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Paper

PRESSURE AND FLOW RATE FLUCTUATIONS

AT HIGH PRESSURE INTENSIFIER PUMPS

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ABSTRACT

The reliability and performance of high pressure pumps are essential for every waterjet cutting equipment. The paper presents the results of measurements of pressure and flow rate fluctuations at intensifier pumps. The recording was done with a flow meter and a high pressure sensor, both suitable for a maximum pressure of 400 MPa. The paper compares the results of hydraulic pressure inside the actuating cylinder at the intensifier as well as high pressure level and flow rate on the discharge connection of the pump. Direct measurement inside the high pressure cylinder and the influence of an accumulator in the high pressure line round out the work.

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1. INTRODUCTION

When designing a high pressure pump for water jet cutting the oil hydraulic unit and the high pressure components are of major importance. Both have an effect on the quality of the output of the pump. Main output parameters are the high pressure and the required flow rate which is depending on orifice size and the operating pressure. Using a pressure sensor and flow meter, suitable for 400 MPa, the dynamics at the outlet can be measured.

To investigate the influence of the accumulator size on the ouput the dampening volume was varied under laboratory condition. The effect of the accumulator is important as the volume influences lifetime of the components within the total high pressure system. Further experiments were made measuring the pressure inside the high pressure cylinder in comparison to the oil hydraulic pressure, to get to know the deviations from the theoretical behaviour. For examination different site tests were made, using typical sequences of pressure curves characteristic for waterjet cutting.

2. BASIS OF HIGH PRESSURE PUMPS

High pressure intensifier pumps are typical for the use in waterjet cutting machines and consist of an oil hydraulic unit which can be hydraulically or electronically controlled. The electronic version can be set up to use flow controlled pumps, suitable also for other fields of applications. The main part of the high pressure pump is the intensifier which is double acting and followed by an accumulator to smoothen the pressure fluctuation arising from the change of direction of the plunger. Fig. 1 shows a typical high pressure pump used for waterjet cutting application and Fig. 2 is the corresponding system diagram of the unit. For one part the tests a pressure controlled pump with 37 kW, 400 MPa operating pressure and 3.8 l/min flow rate was used.

For the chemical industry also intensifier pumps are used e.g. to inject peroxides into a tubular or autoclave reactor, to initiate a polymerisation process in plastic production, e.g. at LDPE plants (Low Density Ployethylene). This pressure intensifiers are hydraulically driven by means of a servo hydraulic rate control system, which ensures a constant volume of oil flow independent of the pressure. Moreover, this control concept enables the manipulation of the acceleration phase of the plunger after the change of direction [1].

Basically this pump is flow controlled and the behavior of the pump can be electronically controlled during the compression phase. Fig. 3 shows the top view of such a high pressure pump equipped with a stand-by intensifier. The features of the pump are: 11 kW power rate, 350 MPa operating pressure and 1.0 l/min flow rate.

3. MESUREMENT EQUIPMENT

All tests and examinations were carried out by means of a DEWE-BOOK-16 measuring system. Fig. 4 shows the measurement equipment at the outlet of the pump consisting of a flow meter, suitable for high pressure application, as well as a high pressure transducer. The following sensors were used for all performed measurements:

- Hydraulic oil pressure sensor, Tecsis, pressure range 0 - 25 MPa
- High pressure sensor, IMT Industrie-Meßtechnik, pressure range: 0 - 400 MPa
- Flow meter, Küppers Elektromechanik, flow range: 0.3 - 1.5 and 0.5 - 4.0 l/min.

4. PRESSURE MEASUREMENT INSIDE THE CYLINDER

To be able to make the changes of pressure inside the high pressure cylinder measurable, the pressure check valve was moved so that the high pressure line, in which the sensor is located, still belongs to the volume of the high pressure cylinder as shown in Fig. 5.

