SELECTED ENGINEERING PROBLEMS
NUMBER5

INSTITUTE OF ENGINEERING PROCESSES AUTOMATION
AND INTEGRATED MANUFACTURING SYSTEMS

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THE EFFECT OF BACKGROUND CURRENT INTENSITY ON THE HYSTERESIS OF PROPORTIONAL VALVES

Abstract: The article presents the results of experimental studies focused on effect of setting background current on the hysteresis of the proportional directional control valve (D1FB series, manufactured by the Parker Hannifin).Described tests were performed according to the Fractional-Factorial Experiment Method (FFEM).In presented experiment influence of the background current, vibrations and the positioning accuracy of hydraulic receivers on pressure pulsations have been omitted.

1. Introduction

Proportional valves are widely used in modern electrohydraulic systems [7], especially in hydrostatic systems. In spite of that fact many users do not fully understood the rules of their actions, what causes limitation of the quality of designed systems.

One of the major drawbacks of proportional directional control valves without internal feedback system is a large hysteresis, resulting mainly from the frictional resistance of moving parts (valve head or slider located in the sleeve) [1,2,4].This may cause problems with the positioning [3,5,6] of a hydraulic drive controlled by the valve or other objectionable effects. Manufacturers reduced the hysteresis of valves by equipping electromechanical transducers with control systems allowing adjustment of a variable DC component, so-called background current (named also like the Dither current intensity) [8]. For described case the movable parts of valves are triggering in vibrations what apparently reduces the influence of friction.

Parameters of the background current intensity have an impact not only on the value of the hysteresis but also on [2]: pressure pulsations, vibration level, lifetime of the proportional valve subassemblies (wear of slider and bushing) and reliability of the hydraulic devices (eg. an appearance of leakages between the valve chambers).

2. Description of the experimental studies

The study was carried out on the basis of hydraulic system consisting of: the proportional directional control valve (D1FBB32FC0NJW0 Parker Hannifin [8]) powered with the

PWD00A-400 amplifier, a rotary hydraulic motor (PGM511A0060B54D3N series) and hydraulic power feeder. An evaluation of an influence of the Dither current intensity on hysteresis of the proportional valve has been realized on the basis of the test stand built according to the hydraulic diagram presented in the figure 1a.

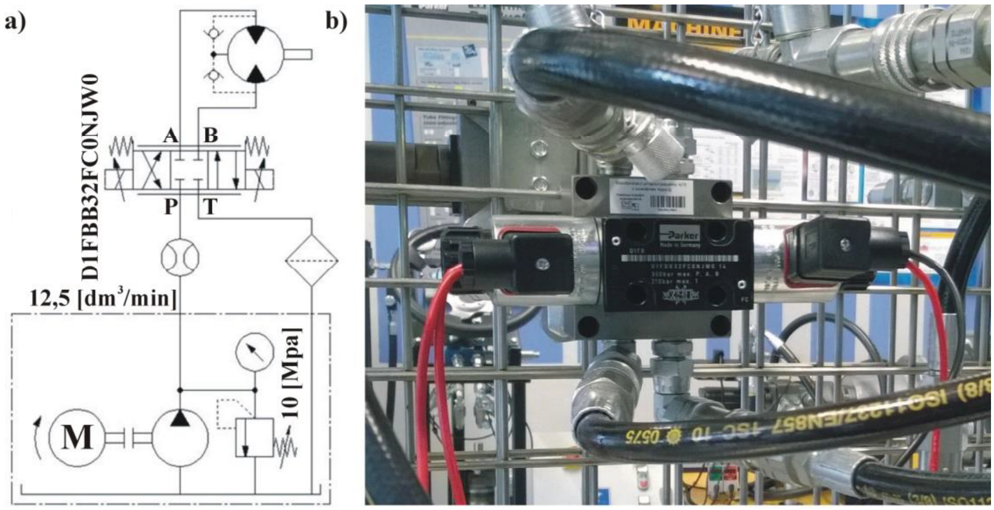

Fig. 1. The test stand: a) the hydraulic diagram, b) view of tested valve

During experiments parameters of the background current intensity were changed within the following ranges:

- frequency - 20÷80 [Hz] (range recommended by the manufacturer 30÷60 [Hz]),
- oscillation amplitude - 0÷8% of the constant component C_C (range recommended by the manufacturer 3÷6% of the C_C value).

