ACTA TECHNICA CORVINIENSIS
BULLETIN OF ENGINEERING

[1.] LUMÍR HRUŽÍK, [2.] MARTIN VAŠINA, [3.] ROMAN SIKORA

DIAGNOSTICS OF DRIVE DYNAMICS WITH HYDRAULIC MOTOR AND INERTIAL MASS

Abstract:
The paper deals with diagnostics of hydraulic drive dynamics with hydraulic motor. Flow and speed of the hydraulic motor are controlled by proportional distributor. There are measured and evaluated time-response characteristics of pressures before and behind the hydraulic motor and time-response characteristics of speeds of the hydraulic motor with the inertial mass on control voltage step change. This voltage is brought to card of the proportional distributor at the same time. The dynamic behaviour of the drive with the hydraulic motor and the inertial mass at ramp change of the control voltage on the card input of the proportional distributor is subsequently measured and evaluated.

Keywords:
hydraulic motor, inertial mass, time – response characteristics, ramp change

INTRODUCTION

Proportional distributors [5] are applied in hydraulic applications to continuous control of flow. The size and direction of flow corresponds to inlet control electric signal. The hydraulic motor with inertial mass controlled by the proportional distributor forms an oscillating system with the eigenfrequency f. The eigenfrequency of the rotary hydraulic motor depends on its geometric volume, moment of inertia of rotating masses, liquid volume and bulk modulus of liquid [1], [3]. The recommended time of the ramp function for run up and run down is calculated in order to reduce unfavourable dynamic effects.

MEASURING EQUIPMENT

The hydraulic drive with the rotary hydraulic motor is controlled by the proportional distributor [2]. The inertial mass is realized by steel discs. The hydraulic pump with constant pressure control is used as the source of pressure liquid. The tank with the volume of 160 dm^3 consists of air filter, thermostat, water level sensor, cooler and low pressure filter. The flow size and direction of liquid are controlled by the proportional distributor with its external control card. Mineral oil [4] was used as the working liquid. The source of control voltage uv is the stabilized voltage source with the potentiometer for step voltage change uv and the functional generator to control ramp function of voltage uv.

Rotating axial piston motor with rotating inclined plate was used as the output consumer. The moment of inertia of rotating masses (i. e. of the rotary hydraulic motor, two rotating discs, brake disc, shaft and mechanical coupling) is $J_M = 6.10^{-2}$ $kg.m^2$ [3] in this case. The hydraulic motor is connected to the proportional distributor by high-pressure hoses with the inner diameter of 0.012 m and the length of 1.6 m. The hydrostatic drive is shown in Fig. 1 [2]. The auxiliary view of the hydraulic motor is displayed in Fig. 2.