The results of measurement (Fig. 6) on a flow controlled pump with a power rate of 11 kW and a flow rate of 1.0 l/min comprise three graphs. The pressure profile of the hydraulic oil system is visible, but only one high pressure side of the cylinder is shown with a maximum value of 300 MPa. The graph indicates the correlation between the low pressure and the high pressure side. Comparing low and high pressure, the high pressure line has a softer start when reaching the adjusted pressure. The second difference is at the end of the boost where the directional way valve causes a pressure peak in the oil hydraulic system. So the differences between high and low pressure are found at the point of discontinuity.

5. RECIPROCATING PUMP CONTROL

Reciprocating pumps suffer the problem that there is a delivery gap (pressure drop, flow reduction) at the reversal point of the plunger. To overcome this problem, a short and fast stroke can be selected. However, choosing a longer stroke to reduce load cycles, a larger plunger diameter to enhance the lifetime of the sealing system and a servo valve to compensate this factor, this delivery gap can be compensated.

The advantage of a servo valve controlled hydraulic system is the possibility to change the flow rate from the target to the maximum in the time span where the plunger changes direction and in the compression phase, which is about 10 % of the stroke at 300 MPa. To be able to investigate the best design of the control signal (boost signal) for the mentioned time gap, measuements of the oil hydraulic and outlet pressure as well as changes in output volume were made. The optimum signal was found in between three zones.

In Fig. 7 there are shown three cases with different boost signals at the 11 kW pump. Also the typical behaviour of the hydraulic system can be seen. To analyze the flow controlled pump and to carry out the optimization on this basis, the following examinations with parameters mentioned as follows were measured: Discharge pressure, flow rate at the discharge outlet and hydraulic oil pressure. For different variations, the program for the servo valve was adapted. The behavior of the measured parameters were recorded for different boost signals at the hydraulic drive. An accumulator with a volume of 0.88 liters was installed in the high pressure line.

In the first case, without a boost signal the system does not reach its potential as it does not use the whole power reserves of the hydraulic system. The second case with a signal of 110 ms gives an acceptable result for flow rate and high pressure. In the third case the boost signal is too dominating, which results in a fish tail profile of the flow rate which is not approved. The parameters of the boost signal could be programmed that way that it always acts in the right intensification of the shifting.

6. MEASUREMENTS WITH DIFFERENT ACCUMULATOR VOLUMES

The installation of an accumulator within the high pressure line is mandatory and inproves the pressure and flow characteristics of high pressure pumps. Fig. 8 shows the results of measurement with and without accumulator on a flow controlled pump. Oil hydraulic pressure, high pressure and flow rate were recorded and compared.

Having small fluctuations of pressure also means small fluctuations in flow concerning the cutting process. Less changes in pressure also result in a positve increase of life time of high pressure components such as tubings, fittings and cutting heads [2] [3].

The difference in pressure fluctuation, influenced by various sizes of the accumulator volume, is indicated in Fig. 9. For the tests the maximum operating pressure was 400 MPa. The measurements were made without accumulator as well as with accumulator volumes of 0.88 and 2.49 liters. At the high pressure pump with 37 kW and a maximum flow rate of 3.8 l/min the pressure fluctuation were nearly 150 MPa without any dampening device. By using a small accumulator the fluctuation was reduced to about 35 MPa, which is still not acceptable for a high performance pump. The best results were possible by using the large volume accumulator with 2.49 liter. In this case the fluctuation was less than 15 MPa, as shown in the graphs.

7. CONCLUSIONS

By using pressure sensors it is possilbe to show the actual correlation between hydraulic pressure and high pressure. To get to know the real flow and its dynamics a flow meter, suitable for the use inside the high pressure line was installed. Constant volume flow and smooth high pressure characteristics are significant criterions. By using an electronic control for a servo valve controlled pump a significant improvement can be verified.

The effect of the accumulator size was shown by using various dampaning volumes. Larger accumulator size reduces the pressure fluctuations, stressing the high pressure components for waterjet cutting. Therefore the design of high pressure pumps can be improved using this possibilities of measurements.

8. REFERENCES

[1] Trieb, F.; Karl R.; Moderer R.: High Pressure And Flow Rate Measurements on Peroxide Dosing Pumps under Laboratory And Site Conditions, ASME-PVP 2006 Conference, Vancouver, Canada, 2006.

