METHODOLOGY FOR MEASURING AND ASSESSING STATIC CHARACTERISTICS OF LIQUID ELEMENTS

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Abstract

The paper is focused on determination of static characteristics of elements used in hydraulic circuits. The elements for which the given characteristics are created are valves - safety and pressure control, hydraulic distributor and hydraulic generator. Measurements were performed at experimental stations and components created in the authors' workplaces. Wiring verification and hydraulic diagrams were created in FluidSIM Hydraulics simulation software. The methodology and method of obtaining characteristics of the type Δp = f (Q), i.e. the dependence between the pressure drop and the flow rate for given hydraulic elements described in this article, may be applicable to other elements creating local hydraulic resistances.

Keywords: Hydraulic, Pump, Valves, Pressure drop, Flow rate

1 Introduction

By using hydraulic elements in hydraulic circuits, it is often necessary to have static characteristics Δp = f (Q) (pressure drop depending on flow rate), which can be obtained either from the catalogs of the respective hydraulic elements or must be determined by measurement.

The static characteristics of the fluid elements are generally measured with a certain type of oil and at a stabilized temperature of 50 °C. *p*-*Q* characteristics are also reported at this temperature. However, in technical practice we often need to investigate the behavior of hydraulic systems at other operating temperatures - low, high or optimal. To do this, we need to know the dependence of static *p*-*Q* characteristics in mathematical terms, also depending on the properties of the oil used and the temperature.

In the catalogs these dependencies are given at certain temperatures or at certain types of oils (possibly at the temperature, density and kinematic viscosity of the liquid). When applying these elements in hydraulic circuits, we need to be able to calculate dependencies Δp = f (Q) for other types of oils and for different temperatures. Similarly, when these characteristics are obtained by measurement.

This work deals with the methodology of measurement, evaluation and description of *p*-*Q* characteristics on the safety and pressure reducing valve, switchboard and gear pump. The above methodology can also be used for other types of hydrostatic elements (Fig. 1), in which there is a hydraulic resistance to movement, such as throttle valves, unidirectional and bypass valves, filters, distributors, coolers, etc. [1], [9].

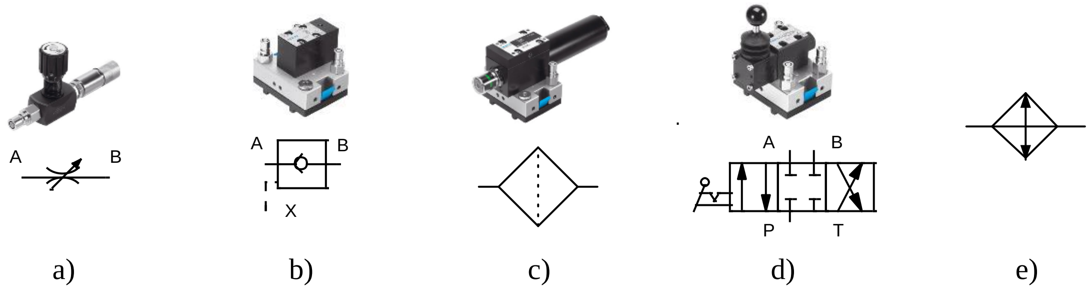

Fig. 1 *Types of elements for measuring p-Q characteristics and their symbols*
a) Throttle; b) a non-return valve; c) filter; d) switchgear; e) cooler

The paper presents a methodical procedure for measuring static characteristics Δp = f (Q) of hydraulic resistance to movement so that it is possible to evaluate the characteristics depending on the hydraulic oil used and at the selected temperature. Actual measurements are made at different hydraulic oil and temperature. The group of oils also includes biodegradable liquids [2], [3].

For such research purposes, but also for pedagogical purposes, measuring stations were built at KS FŠT in the HaPMaS laboratory - one universal one, which allows to measure static and dynamic characteristics of hydraulic pumps, throttle and pressure valves, distributors and other elements for flow rates up to 28 dm^3/min and pressures up to 50 bar [1] and the second easy-to-adjust hydraulic stand from FESTO, on which it is possible to assemble various measuring chains and measure hydraulic element characteristics for flow rates up to 3.7 dm^3/min and pressures up to 60 bar. Similar universal facilities are also built at the Department of Transport and Handling of the Technical University of Nitra [8], [11].

