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Experimental Plotting of Static Characteristics of Rotary Hydraulic Pumps

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Abstract: Present paper presents the experimental plotting of static characteristics such as flow-pressure and flow-speed-pressure in case of rotary hydraulic pumps. Theoretically, a hydraulic pump with constant flow can work up to nominal pressure without influencing the flow, regardless of the load. În practice, based on pumps' specific design, due to internal leakage around sealing elements, real characteristic is different from the theoretical one, which is why it arises the need to plot both experimental characteristics. To plot these graphs, it will be used a specialized test bench consisting in: a hydraulic pump with constant flow, a hydraulic valve, pressure gauge or pressure sensors for measuring the pressure within the hydraulic circuit, and a double acting cylinder with a load at one end to simulate it within the circuit or a non-load cylinder but with throttle valve. Results from experimental research will be subsequently used to validate the research by simulation because plotting the two static characteristics of hydraulic pumps can also be made by developing a hydraulic model within modelling-simuation softwares such as FluidSim.

Keywords: hydraulic pump; hydraulic cylinder; static characteristic; flow; speed; pressure

1. Introduction

Establishing dimensions for hydrostatic pumps which equip actuating systems is made considering two aspects: nominal pressure, which is given by the actuating load (at which there are added energy losses as pressured drop on constituent elements from the hydrostatic engine to the pump) and real flow to attain the kinematics assessed to the load. Manufacturers provide a large range of dimensions for pumps regarding hydraulic (cylindrical) capacity. The pump's design is characterized by certain flow losses (due to clearance/circular hydraulic contacts between the elements with relative movement) which are dependent on pressure difference between discharge and intake (delta p = p discharge - p intake) which implies that real flow will be influenced by normal working condition. Hence, manufacturers provide diagrams, static characteristics and complex charts in order to verify the real flow given by a certain pump, while working at needed pressure.

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2. Experimental Setup

Such characteristic can be plotted experimentally on a specialized test bench.

To plot and highlight the flow-pressure characteristic, in the simulation software called FluidSim, it was realized a hydraulic model, consisting in:

- Hydraulic pump;
- Hydraulic directional valve;
- Double acting cylinder;
- Throttle valve;
- Manometer;
- Hydraulic tank.

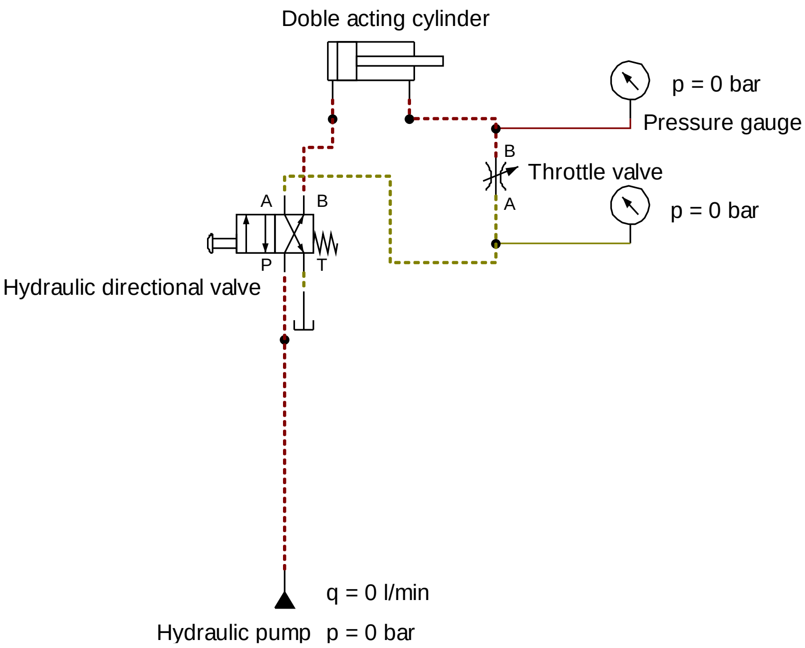

Figure 1 Hydraulic Model in Static State, Performed in FluidSim

2.1. Performing Connections

The hydraulic circuit is actuated by connecting the hydraulic pump (1) to the 4/2 hydraulic directional valve (2). One of the two ways of the directional valve is connected to the inlet of the hydraulic cylinder (3) and the other one to the outlet of the hydraulic cylinder. The throttle valve is mounted on the outlet part of the circuit and before and after the throttle valve there will be mounted two pressure gauges for measuring the pressure drop.

