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INVESTIGATION OF TRANSIENT STATES OF THE HYDRAULIC POWER UNIT COOPERATING WITH THE SERVOVALVE

ZKOUMÁNÍ PŘECHODOVÝCH STAVŮ ZDROJE TLAKU PRO OBVOD SE SERVOVENTILEM

Abstract

Authors present results of laboratory researches carried out on electrohydraulic servodrive which is working under intensive occurring of dynamic states of operation. Carried out laboratory researches aimed to characterise mutual interaction between a servo-drive and a hydraulic power supply. In the paper authors take note of pressure time diagrams in output port of the hydraulic power unit and input port of the servodrive both connected together with hydraulic hose. Authors are studding influence of working parameters settings of the hydraulic power supply into pressure course in the feeding line. We also investigated how real courses of measured pressures are different from the pressure value established for the relief valve.

Abstrakt

Autoři představují výsledky laboratorního výzkumu uskutečněného na elektrohydraulickém servopohonu, který pracuje při intenzivním působení dynamického zatěžování. Tento laboratorní výzkum směřoval k charakterizaci vzájemných interakcí mezi servopohonem a hydraulickým napájecím zdrojem. V příspěvku představili časové průběhy tlaku výstupního kanálu hydraulického čerpadla a vstupního kanálu servopohonu propojených společnou hydraulickou hadicí. Byl rovněž studován vliv nastavených pracovních parametrů hydraulického čerpadla v závislosti na průběhu tlaku v napájecím vedení. Dále byl zkoumán, jak se liší reálný průběh měřeného tlaku od požadovaného průběhu.

1 INTRODUCTION

Overall classification of hydraulic systems for the sake of control distinguished: volumetric control hydraulic systems, throttling control hydraulic systems and both volumetric and throttling control hydraulic systems. In case of hydraulic systems with throttling control receiver should be supply with hydraulic fluid with surplus of output flow in relation with required input flow. Hydraulic power consumption in such systems is realising from pumps set equipped with pressure relief valves at the outlet which provide supply pressure stabilisation. It concerns mainly the systems based on proportional and servovalve technique. This type of systems is used among other things in positioning systems, mechanical vibration generators, active and semiactive vibration reduction systems and so on. In some working conditions of such systems important difficulties with stabilisation of pressure supply may occur. Many factors can be mentioned they may influence to pressure stabilisation accuracy.

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Consequently this may influence on working factors of the hydraulic receiver supplied from such a power supply. As it was presented in publication [JARACZ at al., 2004], above-mentioned hydraulic systems show sensitivity to changes of pressure supply but their mathematical models are mainly created under assumption, that ideal constant-pressure sources are applied [KORZENIOWSKI et al., 2005; KWAŚNIEWSKI et al., 2003; KOŇAŘÍK, 2006; STRÁŽOVEC et al., 2004; PLUTA et al., 2003, SMUTNÝ, P. 2005, TŮMA et. al., 2002]. It may lead to considerable discrepancies between results of simulation tests based on such model and results obtained from real object. To state in what way the real hydraulic pressure supply of throttling control systems behave under dynamic states of receiver work suitable laboratory researches have been carried out.

2 DESCRIPTION OF THE SYSTEM

Investigation has been carried out on electrohydraulic servodrive (Figure 1) connected to the multi-pump hydraulic power supply (Figure 2). Hydraulic power supply with three identical main hydraulic piston pumps delivering power to the electrohydraulic servodrive has been used for researches.

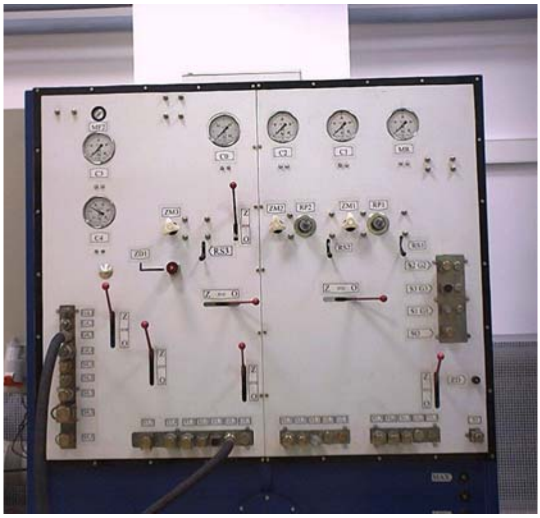

Fig. 1 Electrohydraulic servodrive **Fig**. **2** Hydraulic power supply unit

Simplified circuit diagram of the laboratory stand was presented in the Figure 3, using graphic symbols according to the ISO 1219-1 standard. The presented system enables supply cylinder HC either from one or two pumps. Flow rate of the fluid current, delivering from one or both pumps to the cylinder servovalve SV, can be decreased because of leading pump (pumps) flow current partially to the tank by flow regulators FR. If the hydraulic power supply is working with pumps overrate of outlet flow in proportion to receiver inlet flow, fluid pressure on its output is stabilised by pressure relief valves PV1 or PV2 (or both). Working of the hydraulic power supply can be additionally assisted by hydraulic accumulator HA. Laboratory stand was equipped in displacement transducer DT, pressure transducers PT1 and PT2, as well as flow meter FM. Mentioned measuring components and servovalve SV connected with measuring and control system and computer working with LabVIEW software.