2 Measured elements and composition of measuring devices

The methodology for measuring and evaluating the *p-Q* characteristics will be shown on the 152850 pressure reducing valve and the 152848 safety valve by FESTO, the 4/2 RSP1-062J15-1 switch valve, and the G1 and G2 twin generators (Fig. 2 - 9) [5]. In the case of the valves, at the bottom the manifold plate serves for oil inlet and outlet and for attachment to the measuring panel (Fig. 2 and 4). In Fig. 3, 5, 7 and 9 is shown the hydraulic symbol of the measured elements [10].

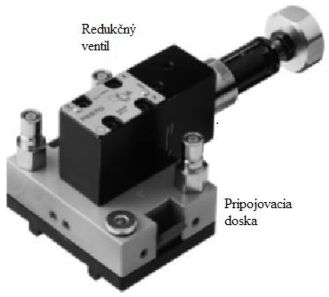

Fig. 2 *Reducing valve 152850 by FESTO*

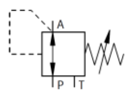

Fig. 3 *Symbol of reducing valve*

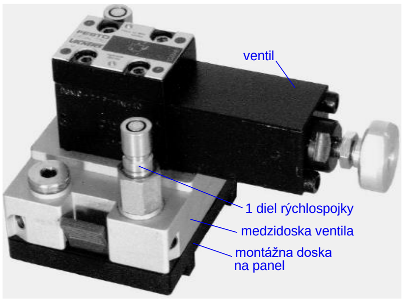

Fig. 4 *Safety valve 152848 by FESTO [5]*

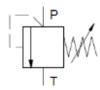

Fig. 5 *Symbol of safety valve; P – inlet of pressure oil, T – outlet of oil*

Fig. 6 *Four-way and two-position switch valve 4/2 RSP1-062J15-1*

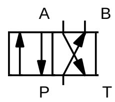

Fig. 7 *Symbol of switch valve 4/2*

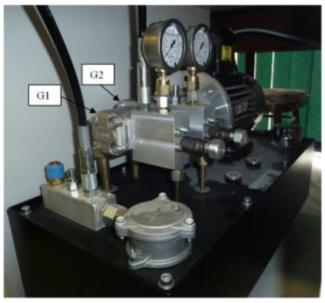

Fig. 8 *Hydraulic unit with double pump G1 and G2*

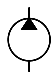

Fig. 9 *Symbol of rotary pump*

The following figures show the real versions of modular type hydraulic measuring systems for individual measuring elements (Fig. 10, 11).

Fig. 10 *General view of an adjustable stand from FESTO (in case of measurement characteristics of hydraulic gear pumps); 1 - work panel, 2 - hose reservoir, 3 - element measuring chain, 4 - writing surface, 5 - integrated sockets, 6 - measuring device, 7 - hydraulic unit with double pump and electric motor*