[2] Herbig, N.; Retschnik, G.; Trieb, F.: Influence of Accumulator Volume on Pressure Fluctuation of The High Pressure System, Proceedings of the 14th International Conference on Jetting Technology, Brugge, Belgium, 1998.

[3] Susam-Resiga, R.: Attenuator’s Volume Influence on High Pressure’s Pulsations in A Jet Cutting Unit, Proceeding of the 11th International Conference on Jet Cutting Technology, Kluwer Academic Publishers, 1992.

9. GRAPHICS

Figure 1. Front view of a high pressure pump for waterjet cutting

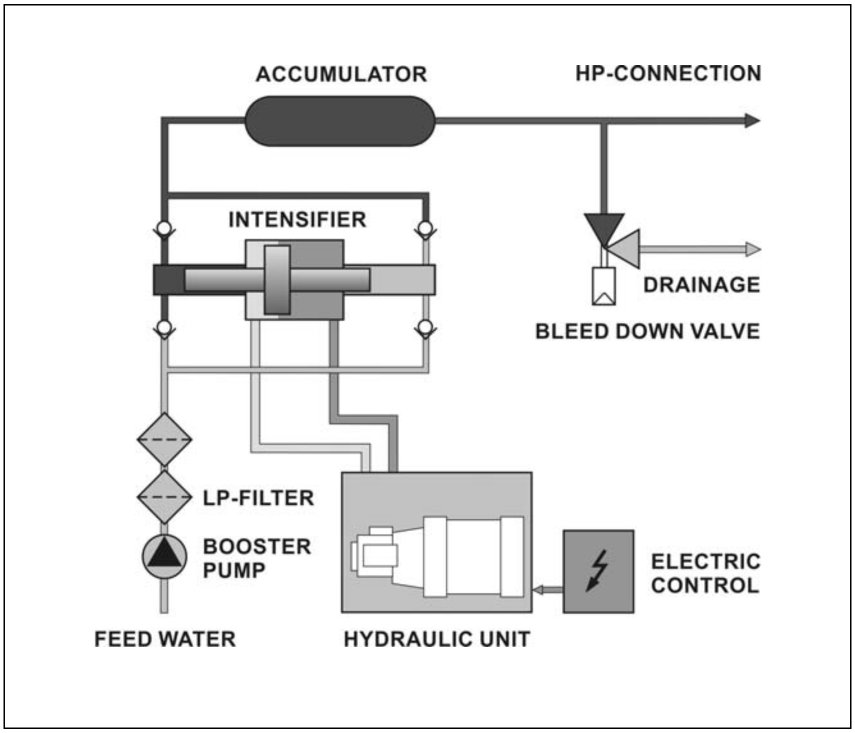

Figure 2. Typical system diagram of a high pressure pump

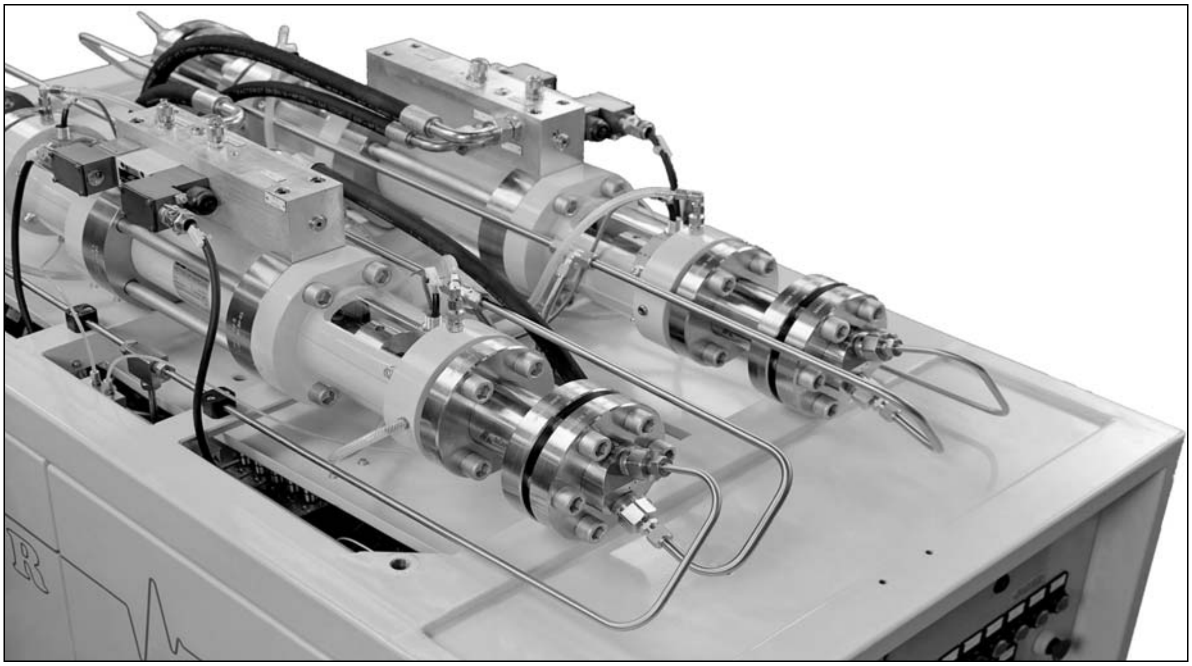

