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SHAPING HYDROSTATIC GEAR START-UP BY MEANS OF HYDROPNEUMATIC ACCUMULATOR

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Abstract: *Some effects accompanying the start-up of a hydrostatic gear are indicated. Special attention is devoted to the acoustic signal. The possibility of attenuating the starting process by means of a hydropneumatic accumulator is considered. The adopted and experimentally verified solution brings about good results as regards dynamic pressure surplus limitation and reduces the A-weighted sound pressure level during the starting of the tested gear.*

Keywords: Hydrostatic gear, pressure, noise, hydropneumatic accumulator.

1. Introduction

In recent years various control systems for shaping the nonstationary state parameters of hydrostatic drive systems have been intensively developed. One should mention here particularly load sensing systems and microprocessor control in proportional technology (Kollek et al. 2010). Nevertheless, because of the relatively low cost and the peculiar operating conditions many heavy industrial machines equipped with constant-delivery pumps are controlled using conventional directional control valves (Watton, 1989). Recently an operating noisiness criterion has been added to the criteria for evaluating machines and equipment, especially machines with a hydrostatic drive. Therefore a properly designed system, besides having the assumed static and dynamic properties, should be characterized by the lowest possible level of emitted noise. Measurements indicate that the displacement pump is one of the main noise generating sources in hydrostatic drive systems. The literature on the subject and the experiments carried out by the authors show that the level of the noise emitted by the displacement pump is proportional to its load (Kudźma, 2001). This should also be expected during nonstationary states of hydrostatic drive systems, where in most cases the pressure during starting has an oscillatory character decaying due to damping, which means that pressure p_{max} occurs and noise characterized by a nonstationary waveform and a maximum level should be expected (Kudźma, 2009).

2. Tested object and measured quantities, measurement chains

The test stand (Fig. 1a) was built from the components of the actual slewing gear of crane DSO 182 T made by FAMABA Głogów Poland. A detailed description of the system shown in Fig. 1a is in the work (Kollek et al. 2010). Flow control valve 11 (Fig. 1a) is a load-sensing valve ensuring the relief of the pump during a hydraulic motor standstill. This can be done by connecting the pump with the tank through a pressure control valve (operating at a low pressure) built into the flow control valve. Moreover, thanks to flow control valve 11 the speed of the hydraulic motor in a certain range is independent of the changing external load. This is owing to the automatic operation of the differential pressure control valve installed

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in the throttle gaps of the flow control valve. A schematic of the flow control valve is shown in Fig. 1b. Dynamic tests consisted in recording the traces of pressure p (bar) and rotational speed n (rpm) after an abrupt flow rate induced excitation corresponding to a sudden change-over of flow control valve 11 (Fig. 1a).