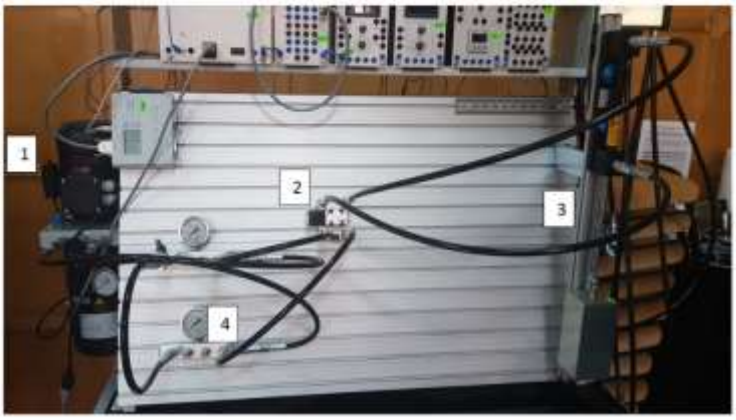

Figure 2. Circuit Setup on the Test Bench

Observation: In case of all hydraulic circuits made in the laboratory, on test benches, it will be ensured the safety mounting (4), formed by a multiple directional control valve of flow for the pump connection, multiple directional control valve of flow for the hydraulic tank connection, valve to start the pump idle, which connects the pump's multiple directional control valve to the one of the hydraulic tank.

2.2. Working Principle

The hydraulic pump is actuated (1), thus resulting in a constant flow of liquid at a certain working pressure. The flow ensured by the hydraulic pump is determined experimentally, with the use of a flowmeter (depicted in fig. 3), connected to an EasyPort acquisition plate (fig 2).

Figure 3. Flowmeter

The liquid is transmitted by the pump to the hidraulic valve (2), which will submit it to the B consumer, meaning the hydraulic cylinder (3) which will move the piston. The piston displacement will move the liquid to the throttle valve (used as a load). In fig. 3, the throttle valve is replaced by a weight attached to the piston's rod, which, depending on the opening, will lead to a change in the hydraulic liquid working pressure.

Follow-up, the liquid is transmitted to the consumer A of the hydraulic directional valve, which will direct it to the tank.

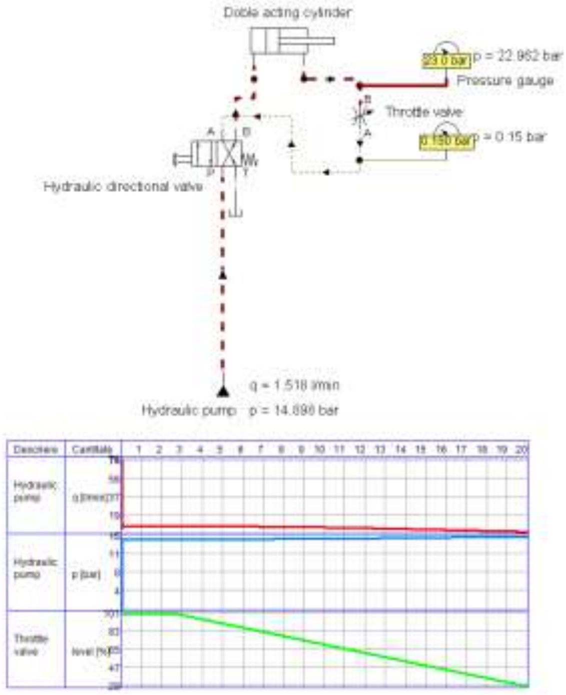

Figure 4. Hydraulic Circuit Modeled in FluidSim

2.3. Plotting the Flow-Pressure Characteristic

To plot the flow-pressure characteristic, in FluidSim it will be established a constant flow for the pump (in case the experimental research is conducted on the test bench from the laboratory, it will be considered the appropriate pump's flow) and the working pressure will be set. In case that at the end of the piston's rod there is no weight attached or no elements which resists to the piston displacement, the flow and pressure are constant, as the predefined values. In case there is a weight attached at the end of the piston's rod, or in this particular case, the throttle valve within the hydraulic circuit, depending on the opening degree of the later element, it will be performed a change in circuit pressure. Hence, for small openings of the throttle valve, it will be obtained an increase in fluid pressure and a decrease in pump's flow. In Figure 5 it can be observed the flow variation depending on pressure, for several opening degrees of the throttle valve.