Figure 3. Top view of peroxide injection pump with stand-by intensifier

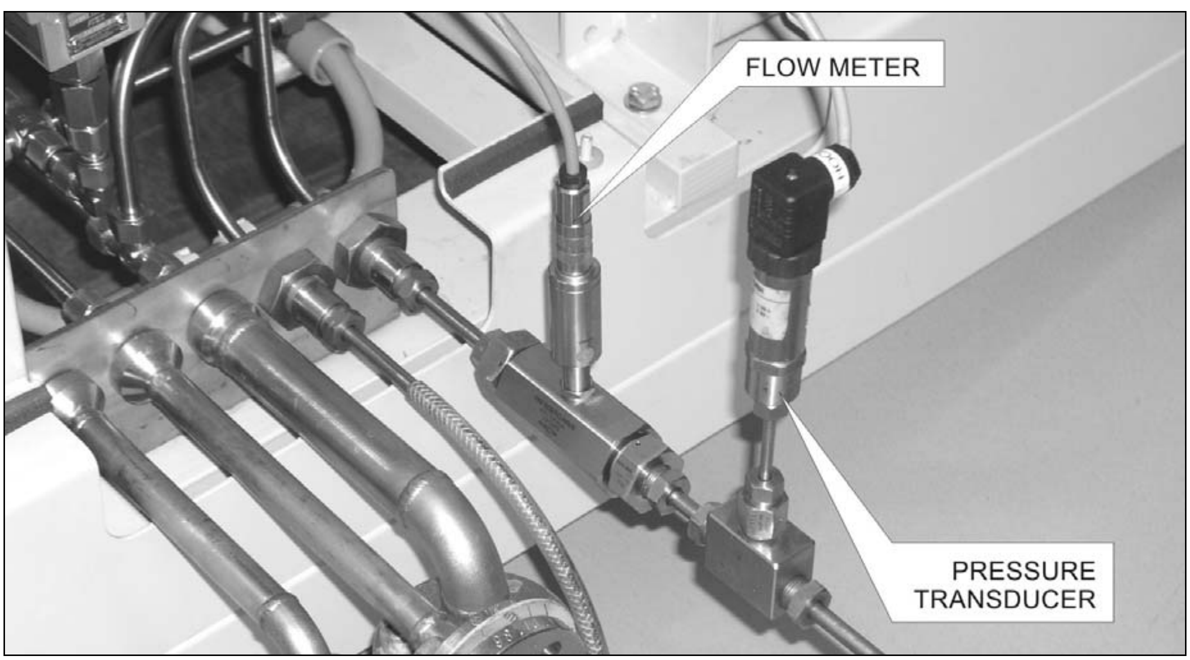

Figure 4. Measurement equipment installed at the discharge side of the pump

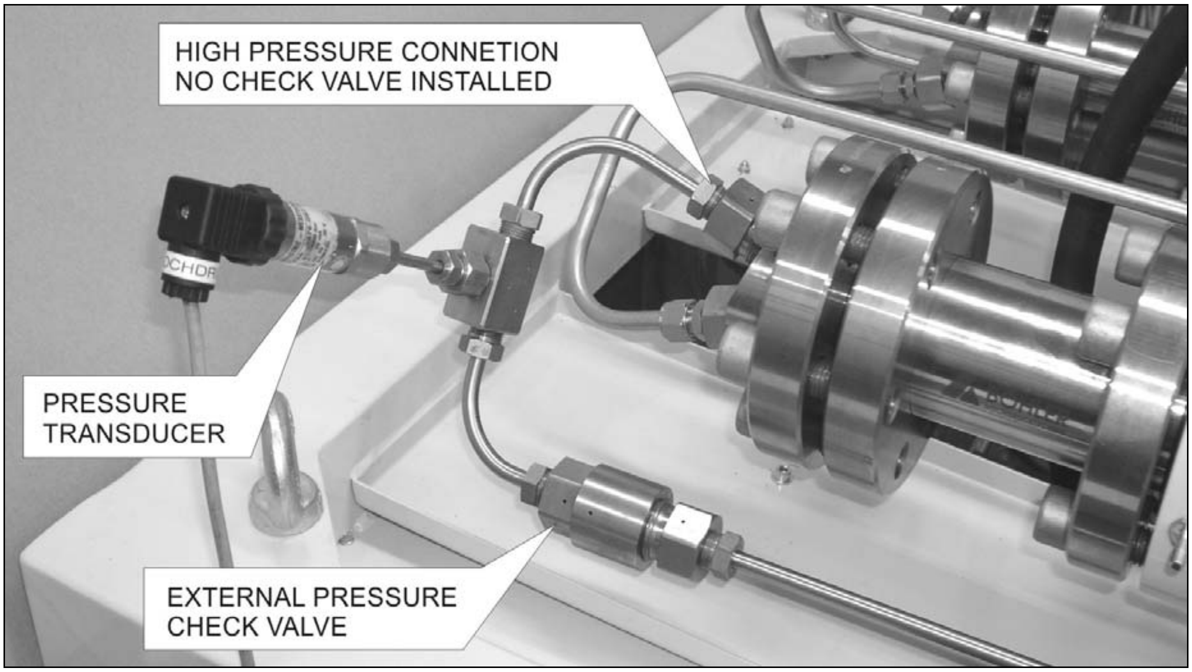

Figure 5. Measurement equipment for pressure evaluation inside the high pressure cylinder