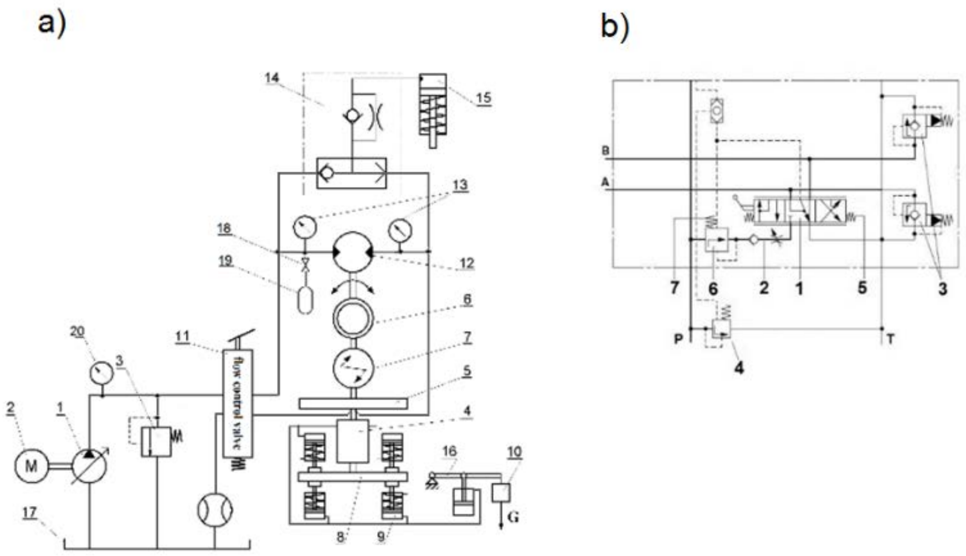

Fig. 1. a) Hydraulic schematic of test stand with marked measuring points, b) Detailed schematic of load-sensing flow control valve: 1 – main spool, 2 – variable orifice with load holding function, 3 – anti-cavitation valves, 4 –unloading valve, 5 – spring fixing slide position in flow control valve neutral position, 6 – pressure compensator, 7 – pressure compensator spring.

Simultaneously the accompanying effect in the form of A-weighted sound pressure level L_A (dB(A)) was recorded (Everest, 2013). The tests were carried out for two cases: with and without a hydropneumatic accumulator and for two values of hydraulic motor speed. Exemplary results for steady speed n = 100 rpm and n = 210 rpm for starting with the hydropneumatic accumulator (accumulator pre-charge pressure p_a = 40 bar) and without it are presented in respectively Fig. 2 and Fig. 3. Accumulator 19 was connected with the gear system by opening cut-off valve 18 (Fig. 1a). The acoustic characteristics for the system operating at hydraulic motor rotational speed n=100 and n=210 rpm are compared in respectively Fig. 4a and 4b.

3. Results

Some of the results obtained are shown in Figs. 2-5. Analysis of the results from Fig. 2 indicates that switching on the hydropneumatic accumulator in the hydraulic system leads to the reduction of dynamic excess pressure (Fig. 2a) - by approx. 20%. However, the accumulator caused an excess of dynamic speed of the hydraulic motor (increase by about 25%) and extended the duration of the transient process (for the pressure by about 2 seconds, and for the hydraulic engine speed by about 4 seconds).

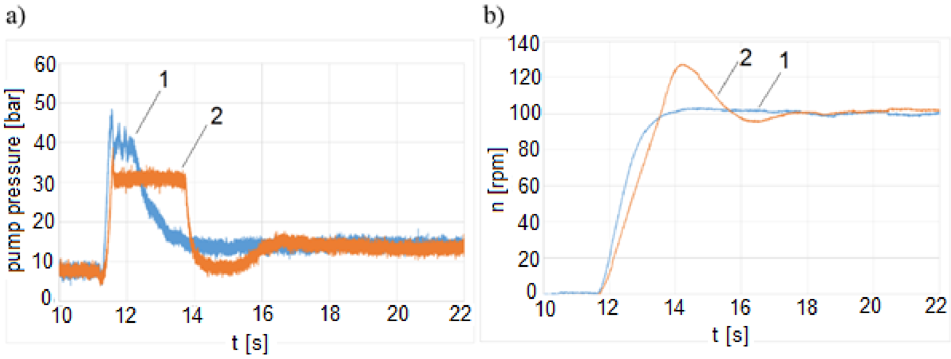

Fig. 2. Trace of pump pressure (a) and hydraulic motor shaft speed (b) during hydrostatic gear start-up: 1 – starting without accumulator, 2 – starting with accumulator. Hydraulic motor shaft steady-running speed n = 100 rpm.

The analysis of the results from Fig. 3 indicates that switching on the hydropneumatic accumulator in the hydraulic system leads to a reduction of the dynamic overpressure (Fig. 3a) by approx. 15%. However, the accumulator caused an excess of the dynamic speed of the hydraulic motor (increase by approx. 27%) and extended the duration of the transient process (for the pressure of approx. 5 seconds, and for the rotary engine speed by approx. 7 seconds).