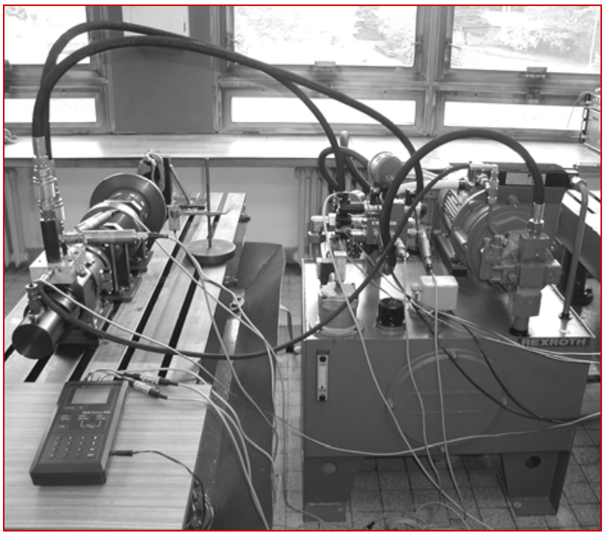

Fig. 1 Measuring equipment

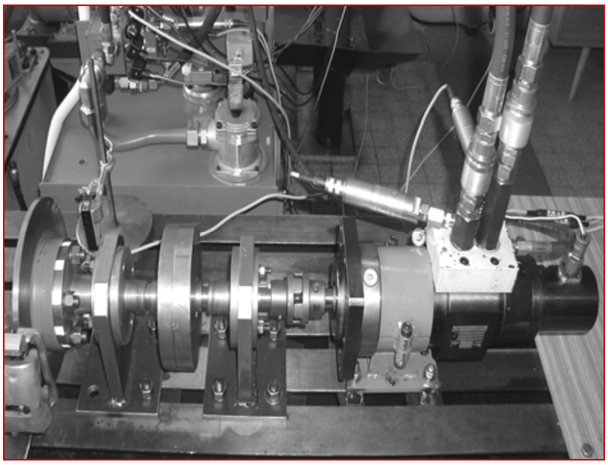

Fig. 2 Auxiliary view of hydraulic motor

The time-response characteristics of the pressure pB on the inlet to the hydraulic motor, the pressure pA on the outlet from the hydraulic motor and the voltage uTD of the tachogenerator were experimentally measured in this case. The time-response characteristics were measured for option of the hydraulic motor with inertial mass realized by steel discs and for option without the discs. The responses of the pressures pA and pB and the voltage uTD to control input signal ramp function were measured for option with the inertial mass. The measurement was realized by the measuring system M 5050 Hydrotechnik. The pressures pA and pB were measured by pressure sensors Hydrotechnik (range (0 ÷ 200) bar) with the measurement accuracy ± 0,5 %. The voltage of the tachogenerator uTD was measured by the voltage sensor Hydrotechnik. The course of speed for the hydraulic motor can be determined from the measured voltage of the tachogenerator uTD (i. e. 16 V = 1000 rpm).

TIME-RESPONSE CHARACTERISTICS OF DRIVE WITH HYDRAULIC MOTOR LOADED BY MASS DISCS

The time-response characteristics of the drive for the hydraulic motor with the mass discs were measured for the control voltage step change uv = (0 ÷ 5) V. The time-response characteristics of the inlet pressure pB and the outlet pressure pA of the hydraulic motor and the voltage uTD of the tachogenerator after the control voltage step change uv = (0 ÷ 5) V are demonstrated in Fig. 3. The measured responses show a vibrating course with significantly damped dynamic processes. The maximal instantaneous pressure pB = 108 bar on the inlet of the hydraulic motor during the first amplitude is considerably higher in comparison with the steady-state value pB = 34 bar. It is possible to determine the vibration period T of the pressure between the 3rd and the 4th response oscillations:

$$T = 37.345 - 37.1 = 0.254 \text{ s} \tag{1}$$

The corresponding system eigenfrequency f is subsequently given by the formula:

$$f = \frac{1}{T} = 4.1 \text{ Hz} \tag{2}$$

The significant maximum of the pressure pB = 97.4 bar in comparison with the steady-state pressure pB = 26 bar was measured after the control voltage step change uv = (0 ÷ 4) V.
The maximum of the pressure pA = 122.5 bar on the outlet of the hydraulic motor at the first pressure oscillation from the steady-state value pA = 24 bar was measured at the control voltage step change uv = (5 ÷ 0) V. The pressure pA was subsequently reduced to the value pA = 0 bar at the hydraulic motor stop.
The significant maximum of the pressure pA = 82.4 bar in comparison with the steady-state pressure pA = 18 bar was measured in the hydraulic motor outlet after the control voltage step change uv = (4 ÷ 0) V.

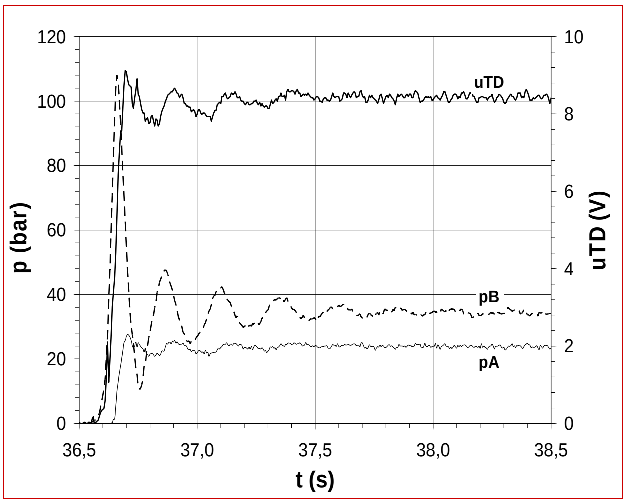

Fig. 3 Time-response characteristics of pA, pB, uTD, uv = (0 ÷ 5) V, with inertial mass.