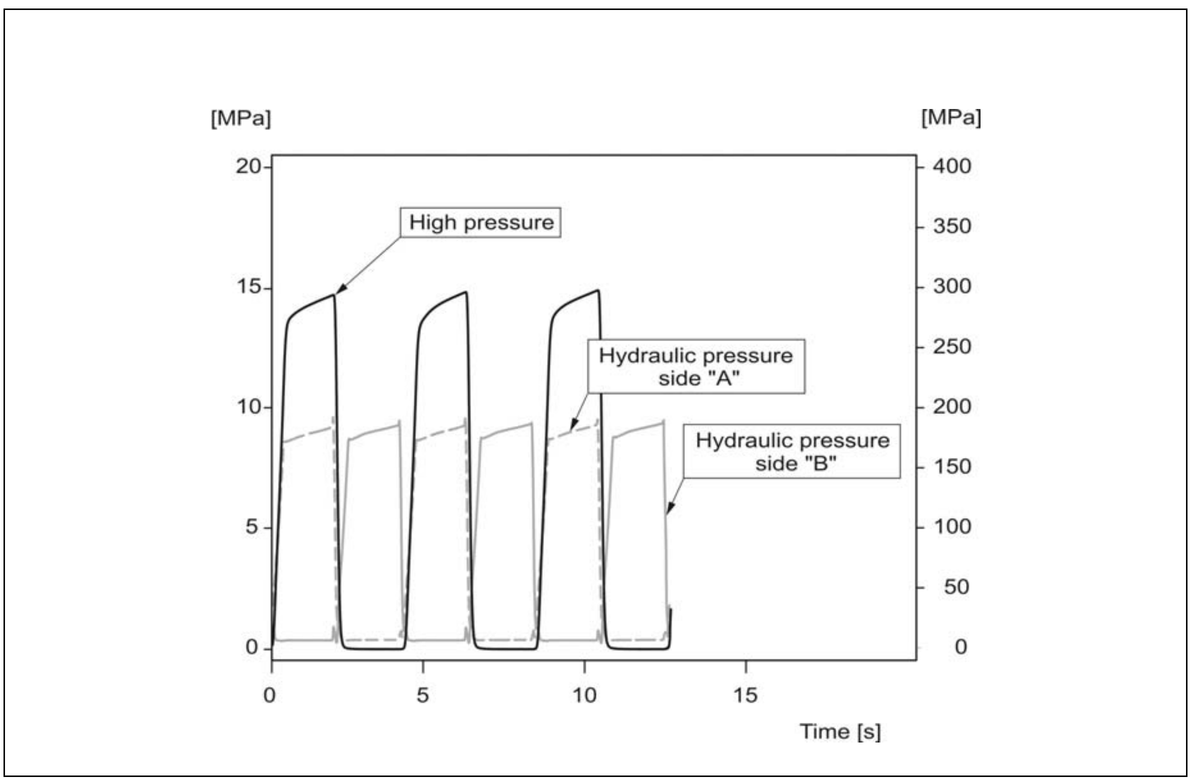

Figure 6. Direct measurement inside the high pressure cylinder

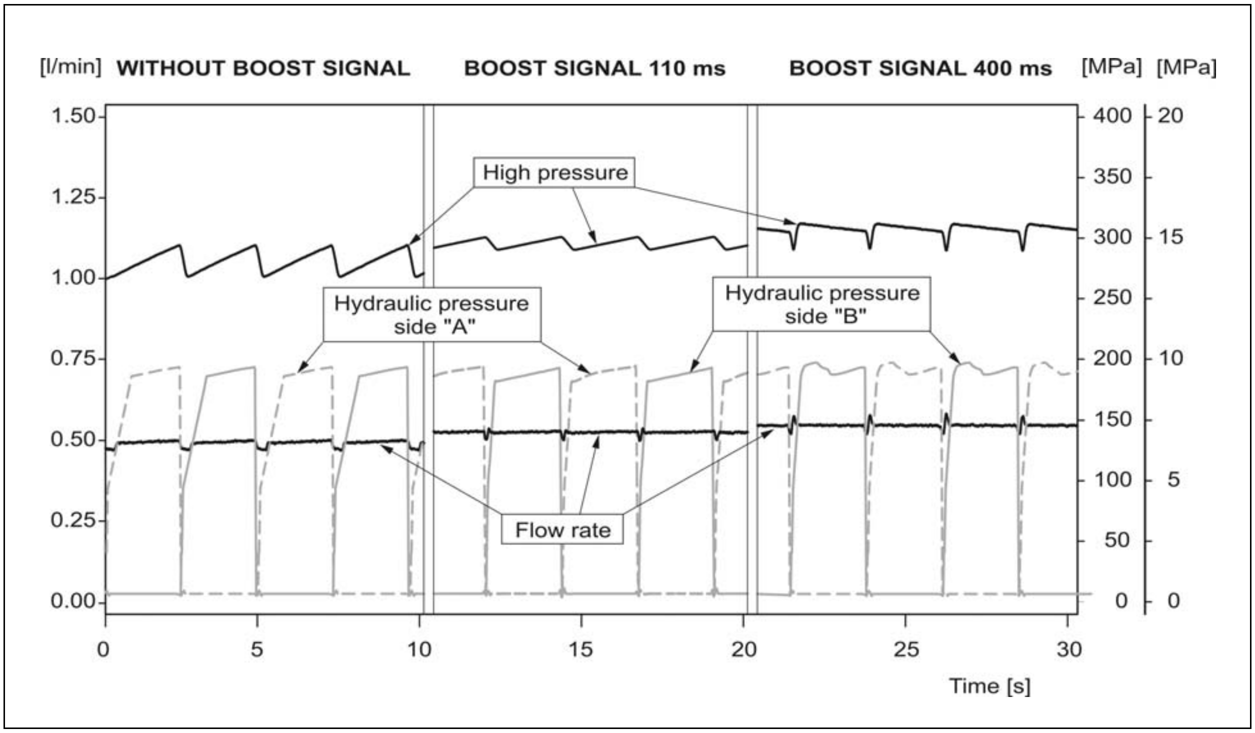