3. The effect of Dither current on the valve hysteresis

Measurements were carried out for several Dither current parameter settings, including set points compatible with default manufacturer and without a Dither current intensity modulation.

Figure 2a shows example characteristics obtained as a result of the static test of the D1FB proportional directional control valve without Dither control. In the presented case the largest apparent value of the hysteresis occurs in the control voltage values about |4|V.This is due to the insensitivity of a turbine flow meter used for measuring the flow rate.

The hysteresis value for the linear part of characteristics has been determined at the absolute value of control voltage equal |6| V. In order to eliminate fluctuations of recorded hysteresis values, the following procedure was adopted:

- regression lines were determined for various runs (ascending and descending) in terms of the control signal 5÷7V (a flow from P to B direction) and -7÷-5V (the flow from P to A direction),
- on the basis of obtained regression equations a flow rate or rotational speed of the receiver were determined (6V - the flow from P to B and -6V - the flow from P to A),
- the hysteresis value is defined as the difference between regression equations (of the flow or rotation of the receiver) divided by the maximum value of the recorded value.

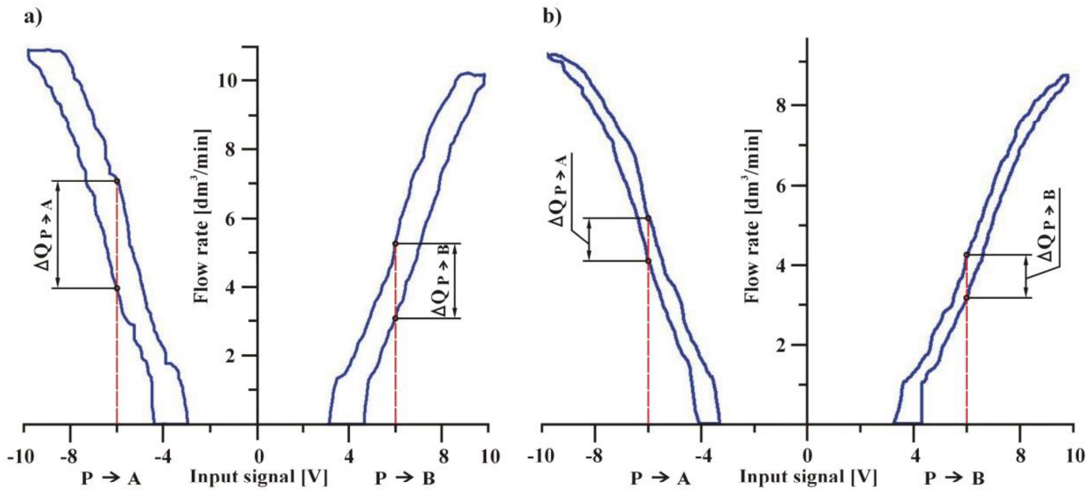

Fig. 2. Static characteristics of the proportional directional control valve (type D1FB): a) without Dither control, b) with the Dither control

The obtained experimental results for selected valve control settings and partial scores (S_c) for accepted Dither current settings are shown in Table 1.

Tab. 1. Results of performed laboratory tests with partial scoring (Sc=0÷5, maximum value means best meet the requirements)

