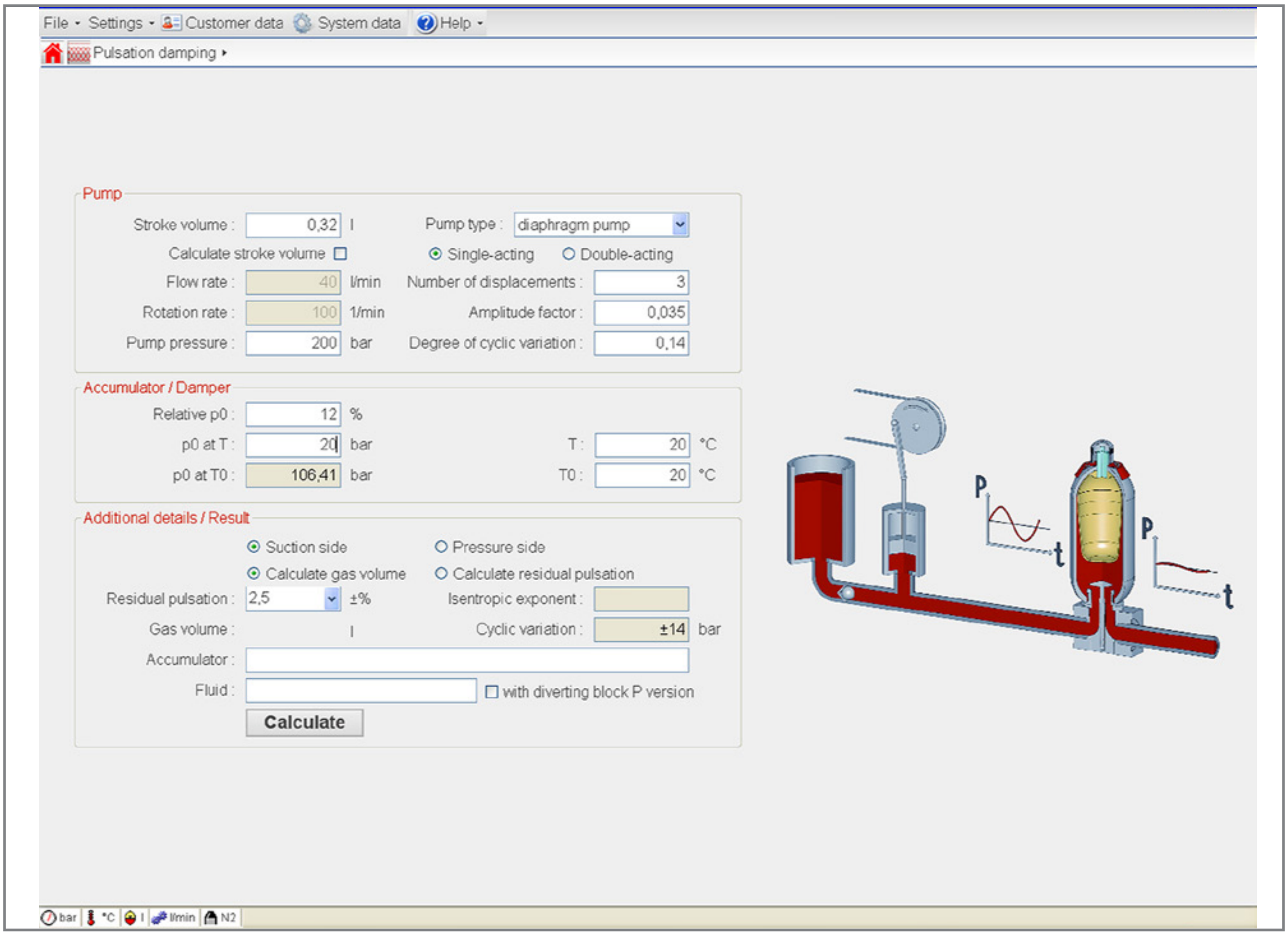

Figure 7 Accumulator simulation program
Source: Hydac, 2012

Pressure shocks were measured in the circuit without the hydraulic accumulator, in particular at the beginning of cycles. These pressure shocks were measured in the designed device. The aim of this work was also to dampen the pressure shocks in the hydraulic circuit using the hydraulic accumulator added to the circuit of the test device. Undesirable pressure shocks created by the hydraulic circuit are captured during measuring in a graph (Figure 8). This graph shows the size and course of pressure shocks at the beginning of cycles.