Time-Response Characteristics Of Drive With Hydraulic Motor Without Inertial Mass

The time-response characteristics of the drive for the hydraulic motor without the inertial mass were measured for the control voltage step change uv = (0 ÷ 5) V. The time-response characteristics of the inlet pressure pB and the outlet pressure pA in the hydraulic motor and the voltage uTD of the tachogenerator after the control voltage step change uv = (0 ÷ 5) V are displayed in Fig. 4. The run up of the hydraulic motor is smooth (see Fig. 4).

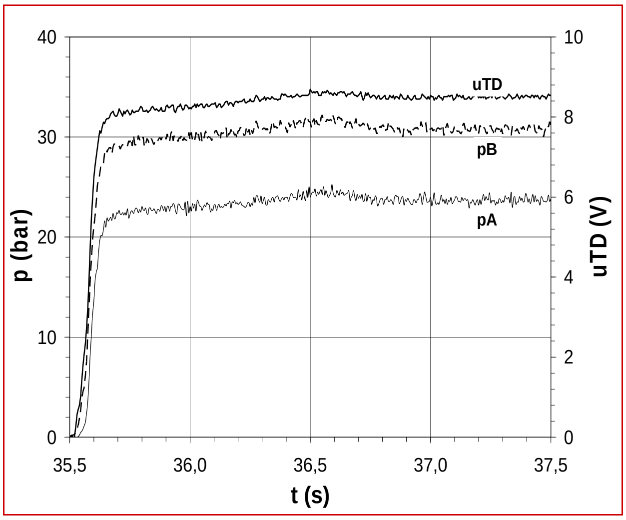

Fig. 4 Time-response characteristics of pA, pB, uTD, uv = (0 ÷ 5) V, without inertial mass

Response Of Drive With Hydraulic Motor Loaded By Mass Discs On Ramp Function

The responses of the drive with the hydraulic motor loaded by mass discs on the control voltage linear ramp functions uv = (0 ÷ 4) V and uv = (4 ÷ 0) V were also measured. The time of the linear ramp function was T = 2 s in this case. The responses of the quantities pA, pB and uTD during the ramp function uv = (0 ÷ 4) V for the time T = 2 s are displayed in Fig. 5 [2]. From Fig. 5 is evident that there is not significant pressure peak due to slow run up of the ramp function of the control voltage. The peak pressure on the hydraulic motor inlet is only pB = 33.1 bar, while in the case of the steady-state is the pressure pB = 26.5 bar. Similarly, the responses of the quantities pA, pB and uTD during the ramp function uv = (4 ÷ 0) V for the time T = 2 s are displayed in Fig. 6 [2].

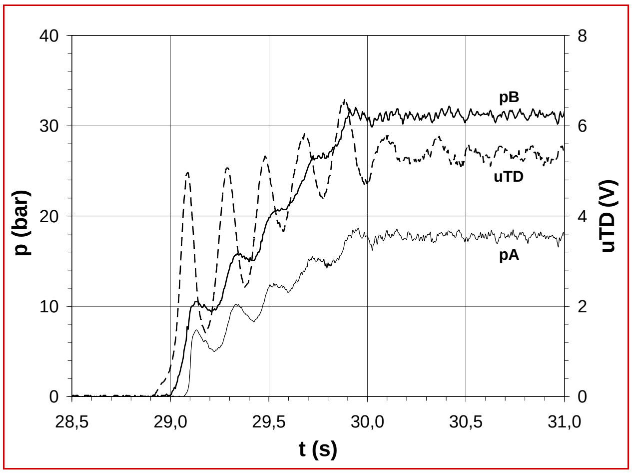

Fig. 5 Responses of pA, pB, uTD, ramp function uv = (0 ÷ 4) V, T = 2 s, with inertial mass