FFEM indexes				Hysteresis at |6|V input signal				Standard deviation of hysteresis				S_c
		f_r	A	Δn	ΔQ	Δ n	ΔQ	s(Δn)	s(ΔQ)	s(Δn)	s(ΔQ)	
x_1	x_2	[Hz]	[%]	P-B	P-B	P-A	P-A	P-B	P-B	P-A	P-A	
-1	-1	29	1,2	12,3%	13,6%	15,7%	17,7%	1,70%	1,73%	1,68%	2,03%	**2**
-1	1	29	6,8	7,4%	8,9%	8,4%	9,8%	0,09%	0,71%	0,56%	1,25%	**4**
1	-1	71	1,2	16,7%	18,1%	19,8%	21,3%	2,38%	1,66%	1,53%	1,58%	**1**
1	1	71	6,8	8,7%	9,9%	9,8%	10,8%	0,60%	0,14%	0,97%	0,89%	**3**
-1,41	0	20	4	7,6%	9,0%	8,3%	9,4%	1,46%	1,68%	0,94%	0,99%	**3**
1,41	0	80	4	10,9%	12,0%	14,5%	15,8%	1,10%	1,38%	1,20%	1,59%	**2**
0	-1,41	50	0	18,8%	19,6%	21,9%	23,8%	1,55%	1,65%	1,74%	1,51%	**0**
0	1,41	50	8	7,2%	8,1%	7,6%	9,3%	0,55%	0,31%	0,83%	1,25%	**4**
0	0	50	4	9,2%	10,2%	8,9%	10,9%	0,77%	0,99%	0,48%	0,95%	**3**

It is noted that tested proportional directional control valve is characterized by a certain asymmetry in operation:

- flow in the direction P→A is characterized by a noticeably bigger hysteresis (smaller backlash of slider in the sleeve),
- differences in the maximum values of flows (directions A→P and P→B) result from unsymmetrical grooves made on the edges of the slider (A:B→2:1 version).

5. Conclusions

Presented results of experimental studies focused on the impact of Dither current settings (especially frequency and amplitude) on the hysteresis of proportional valve lead to the following conclusions:

- hysteresis of proportional directional control valves is much more sensitive to the Dither amplitude than its frequency, therefore the correct setting of the valve in order to minimization of the hysteresis should take into account in the first instance the Dither amplitude,
- control with the low frequency of Dither current (below the limit frequency of the valve) may result in adverse pressure pulsations and this may cause rising resonance in the driven machine and in consequence to its failure or damage.
- exist the need to optimize the setting holding current (chosen by the producers of proportional valves according to the general principles of tuning without considering the impact of the external loads).

Additionally it must be taken into consideration the characteristics of the receiver (hydraulic cylinder), which affects at the accuracy of the entire system. The next step will be connected with investigations including dependence of the control parameters and valve lifetime (in terms of vibration and amplitude of valve slider).

References

1. Barbachowski E., Klarecki K.: Methods for Correcting The Characteristics of Proportional Valves “Selected Engineering Problems” 2011, No. 2, pp. 29–34(in Polish).
2. Klarecki K., Hetmańczyk M., Rabsztyn D.: Multi-Criteria Optimization of The Dither Current Intensity in The Case of Proportional Valve. “Vibroengineering Procedia” 2014, Vol. 3, pp. 82-87.
3. Klarecki K., Hetmańczyk M., Rabsztyn D.: Influence of The Controller Settings on The Behaviour of The Hydraulic Servo Drive. “Mechatronics-Ideas for Industrial Application. Advances in Intelligent Systems and Computing” 2015, Vol. 317, pp. 91-100.
4. Kudźma Z.: Test Stand for Estimation of Static and Dynamic Characteristic of Proportional Hydraulic Valves. “Measurements Automation and Robotics” 2014, Vol. 3, pp. 112-119 (in Polish).
5. Milecki A.: Linear Electro Hydraulic Servo Drives. Poznan: Poznan University of Technology Publishing, 2003 (in Polish).
6. Pizoń A.: Electro Hydraulic Analog and Digital Automation Systems. Warsaw: WNT Publishing House, 1995 (in Polish).
7. Tomasiak E., Klarecki K., Barbachowski E.: Servo Drives in Machine Construction. “Hydraulics and Pneumatics” 2009, No. 1, pp. 16-20 (in Polish).
8. Materials developed by Parker Hannifin: Direct Operated Proportional DC Valve Series D1FB.www.parker.com/literature/Hydraulic%20Controls%20Europe/HY113500UK/PDF_2013/D1FB%20UK.pdf.