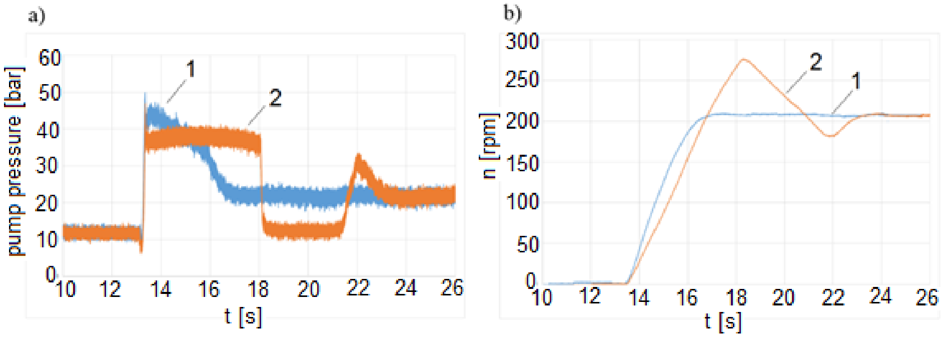

Fig. 3. Trace of pump pressure (a) and hydraulic motor shaft speed (b) during hydrostatic gear start-up: 1 – starting without accumulator, 2 – starting with accumulator. Hydraulic motor shaft steady-running speed n = 210 rpm.

The tests showed a close correlation between the measured A-weighted sound level and the pump operating pressure. Hence the conclusion that sound pressure level depends on the hydraulic system duty cycle. The power of radiated sound energy depends on the hydraulic power transmitted to the system in a device with hydrostatic drive (Osiński, 2013).

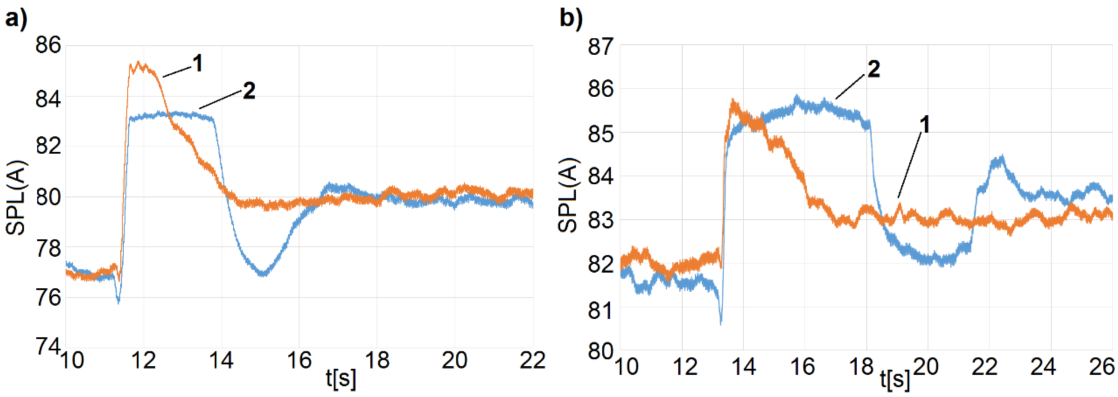

Fig. 4. Acoustic characteristics determined for motor shaft rotational speed: a) n=100 rpm, b) n=210 rpm: 1 – starting without accumulator, 2 – starting with accumulator.

Regardless of the duty cycle of the system, three dominant components with midband frequencies: 315, 400 and 500 Hz occur in the spectrum (Fig. 5). The octaves have the dominant influence on the global level of emitted noise and their source is the multi-piston pump (the fundamental component and the first harmonic).