Figure 7. Influence of the boost signal on flow rate and high pressure

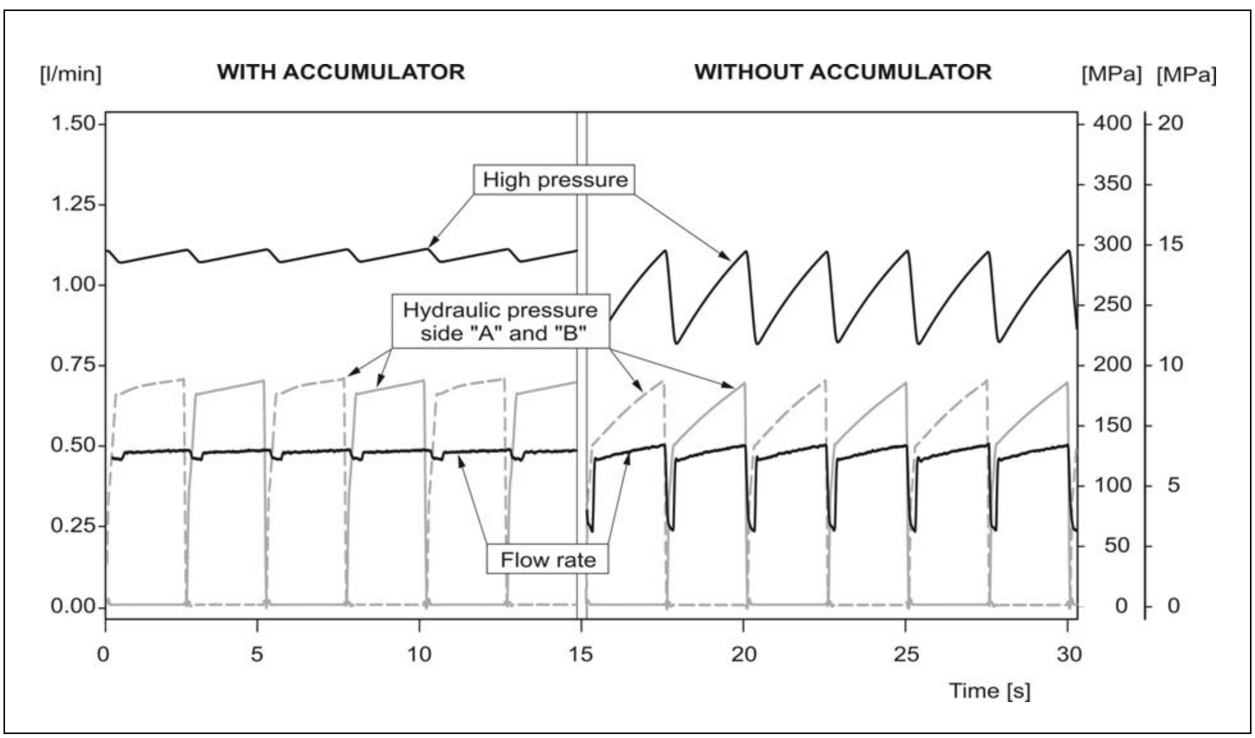

Figure 8. Flow rate and pressure level with and without high pressure accumulator