Pressure shocks recorded in the hydraulic circuit before adding the hydraulic accumulator reached the amplitude of pressure pulses in the range of 16–24 MPa. They occurred at the beginning of cycles and were repeated regularly. After adding the diaphragm accumulator to the test circuit, the measurement was repeated again. The measured values were recorded in the graph (Figure 9). The measurement was focused on the size and course of pressure shocks at the beginning of cycles. These fluctuations of pressure shocks at the beginning of cycles were successfully dampened to 19–21 MPa.

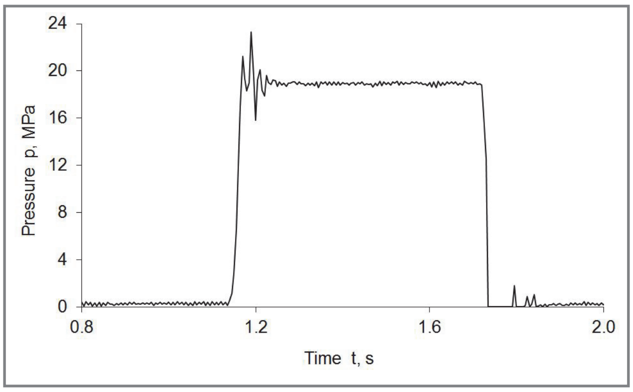

Figure 8 Course of pressure shocks without hydraulic accumulator

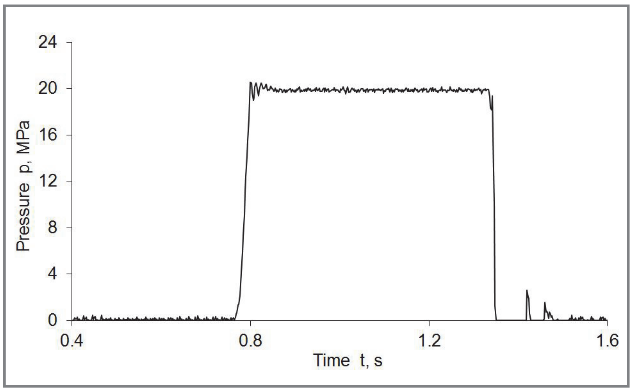

Figure 9 Course of pressure shocks with hydraulic accumulator

Conclusion

During operation in hydraulic circuits, there are undesirable pressure shocks caused by the hydraulic circuit itself that adversely affect every single part of the hydraulic system. In addition to the negative impact on parts of the system, they cause excessive noise, vibration and wear of hydraulic pipe joints. There was designed the device for simulating pressure shocks in laboratory conditions. The aim of this work was also to verify the design of the hydraulic accumulator by which it would be possible to dampen pressure shocks. After adding the hydraulic diaphragm accumulator to the test device, measurements were repeated. During the second measurement on the device with added diaphragm accumulator, it was shown that pressure shocks were successfully dampened at the beginning of cycles. During the second measurement, pressure shocks ranged between 19 MPa and 21 MPa.

The design of the device for simulation of pressure shocks was based on parameters of measured pressure courses occurring during operation in tractors. The advantage of the device is in allowing the use of various types of hydraulic pumps and setting various operating parameters of hydraulic circuits.

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Contact address:
Stanislav Lindák, Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Transport and Handling, Tr. Andreja Hlinku 2, 949 76 Nitra, Slovak Republic, e-mail: stanislav.lindak@gmail.com