Table 1. Measured Values

Current number	Pressure [bar]	Flow [l/min]
1	2.50	2.39
2	5.00	2.35
3	10.00	2.32
4	15.00	2.30
5	20.00	2.28
6	25.00	2.26
7	30.00	2.24
8	35.00	2.20
9	40.00	2.18
10	45.00	2.10
11	50.00	1.20
12	55.00	0.20

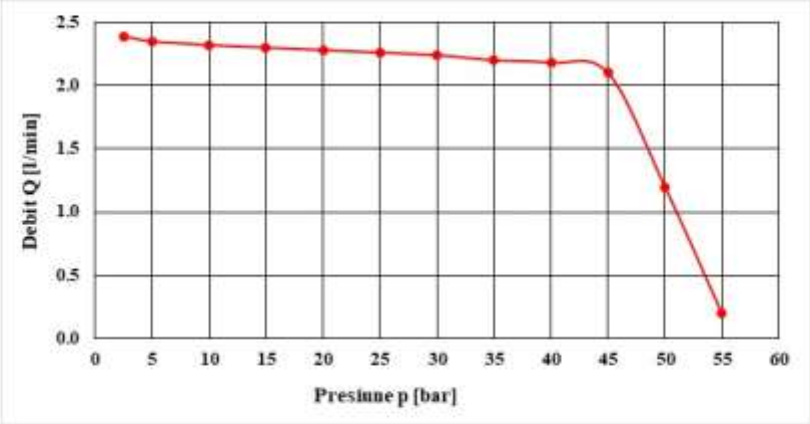

Figure 5. Flow-pressure characteristic

Observation: In order to plot the characteristic from fig. 5, pump's flow was set to $Q = 2.5l/min$, and maximum working pressure was $p = 55bar$.

To choose the motor for actuating the pump, it is necessary to plot the static flow-speed-pressure characteristic (Q-n-p). Therefore, in the FluidSim simulation software was performed a hydraulic model, consisting of:

- Hydraulic pump with constant flow;
- Hydraulic valve;
- Double acting cylinder;
- Throttle valve;
- Manometer;
- Hydraulic tank.

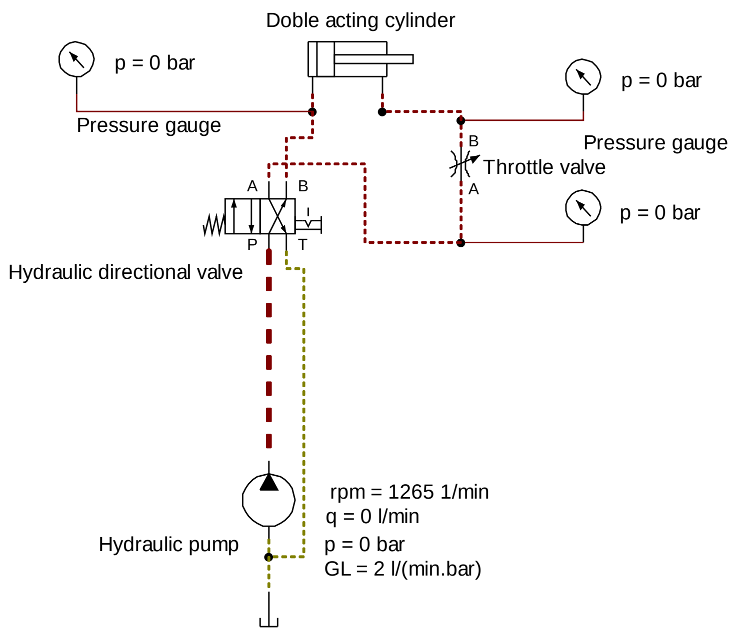

Figure 6. Hydraulic Model in Static State, Made in FluidSim

2.4. Connection Setup

To actuate the hydraulic circuit, there are made the same steps as for plotting the flow-pressure characteristic.

