Some Pressure Drops Characteristics for Pressure Valves Operation within the Hydraulic Circuit

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Abstract: *At present time, most machines and equipment in the industry use hydraulic actuation to ensure the fulfilment of the required work process. It represents a force system that successfully copes with the demands that the actuation of any working organ implies, but which must be well dimensioned and protected against overloads by means of protective equipment. The pressure valves represent protection elements of the hydraulic circuit against pressure peaks formed on the network as a result of some unpredictable external factors. Being offered in different constructive variants, the valves ensure several functions in addition to the protection function of the hydraulic circuit, such as pressure reduction, sequential, unloading or balancing. Constructive models can be normally closed or normally open, as is the case with pressure reduction valves. Some constructive solutions of valves, directly operated and pilot operated, are presented as well as some specific characteristics of these devices presented in terms of flow rate and pressure drops that usually occurs when they are installed in the circuit function of pressure stages registered during the installation operation.*

Keywords: *Hydraulic actuation, pressure valve, flow rate, pressure drop*

1. Introduction

The hydraulic actuation system has proven its efficiency in most applications in all industrial branches so far, being used mainly where force is needed to perform various tasks that are difficult to achieve by means of other drive types.
But this actuation type, based mainly on the working fluid circulation in terms of volumetric flow rate at high pressure values represents an assembly that must be very well dimensioned and made up according to the requirements for which it is intended to meet, because all component elements of the force circuit are strongly stressed by the hydrostatic forces that are inevitably formed because of high-pressure values within the system.
In this sense, in addition to the prior dimensioning of the circuit elements, the working pressure values at which the system is designed to operate must also be conditioned, so that any pressure peaks beyond of these values to be discharged to the tank in such a way as to protect the constituent elements of the network. This objective is ensured by means of pressure valves, which are primarily circuit protection devices in addition to the main function of regulating pressure values.
Devices for regulating pressure values are present in all hydraulic actuation systems, thus having the possibility to perform a wide variety of functions such as ensuring an imposed limited pressure value, up to ensuring a certain pressure value on a certain portion of the circuit that is required to operate a circuit component.
The main groups of pressure valves are represented by safety valves, pressure relief valves, sequence valves, discharge valves, connecting or disconnecting from the circuit of an apparatus, or balancing valves. Regarding the functional model, pressure valves are differentiated as normally open or normally closed versions.
Like any device that is added to the hydraulic circuit, pressure valves can induce a pressure drop in the system, which is usually presented for the pressure groups at which the valve operates, and by the volumetric flow rates of the circulating working fluid. These specific characteristics are presented in this paper for four groups of working pressures to highlight the dissipative aspect when introducing these pressure regulators into the hydraulic network.

2. Constructive solutions for pressure valves

Since the operation of the hydraulic drive circuit involves a continuous operation of the pump, the pressure value of the working fluid may exceed certain values that would endanger the integrity of the system at some moment in time if the working body encounter a resistance in operation for example that can lead to the hydraulic motor stop. This aspect is remedied by using pressure valves which, by adding to the hydraulic circuit, have the possibility to protect the hydraulic circuit from pressure peaks.
This is the reason why the design engineers of the hydraulic installation consider the inclusion of protective elements on the circuit that have the role of adjusting the pressure values of the working agent in order to avoid hydraulic system damage.
The use of pressure valves ensures a direct control of applied force at the circuit working body obtained at a reasonable level of working pressure. Other benefits of using pressure valves are represented by ensuring the sequential operation of the hydraulic actuators, limiting the pressure values to a safety level in operation, reducing the pressure values in the main circuit to ensure the operation of an auxiliary circuit, adjusting the pressure on certain portions of the circuit and discharge of pressure peaks at a given time.
A pressure relief valve direct operated is schematically presented in figure 1. The closing element is kept in position by means of a spring, while the valve opening can be done based on the hydrostatic pressure forces values that are formed on the front surface of the closing element, when the system pressure is able to overcome the elastic force in the spring. It represents a normal closed constructive pressure valve model.