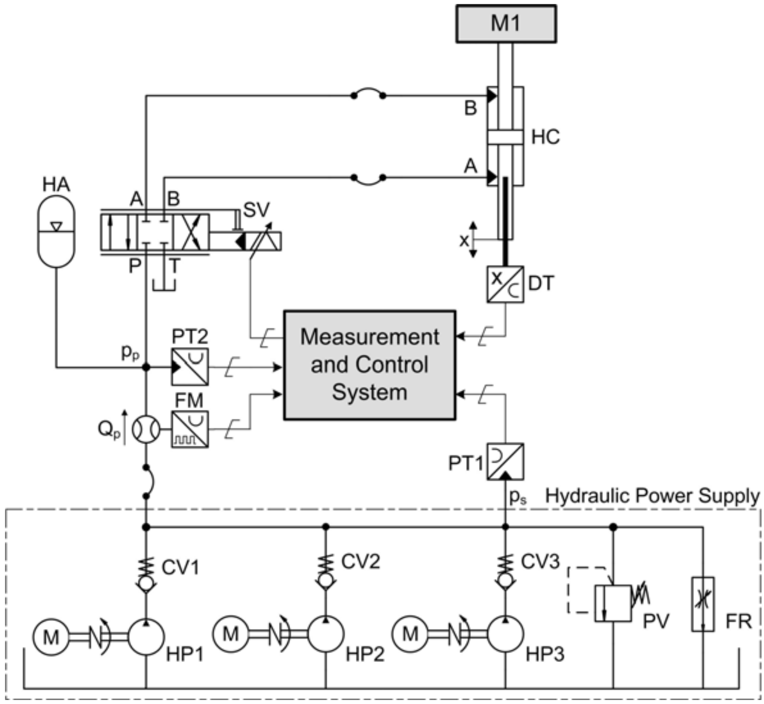

Fig. **3** Circuit diagram of the hydraulic power supply loaded by electrohydraulic servodrive:
HC – hydraulic cylinder, HA – hydr. accumulator, HP1, HP2 and HP3 - hydraulic pumps,
PV – relief valves, FR – flow regulator, SV – electrohydraulic servovalve,
P, A, B and T – servovalve ports, CV1, CV2 and CV3 – shut-off valves,
DT – displacement transducer, PT1 and PT2 – pressure transducers, FM – flow transducer,
M – electrical motor, M1 – load, p_s and p_p – pressures, x – piston displacement

3 LABORATORY TESTS

Transient states of investigated hydraulic system come mainly from inlet flow changes of the hydraulic cylinder, controlled in the presented system by servovalve SV. As the result of inlet flow changes there is pressure relief valves interaction, where changing flow rate is directed. In extreme cases pressure relief valve is completely closed or lets in the whole flow current generated by pump. Construction features (e.g. valve head mass, spring stiffness, viscosity dumper parameters) strongly influence pressure value stabilised by pressure relief valve. Many experiments were carried out, where working receiver parameters and its loading, amount of working pumps and value of relief valves opening pressure were changed and additionally an accumulator was connected. During the researches pressure p_s was measured on the outlet of the hydraulic power supply (transducer PT1) and p_p on the inlet of the servovalve SV (transducer PT2) as well as piston displacement x of the cylinder CH (transducer DT). Giving suitably chosen piston displacement course from the control system above-mentioned physical quantities were registered.