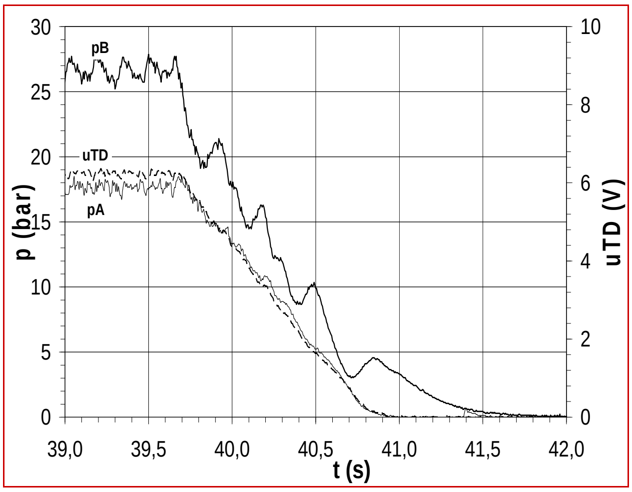

Fig. 6 Responses of pA, pB, uTD, ramp function uv = (4 ÷ 0) V, T = 2 s, with inertial mass

CONCLUSION

The effect of the inertial mass on significant pressure overshoot (during the run up) on the hydraulic motor inlet and significant growth of pressure (during the braking) on the hydraulic motor outlet are evident from the measured time-response characteristics of the investigated drive with the hydraulic motor. The elimination of pressure peaks in the hydraulic motor during the run up and the braking is evident from the measured responses at the control voltage uv of ramp functions of the investigated drive with the hydraulic motor.

There is evident the influence of the time behaviour of the control voltage uv on the course of the pressure pB on the hydraulic motor inlet at its start with the inertial mass. For the step change of the control voltage uv (0 ÷ 5) V, the response of the pressure pB has the expressive first maximum pB = 97.4 bar at the first oscillation in comparison with the response of the pressure pB at the small ramp function (see Fig. 5) of the control voltage uv (0 ÷ 4) V. The time behaviour of the control voltage uv on the time dependence of the pressure pA on the hydraulic motor outlet is similarly evident at its stopping with the inertial mass from the measuring data. The pressure response at the step change of the control voltage uv = (4 ÷ 0) V has the expressive first maximum pA = 82.4 bar at the first oscillation in comparison with the pressure response on the small ramp function (see Fig. 5) of the control voltage uv = (4 ÷ 0) V.

REFERENCES

[1.] *Kolektiv autorů: Příručka hydrauliky svazek 2. Proporcionální technika a servotechnika, Lohr am Main: Mannesmann Rexroth GmbH, 1986.*

[2.] *PAVLOK, B., HRUŽÍK, L.: Dynamika LS systému s rotačním hydromotorem, Technická zpráva k HS 338401, VŠB–TU Ostrava, 2004.*

[3.] *VAŠINA, M.: Energeticky úsporné hydraulické systémy zvedacích a nakládacích zařízení montovaných na nákladní automobily. Disertační práce, Ostrava: VŠB–TU Ostrava, 2000.*

[4.] *VAŠINA, M.: Physikalische Eigenschaften von Flüssigkeiten. In: Jemná mechanika a optika, No.10, 2004.*

[5.] *WILL, D., GEBHARDT, N.: Hydraulik Grundlagen, Komponenten, Schaltungen, Berlin; Heidelberg; New York: Springer, 2008*

AUTHORS & AFFILIATION

1. LUMÍR HRUŽÍK,
2. MARTIN VAŠINA,
3. ROMAN SIKORA

1. DEPARTMENT OF HYDROMECHANICS AND HYDRAULIC EQUIPMENT, VŠB - TECHNICAL UNIVERSITY OF OSTRAVA, CZECH REPUBLIC
2. DEPARTMENT OF PHYSICS AND MATERIAL ENGINEERING, TOMAS BATA UNIVERSITY IN ZLÍN, CZECH REPUBLIC
3. DEPARTMENT OF MECHANICS, VŠB - TECHNICAL UNIVERSITY OF OSTRAVA, CZECH REPUBLIC