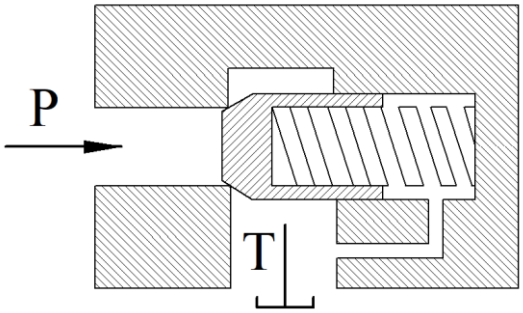


Fig. 1. Pre-set direct operated pressure relief valve

The constructive models of pressure relief valves have the possibility of limiting the ceiling pressure in a hydraulic circuit by creating an alternate path for fluid flow when a certain regulated pressure level is reached. It protects the system from having excess pressure as what is required in all fixed-volume pump circuits. Relief valves are important when actuators stall with the still-in-shifted-position directional valves.
The counterbalance valve protects the hydraulic system from line failure, pressure shocks, enabling the free fluid flow on a certain direction.
Being used for adjusting the pressure values within hydraulic circuit parts, the pressure-reducing valves are actuated by the pressure flowing downstream that tends to close as it reaches valve setting. They are usually used with a check valve that also enables the reversal fluid flow.
The unloading valve is used to send the excess fluid to the tank, at low pressure values.
These constructive variants are used mainly within high-low pump circuits, where there are two pumps that move an actuator at low pressure and high speed. So, the circuit can be positioned on a single pump, giving off high pressure to do the work.
The unloading pressure valves ensure the excess fluid circulation to the tank, especially for the situations of cylinder rod retraction.
The construction model corresponding to a pressure valve device is constituted by a body with inward orifices necessary for the circulation of the working fluid between the active plant branches and a valve closing/opening element maintained in the closed state by means of a compression

spring which ensures the blocking of the circulation fluid flow to the tank if the pressure value is within the parameters for which the system is operating safely.
When the pressure value rises above the value set on the valve (spring elastic force value), the locking piece is moved from the initial locking position by means of the action of hydrostatic forces, at which point the working fluid can circulate behind the enclosure being directed to the system tank, reducing the momentary pressure value in the system to the initial value.
Once the pressure value has been lowered, the closure element is again moved to the initial position, ensuring the closure of the fluid drainage orifices, which is maintained until a further increase in the system pressure value when the recovery cycle is achieved.
The constructive principle of a pressure relief valve direct operated with the possibility to adjust the pressure level is presented in figure 2.

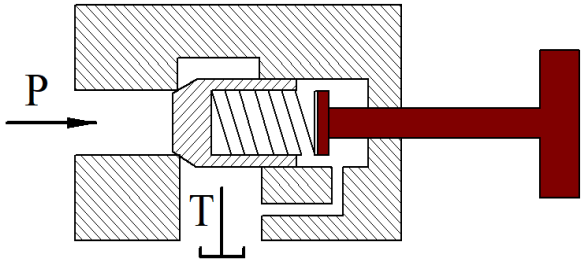


Fig. 2. Pressure relief valve direct operated with the possibility to adjust the pressure level

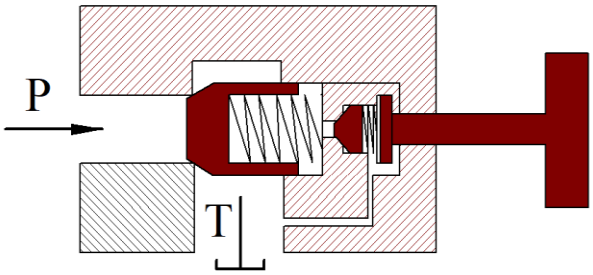


Fig. 3. Pilot operated relief valve

For the pilot operated pressure valve version, it is considered a higher circulating fluid flow rate, higher pressure values and is adopted for a stable operation that does not induce vibrations and wear of the valve closing member. It thus presents a more complex construction (figure 3), consisting in principle of two distinct components: a directly controlled valve called a pilot and an execution valve or the main valve, while the connections between the two assembly components being made in the overall body of the two devices.
During the operation of the pressure valve inside the hydraulic circuit the hydrostatic pressure forces are considered (F_h), which acts directly on the blocking element part determining a displacement and the discharge opening surface (A), enabling the working fluid return to the tank.
The necessary mechanical work (L_h) for the closure element movement inside the pressure valve is force and displacement dependent, for which a hydraulic fluid volume (V) is circulated, which also enters in calculating the required energy amount raised at the momentary pressure value. 000