For the first set of researches triangle signal with suitable frequencies and amplitudes selection. Registered and presented in the Figure 4 charts show hydraulic power supply response to the working servodrive as a triangle shape generator. This disturbance appears at the moment of piston velocity sign changes, what is visible in the pressure diagrams. During this laboratory test pump PH1 with the output flow of 16 l/min was working and pressure relief valve PV1 was set to opening pressure 14 MPa (with rated flow 16 l/min). Lumped mass M1 was 25 kg. Presented results in the Figure 2a concern the situation, where servodrive was controlled by triangle signal with frequency 2.5 Hz and amplitude 10 mm. Piston was moving with the mean velocity 0.1 m/s what corresponds to inlet flow 6.92 l/min. For such cylinder motion parameters, mean pressure value measured in the outlet of the hydraulic power supply was 13.64 MPa, and in the inlet of servovalve 13.57 MPa. Range of the pressure value changes measured on hydraulic power supply and servovalve were corresponding to the values 0.56 MPa and 0.41 MPa. During the second experiment piston motion amplitude was changed to 20 mm. Piston was moving with the velocity of 0.2 m/s (Fig. 2b) what corresponds to inlet flow 13.84 1/min. For such cylinder motion parameters, mean pressure value measured in the outlet of the hydraulic power supply was 12.84 MPa, and in the inlet of servovalve 12.73 MPa. Range of the pressure value changes measured on hydraulic power supply and servovalve were corresponding to the values 0.88 MPa and 0.64 MPa. Pressure courses registered using transducer PT1 include component represented by pressure pulsation with amplitude about 0.1 MPa and frequency 175 Hz. This feature characterised the piston pumps operation used in hydraulic power supply. This pulsation is not visible in the diagrams of pressures measured by transducer PT2. Flexible hydraulic hose connecting power supply with receiver is working as a low pass filter. Where velocity sign is changing, rapid pressure increase appears what is caused by receiver inlet flow decrease, reached as the effect of servovalve SV control. Observed response of the system indicates that investigated hydraulic power supply possesses the features of oscillatory object, connected with dynamic features pressure relief valve. Because of the fact that dumping ratio of the valve head is rather small, step or impulse flow rate change in this valve causes, that valve head achieved equilibrium position in an oscillation way. From the schema presented in the Figure 1 follows, that value of this dumping ratio depends on working point of the relief valve. Increasing amplitude or frequency of piston motion leads to the decrease of power supply line mean pressure value. For velocity 0.1 m/s supply pressure drop of 2.6% was observed. When velocity increases twice it leads to pressure drop of 8.3%. Further velocity increasing lead to even higher supply pressure drop.

a) b)

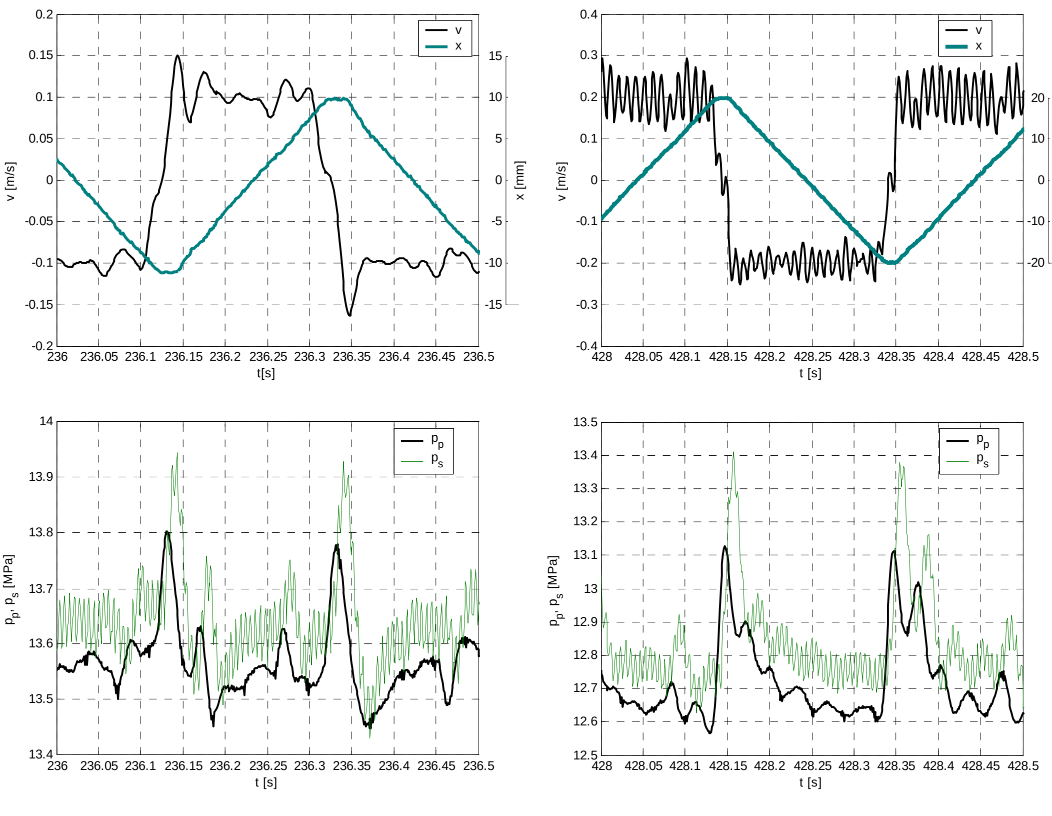

Fig. **4** Time diagram of the piston velocity *v* and displacement *x* as well as pressure p_s and p_p for triangle control signal with frequency 2.5 Hz and amplitudes: a) 10 mm, b) 20 mm