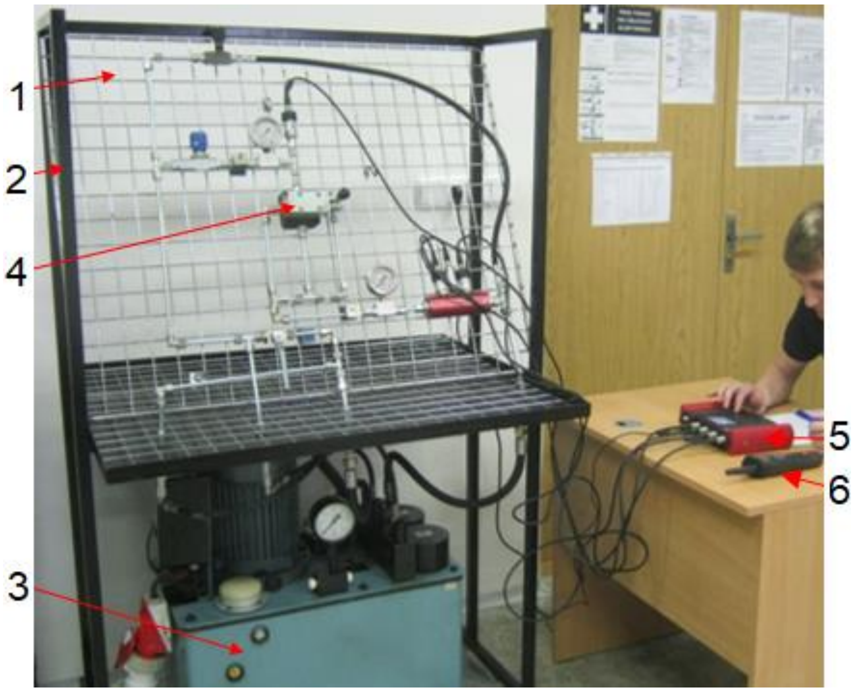

Fig. 11 *General view of the universal hydraulic stand (in case of measurement characteristics of safety valve) 1 - grate surface, 2 - stand frame, 3 - hydraulic unit, 4 - measured hydraulic distributor, 5 - measuring instrument HGM 3000, 6 - measuring instrument of temperature and humidity of the environment*

3 Hydraulic circuits with measuring chains

The hydraulic systems used with the measuring chains are shown in Fig. 12 – 15. FluidSim Hydraulics simulation program was used to draw measurement chains as components of hydraulic circuits using standardized symbols.

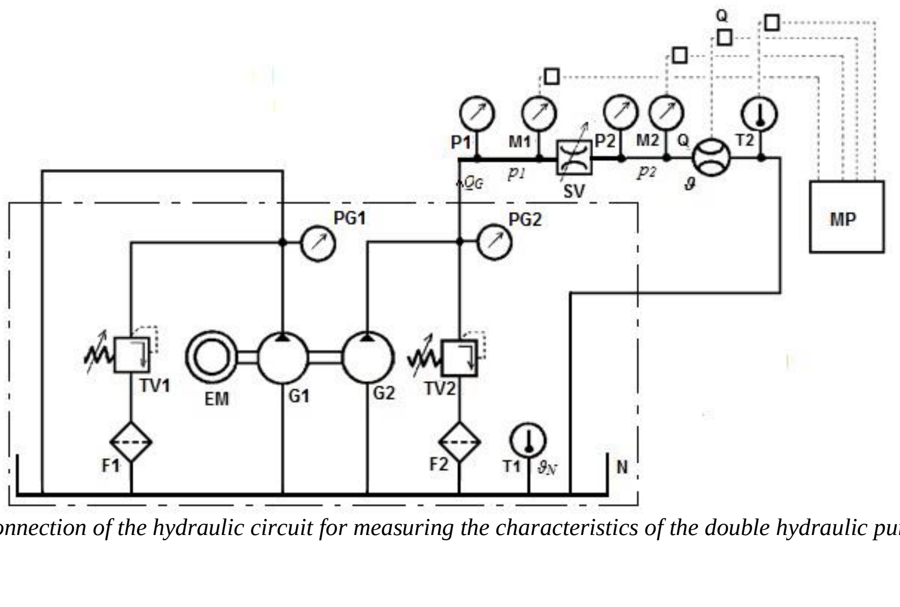

Fig. 12 *Connection of the hydraulic circuit for measuring the characteristics of the double hydraulic pump G1 and G2*