$$F_h = p \cdot A \tag{1}$$

$$L_h = p \cdot A \cdot s_a \tag{2}$$

$$V = A \cdot s_a \tag{3}$$

$$E = V \cdot p \tag{4}$$

The movement resistances at the closure element are constituted by the compression spring elastic force which is acting directly on the pressure valve locking element to maintain the pressed position.
The spring elastic force (F_a) can be described as compression spring constant (c_a) combined with displacement value (s_a) which is achieved when the spring is compressed due to the hydrostatic forces action: 0

$$F_a = s_a \cdot c_a \tag{5}$$

$$F_a = \frac{G \cdot d_w^4 \cdot s_a}{8 \cdot D_a \cdot n} \tag{6}$$

$$s_a = \frac{8 \cdot D^3 \cdot F_a \cdot n}{d^4 \cdot G} \tag{7}$$

where:
D_a - spring average diameter;
d_w - spring wire diameter;
G – shear modulus;
n - spiral number.

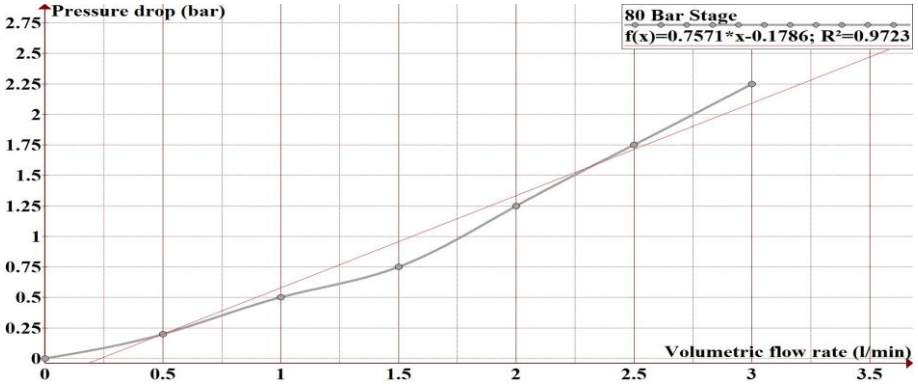
The functioning stages for the pressure valves are acquired according with the involved forces values. Thus, when the hydrostatic pressure forces are lower than the spring force value the pressure valve remains closed and when this value exceeds the spring elastic force value, the valve opens and sends the working fluid excess direct to the tank, while the momentary pressure peak value of the system is discharged.

$$\begin{cases} F_h < F_a \ - \text{Pressure Valve Closed} \\ F_h > F_a \ - \text{Pressure Valve Open} \end{cases}$$

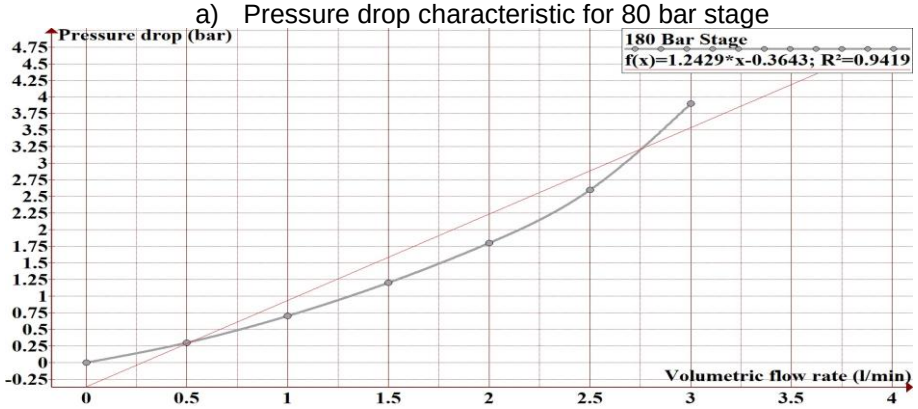
In general, the pressure valve models are normally closed, being activated only when the system high pressure values arise. If the hydraulic circuit would not have such a protective component mounted, the pressure would increase up to the energy limit of the pumping group and ultimately produce damage to one of the system components (breakdown of the hydraulic ducts, destruction of the distributor, etc.). 0