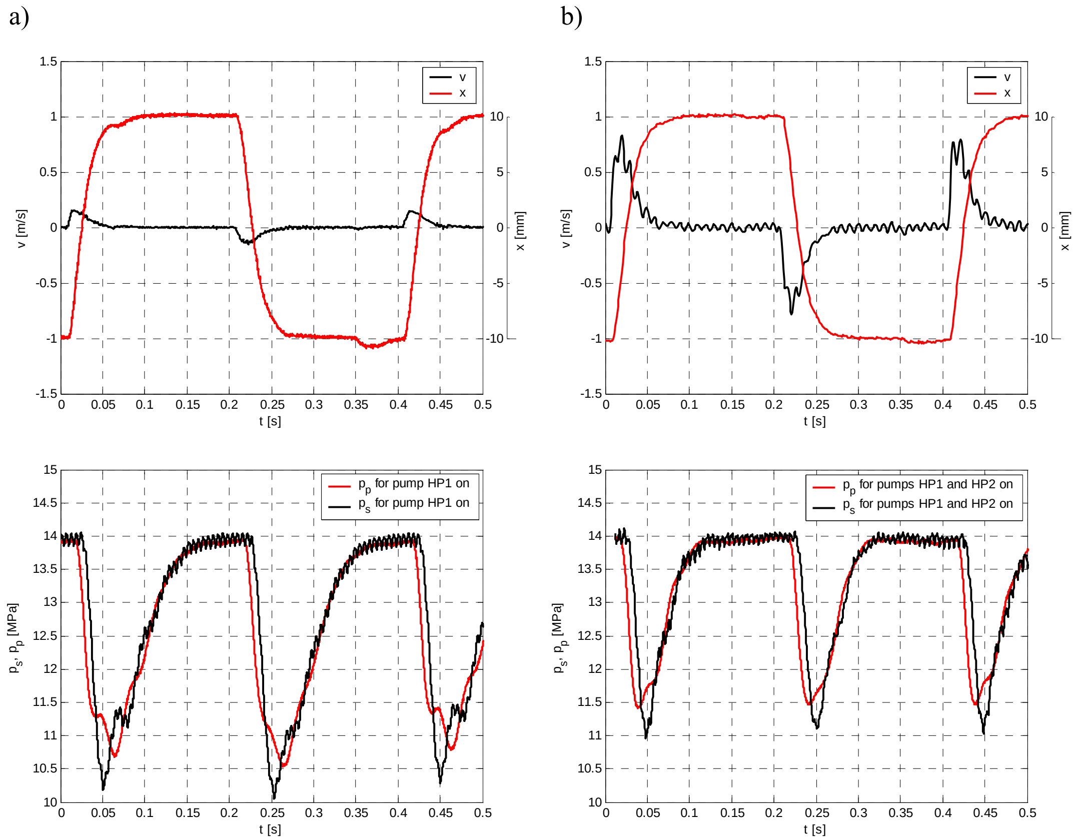

Fig. 5 Time diagram of the piston velocity v and displacement x as well as pressure p_s and p_p for square control signal with frequency 2.5 Hz and amplitude 10 mm for:
a) one hydraulic pump HP1 on; b) two hydraulic pumps HP1 and HP2 on

4 CONCLUSION

Presented in the paper laboratory researches of hydraulic power unit, cooperated with electrohydraulic servodrive, which is characterised by dynamic absorptivity changes, make possible to register results of investigation indicating significant mutual interaction between both systems. Investigated hydraulic power unit is not always stiff enough source of constant pressure in dynamic states of operation. For some working parameters of hydraulic power unit and servodrive, pressure supply indicates considerable susceptibility to changes in working conditions. Next the disturbances in supply pressure courses influence into mapping accuracy of control signal shape and dynamic properties of hydraulic receiver. The influence to the supply pressure value possesses among others surplus of the hydraulic power supply output flow, shape and parameters of a control signal used for hydraulic receiver steering, static and dynamic characteristics of the pressure relief valve, cooperation with hydraulic accumulator, and parameters of hydraulic supply pipe. Results of laboratory researches lead to the conclusions how hydraulic throttling control systems should be modelled. Simulations of such systems are usually carried out for mathematical models assuming constant pressure supply. It may lead to important discrepancies between results obtained form simulations and real courses of appropriate physical quantities. Therefore hydraulic throttling control systems working under frequently appearing dynamic states stiff pressure supply source model maybe not be sufficient.

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