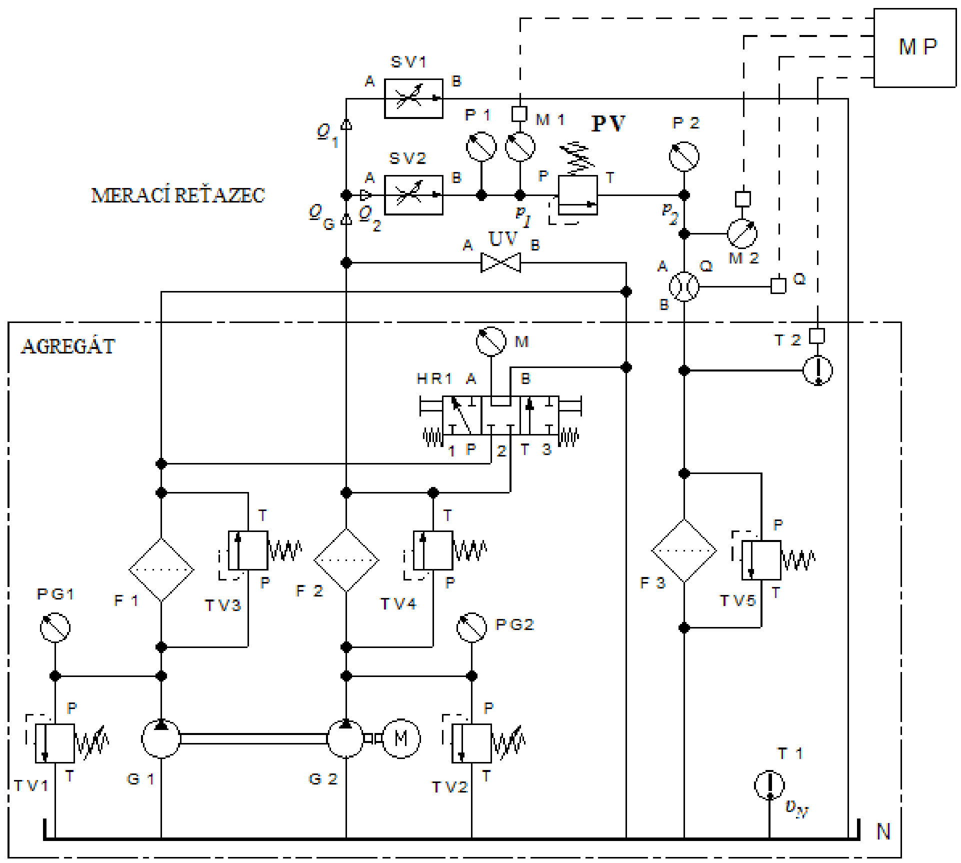

Fig. 13 *Connection of the hydraulic circuit for measuring the characteristics of the PV safety valve*

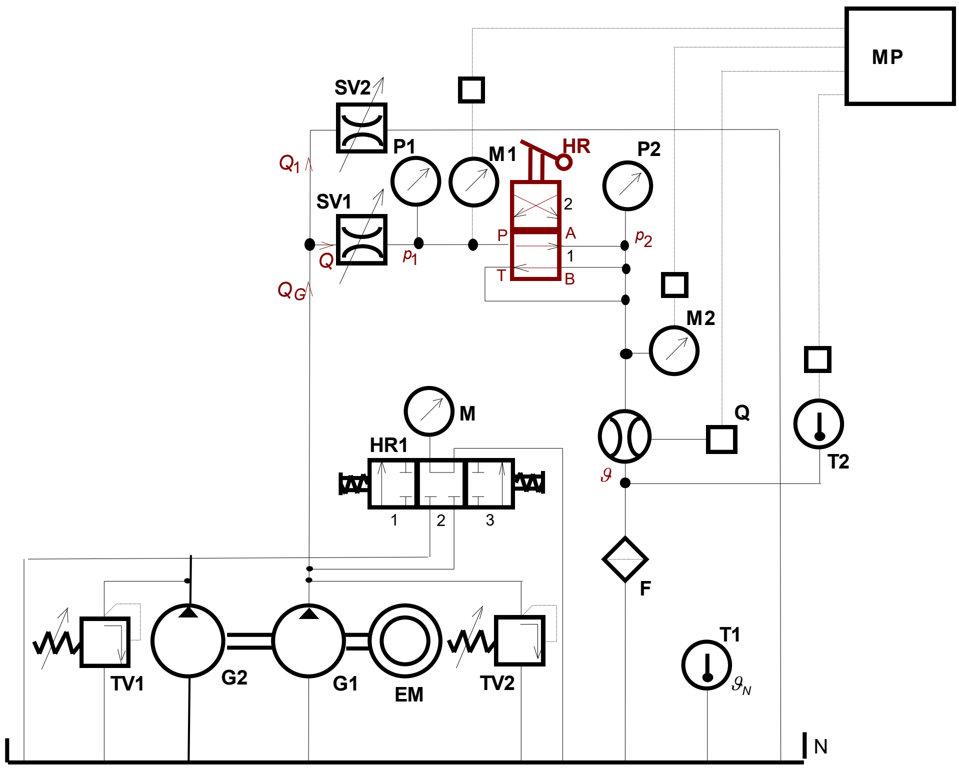

Fig. 14 *Connection of the hydraulic circuit for measuring the characteristics of the HR 4/2 switch valve*