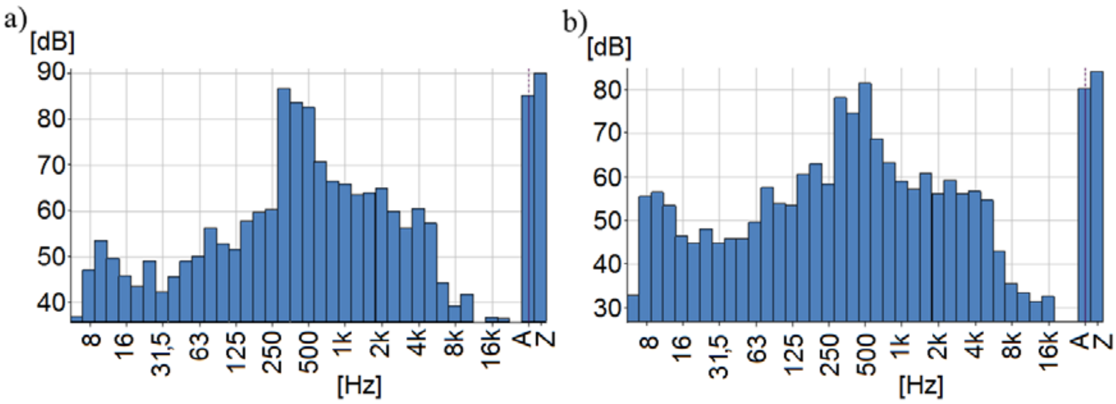

Fig. 5. Octave spectrum for system operating without accumulator: a) 12th second of operation, b) 20th second of operation.

The hydraulic and acoustic investigations have shown that:

a. as the rotational speed is increased, the pump operating pressure rises by about 5 bars, whereby the emitted noise level increases by ΔL_A (on average by 5dB(A);
b. if the accumulator is absent, the acoustic characteristic has a gentler shape in the rotational speed stabilization phase;
c. the system with the accumulator is characterized by greater pressure oscillations, whereby the source of the measured noise has a nonstationary character;
d. the system without the accumulator reaches the assumed speed faster;
e. the dynamic surplus (the dynamic amplification factor) is the highest for the system without the accumulator;
f. regardless of the duty cycle, three fundamental components with midband frequencies of 315, 400 and 500 Hz occur in the spectrum; the displacement pump being the source of the sound-generating vibrations;

4. Discussion and conclusions

Some of the test results presented here show the effect of the hydropneumatic battery on the hydrostatic transmission start-up process. Attention was focused on the pressure at the pump, the speed of the hydraulic motor and A-weighted sound pressure level SPL(A). When the hydropneumatic accumulator is introduced, this results in a reduction in pressure during the starting of the tested gear by a few to 10-20 bars, which amounts to 15-20% of the pressure during the starting of the system without the accumulator. The appearance of dynamic surplus speed of the hydraulic motor was noticed.

When selecting a hydropneumatic accumulator to reduce excess pressure dynamic, one should take into consideration: the expected operating pressure range (p_1, p_2), the useful volume of liquid which should be stored in the accumulator during its charging and return to the system during unloading. ΔV (Kotnis, 2011). Moreover, the gas compression and expansion rate should be estimated to establish the polytropic exponent. It is very important to determine the precharge pressure p_0 of the accumulator (usually $p_0 = 0.9\, p_1$). On this basis, the volume V_0 of gas is determined and a accumulator with a nominal volume V equal to V_0 or slightly larger is selected from the catalog.

References

Kollek, W., Kudźma, S., Kudźma, Z. and Stosiak, M. (2010) Influence of hydropneumatic accumulator on noise during start-up of hydrostatic drive system (in Polish). *Hydraulika i pneumatyka*, 30, 1, pp. 17-20.

Watton, I. (1989) *Fluid power systems. Modeling, simulation, analog and microcomputer control.* Prentice Hall International (UK) L.t.d., London.

Kudźma, Z. (2001) Reduction of the noise of the hydrostatic gear during its starting (in Polish). *Hydraulika i Pneumatyka*, 21, 6, pp. 10-15.

Kudźma, Z. and Łomotowski, G. (2009) Control of hydrostatic gear starting with regard to noise minimization (in Polish). *Hydraulika i Pneumatyka,* 29, 3, pp. 5-10.

Everest, F. A. and Pohlmann, K. (2013) *Master Handbook of Acoustics.* McGraw-Hill Companies, Inc., New York.

Kotnis, G. (2011) *Construction and operation of hydraulic systems in machines.* KaBe Publishing House, Krosno.

Osiński, P., Kollek, W. (2013) Assessment of energetistic measuring techniques and their application to diagnosis of acoustic condition of hydraulic machinery and equipment. *Archives of Civil and Mechanical Engineering*, vol. 13, 3, pp. 313-321.