3. Pressure drop characteristics

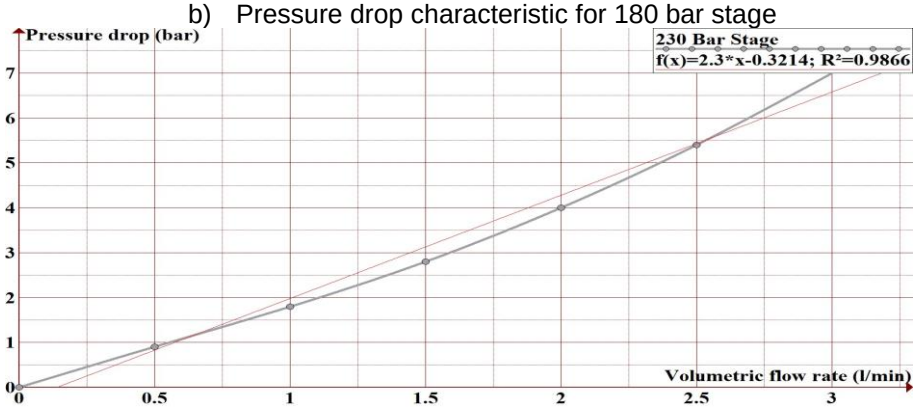
For the pressure valves used within the working hydraulic circuit, the information is mainly provided regarding the main parameters that must be considered for the adoption and use of the constructive model in the respective installation. These parameters relate to set pressure values and pressure drop.
Adjusting the pressure level by means of a certain valve is achieved by lamination of the working fluid as it passes through a device section. This process is always accompanied by energy losses due to the decrease in the pressure value when the working fluid circulates between the pressure source and the pressure signal receiver.
The pressure valves characteristics are thus presented by means of specific diagrams for each constructive valve size that define the specific values of pressure drop and volumetric flow rate for different working pressure steps (figure 4).



a) Pressure drop characteristic for 80 bar stage



b) Pressure drop characteristic for 180 bar stage



c) Pressure drop characteristic for 230 bar stage

Fig. 4. Pressure valve characteristics for three pressure stages

The pressure signal that can perform the displacement of the locking element, initially being in a closed position, is taken from the main circuit powered by the pump. It is the compression spring constant that determines the adjusted value of the pressure required to open the pressure valve. Also, such pressure valves models benefit from the adjusting system, needed to pre-set the pressure value at which the valve can be opened and for higher circulation fluid flow rates, for which case constructive models with pilot are used.
The pressure valves are used in circuits at pressure values in the range of 315-630 bar and fluid flow rates of 80-330 l/min, but pilot operated construction variants are capable to circulate higher flow rates values of up to 650 l/min.

4. Conclusions

The operation of a working hydraulic circuit involves a continuous flow rate of working fluid agent transported due to the pump action at certain values of the working pressure.
In order to protect the circuit from overload, to disconnect or connect a certain component to the network, valves specially designed to perform these operations in the circuit are needed.

The principle solutions of the directly operated and pilot operated pressure valves are presented, highlighting the efforts to which they are subjected for operation.
Also, some functional characteristics of the pressure valves have been presented in this paper to highlight the pressure drops that are recorded when such a component is added to the network or the working hydraulic circuit.
The presented characteristics are for three groups of working pressures at which the installation can work, being exemplified steps of low, medium and higher pressure values, being shown the pressure drops according to the volumetric flow rate transported.
It is thus possible to identify the dissipative character of these devices when working in the network, given the fact that there is an energy consumption for using these devices in the network, which increases exponentially with the volumetric flow rate, and the values can be identified on the three pressure steps that are shown.
It can be said that these devices are constituted as a resistance that appears in the way of the flow of the working fluid in the hydraulic circuit, being quantified to the total of the resistances that appear in operation that must be defeated by the system pump, which provides the nominal flow rate of the network at the nominal pressure.
Given the fact that the pump works continuously, the surplus fluid flow rate that contributes to the rise of the pressure values at a given moment is discharged to the tank by means of the discharge valves, or if it is about the connection valves they can come into operation and feed a circuit branch when the pre-set pressure value is reached. The same situation happens for the case of disconnection of a network element.
The role of the pressure valves is a special one within the operation of the hydraulic actuation circuit precisely through the multiple possibilities that ensure the functionality and reliability of the system once they are well established and sized for certain applications with specific usage requirements.

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