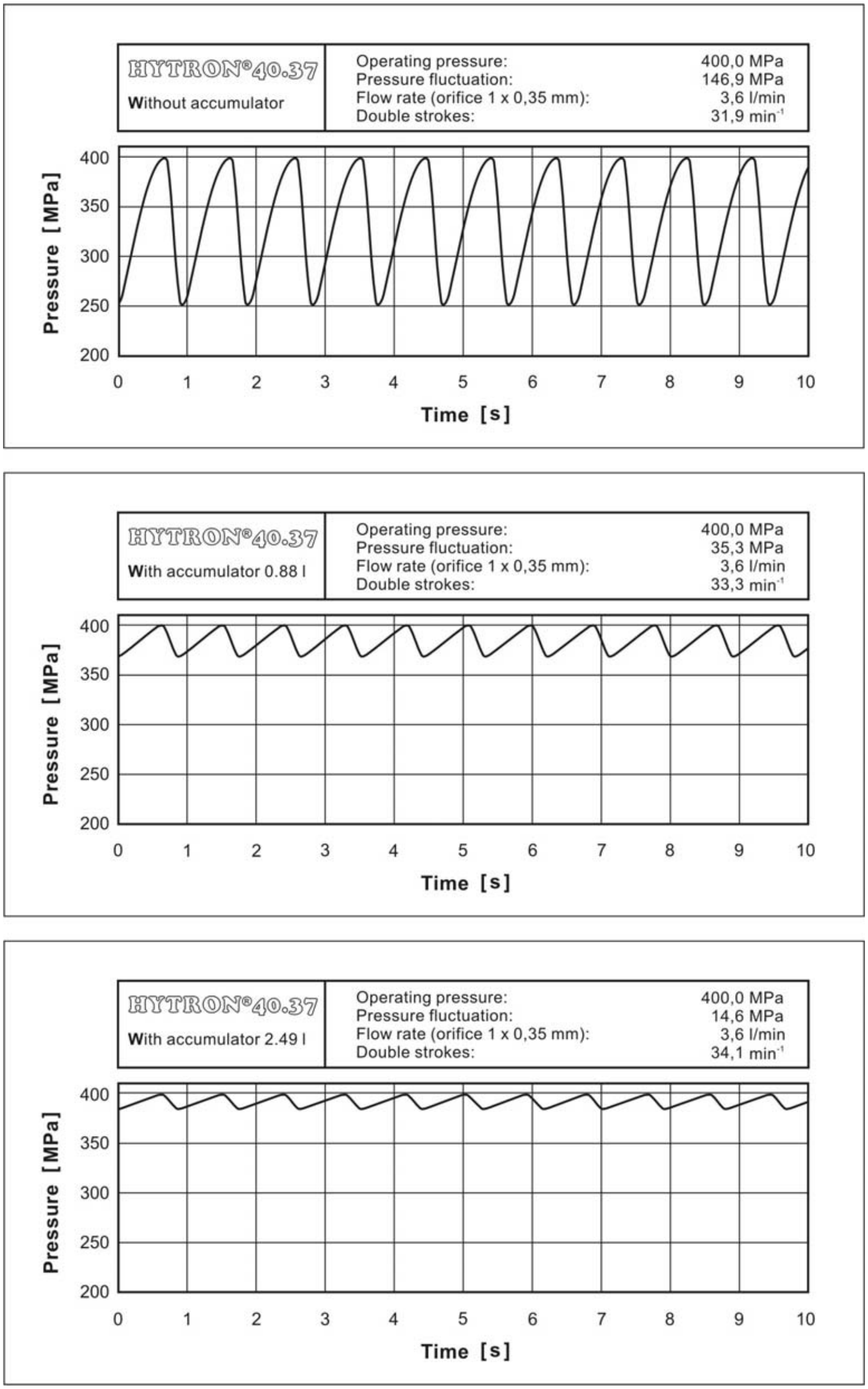

Figure 9. Pressure fluctuation depending on the volume of the accumulator