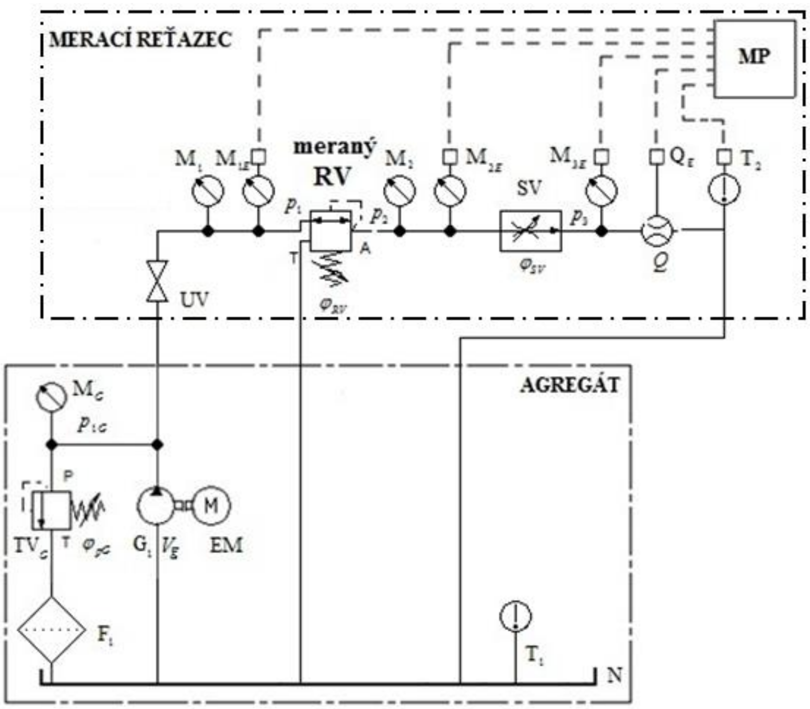

***Fig. 15** Connection of hydraulic circuit with RV pressure reducing valve by FESTO*

The following elements and quantities were used in the hydraulic measuring circuits (Fig. 12 - 15): EM- electric motor (M in circle), F, F1, F2, F3 - filters, TV1 - TV5 - filter pressure valves F1 - F5, G1, G2 - gear pumps, M_G - pump pressure gauge, M_1 (P1), M_2 (P2) - pressure gauges for pressure measurement p_1 and p_2, M_{1E} (M1), M_{2E} (M2), M_{3E} - electrical pressure sensors p_1, p_2 and p_3, MP - measuring instrument, N - tank, p_1, p_2 - pressures before and after measured elements, Q_G, Q_1, Q_2 – hydraulic pump flow, branched flow, Q - flowmeter, Q_E - electric flow sensor, SV - throttle valve, T_1 - tank thermometer N (ϑ_N), T_2 - electric temperature sensor ϑ in measured circuit, TV_G - pump safety valve, TV1, TV2 - pump safety valves G1, G2, UV - shut-off valve, HR1 - push button switch 4/3 for pressure measurement with manometer M with mechanical position switching; measured elements: RV - pressure reducing valve, PV - safety valve, HR - distributor, G_1, G_2 generators, MP - measuring and recording device.

4 Methodology of measurement and evaluation of characteristics

In this section, it is necessary to set out the initial assumptions and procedures of the research so that these steps can be repeated to confirm achieved results.

MOL Hykomol SAE 80W automotive gear oil were used to measure the characteristics of the pressure reducer and gear pumps, OH HM 32 mineral oil for safety valve and distributor. The oil working temperature was continuously recorded.

The measurement was carried out using the HMG 3000 hand-held multichannel measuring instrument with the HMGWIN 3000 evaluation program from Hydac. The recordings from the measuring equpment were transferred to a PC into the evaluation frame, where the waveforms for all settings were subsequently adjusted. Due to the significant undulations of the higher harmonic signals, the waveforms were adjusted by a band-pass filter. The measuring set allowed further computer processing of the results and evaluation of the characteristics depending on the hydraulic oil and temperature used. Necessary values were calculated in EXCEL software.

Electric sensors were used for sensing the pressure, flow and temperature of the working fluid. The device allows recording at 0.001 seconds. For our static measurements a time step of 0.05 s was used.

5 Results of experiments

In Fig. 16 - 19 are the results of measuring flow characteristics for Δp = f (Q) of all measured elements. The summary static characteristics were replaced by second degree polynomials with a high degree of quadratic regression R^2. Their shapes are shown in the figures.