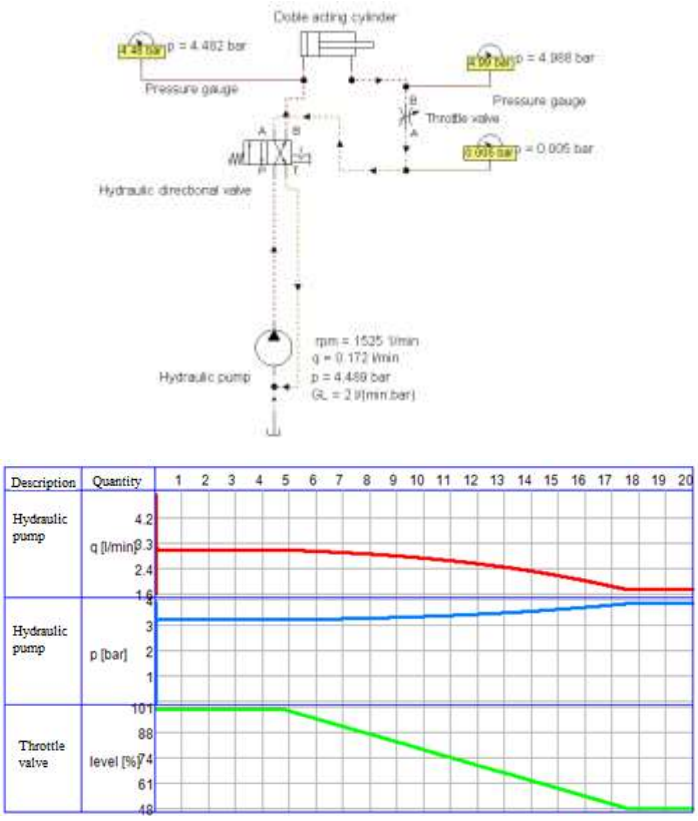

Figure 7. Working Hydraulic Model, Made in FluidSim

3. Plotting the Flow-Speed-Pressure Characteristic

To plot the flow-speed-pressure characteristic, within FluidSim it will be set a constant flow for the pump (it will be considered the pump's flow used on the test bench) and it will be set a certain working pressure. When actuating the pump, it will be observed that for a constant value of pressure within the hydraulic circuit (obtained due to the usage of the throttle valve), it will result a certain flow and a certain speed. Changing the speed, but for the same working pressure, it will be obtained an increase in pump's flow.

Table 2. Values Measured in FluidSim

Flow [l/min]	Speed [rpm]	Pressure p_1 [bar]	Flow [l/min]	Speed [rpm]	Pressure p_2 [bar]
6	1000	27.038	5.549	1000	363.005
6.6	1100	27.023	6.087	1100	363.111
7.2	1200	27.018	6.645	1200	363.082
7.8	1300	27.068	7.177	1300	363.194
8.4	1400	27.045	7.726	1400	363.211
9	1500	27.057	8.29	1500	363.155
9.6	1600	27.014	8.717	1600	363.67
10.2	1700	27.02	8.741	1700	365.72

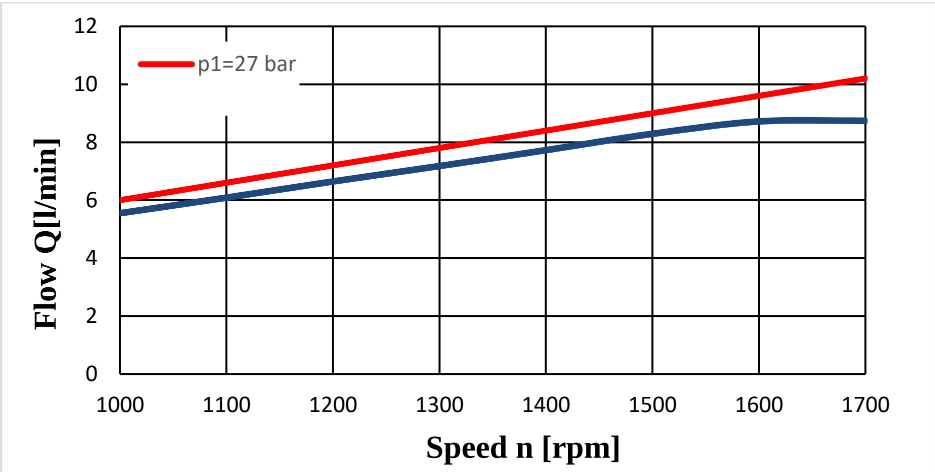

Figure 8. Flow-Speed-Pressure Characteristic

As it can be observed from fig. 8, pump's flow also varies depending on speed. This variation is almost linear for a certain working pressure. For other pressure regimes, can be plotted different characteristic curves, resulting in a family of such curves $Qf(n, p)$, for both the working pump and hydraulic motor.

From fig. 8 it can also be observed the loss in flow due to the working pressure, which is higher with the increase in pressure.

4. Conclusions

The characteristics presented within this paper are useful to help choose elements which will be used for the actuating system, but real flow can also be influenced by the hydraulic liquid temperature (previous characteristics have been plotted considering a constant temperature of 250C), and also by the technical status of the components (such as the wear degree of the pump) which can lead to a slow decrease in outlet flow.

5. Acknowledgement

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