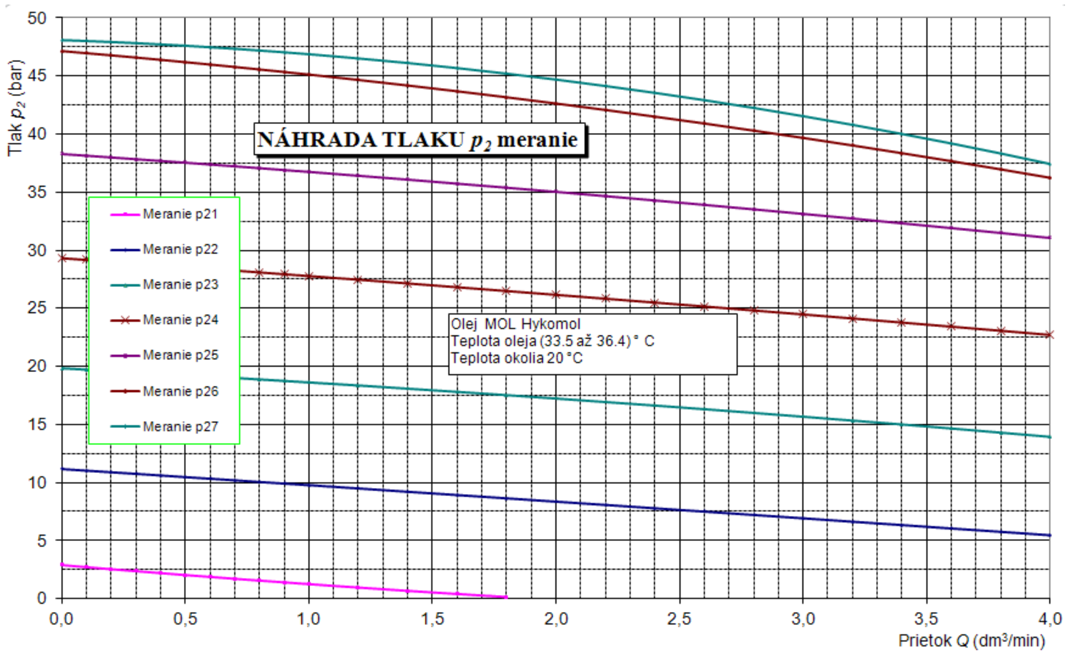

Fig. 16 *Summary static flow p_2-Q measurement characteristics with all RV pressure regulator settings*

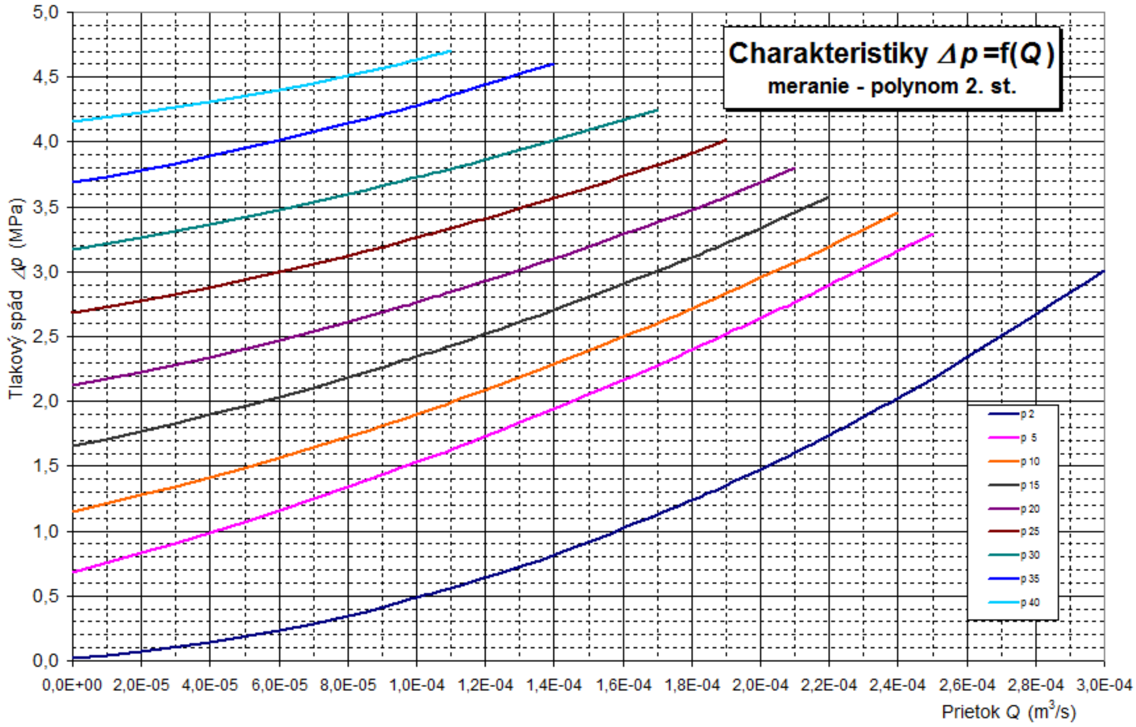

Fig. 17 *Summary characteristics Δp - Q of the PV safety valve for its various settings*

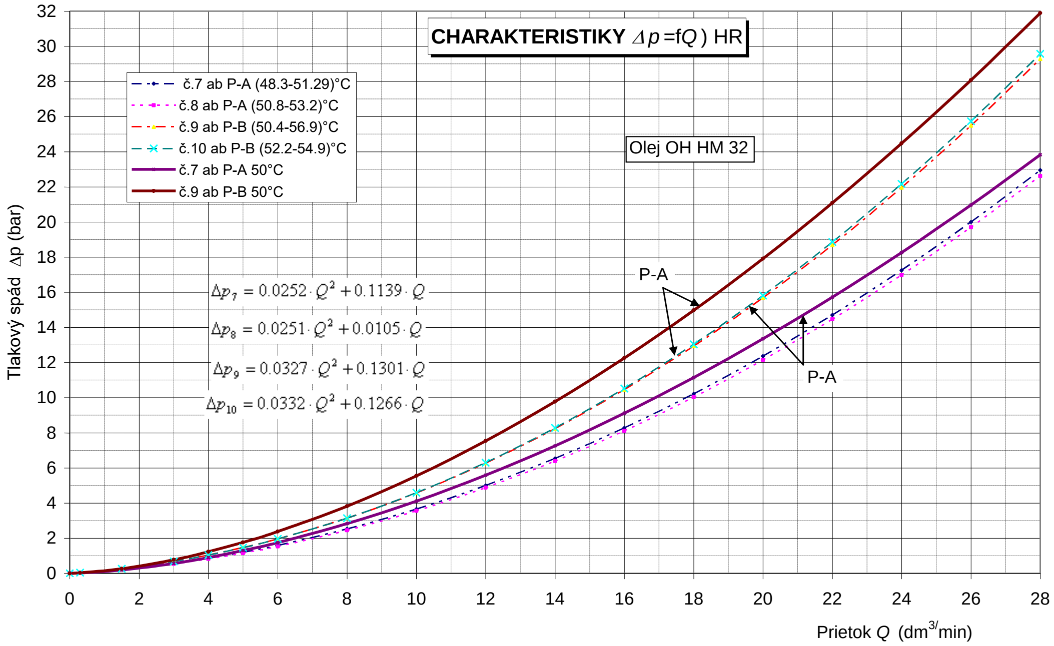

Fig. 18 *Pressure drop as a function of HR flow distributor valve; solid lines are for OH HN 32 oil at an oil temperature of 50 °C*

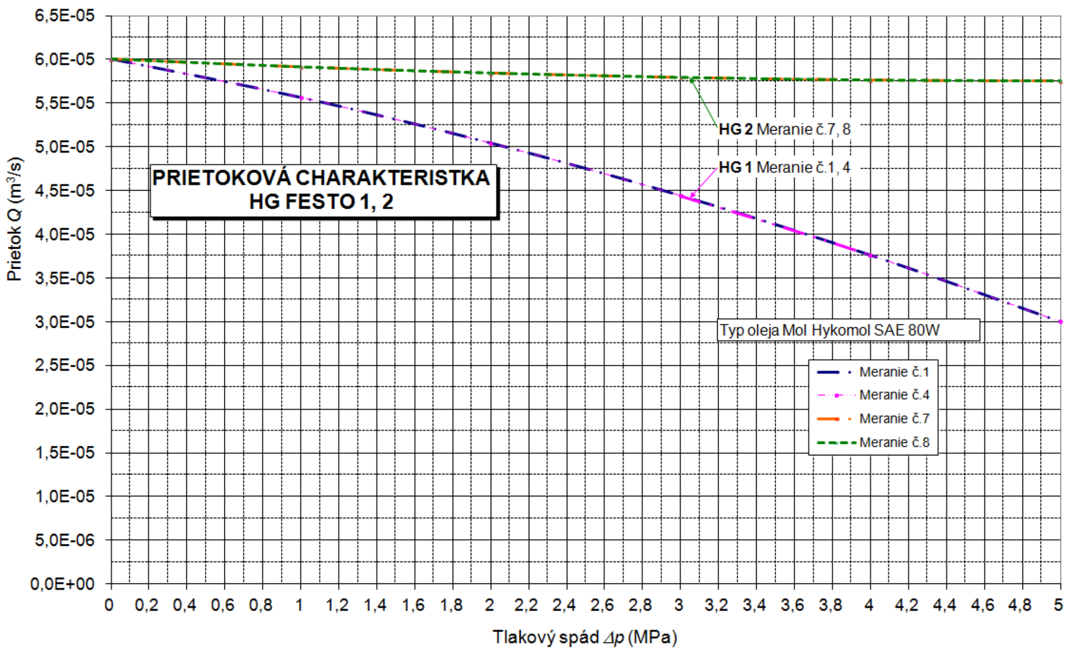

Fig. 19 *Example of summary flow characteristics of double hydraulic pump HG1 and HG2*

6 Conclusion

The paper presents the methodology of measurement and evaluation of static p-Q characteristics of hydraulic resistance against movement of four fluid elements. Based on these results, the present method not only allows to measure the static characteristics, but also to calculate the dependence Δp = f (Q) for different types of hydraulic oils and at different temperatures, for example low, high or optimal, when investigating the properties of the hydraulic system used as a whole.

The methodology is presented on the example of measurement of static characteristics on the hydraulic reduction and safety valve, distributor and gear pump, on specific two measuring stands with specific measuring chains, using a measuring instrument and evaluation program. According to this methodology it is possible to calculate the dependence Δp = f (Q) for practical purposes also on the basis of catalog data from the manufacturer of the relevant elements (e.g. for throttle, relief valves, distributors, filters, etc.). It is also possible to recalculate these characteristics for biodegradable liquids if we obtain the characteristics of e.g. for mineral oils [3], [8].

Acknowledgements

The paper is processed with the support of the project KEGA no. 028SPU-4/2019. Practical utilization of design and testing knowledge of transmission systems of hydraulic mechanisms of mobile agricultural and forestry machinery.

Authors are grateful for the support of experimental works by project „New materials and technologies for the 21st century industry “, ITMS code 2014+ :313011T546, of the Operational Program OPVaI.

References

[1] J. Baroška: Hydrostatické mechanizmy. Hydropneutech, s.r.o. Žilina, Tlačiareň P a M Grafické štúdio, 2012. ISBN 978-80-970 897-2-6.

[2] A. Hitchcox: Pressure-control valves. [online] [cit. 2019-11-10]. Dostupné na internete: http://www.hydraulicspneumatics.com/200/Tech Zone HydraulicValves /Article/True/6411/TechZone-HydraulicValves.

[3] Ľ. Hujo, J. Kosiba, J. Jablonický, J. Tulík:. Load characteristics of three-point tractor linkage. In Naučni trudove : zemedelska technika i technologii, agrarni nauki i veterinarna medicina, remont i nadeždnosť : zemedelska technika i technologii, agrarnye nauki i veterinarnaja medicina, remont i nadežnosť. ISSN 1311-3321. Ruse, Bulharsko : University of Rousse “Angel Kanchev”, 2012, tom. 51, seria 1.1, s. 172-176.

[4] Katalóg Benzina. Brno 1982.

[5] Katalógy firmy FESTO.

[6] Katalógy firmy HYDAC.

[7] B. Kopiláková, J. Turza, Ľ. Hujo, J. Kosiba: Evaluation of hydraulic resistance in various liquids and temperature. In: Tribology in Industry. - ISSN 0354-8996. - Vol.39, No.1(2017), p.12-135.

[8] R. Majdan, Z. Tkáč, J. Kosiba, J. Tulík, Ľ. Hujo: The tests of biodegradable fluid type mol farm UTTO Synt. In Interfaces ´11 : science and innovation for sustainable progress in petroleum refining and petrochemistry : proceedings, 28-30 September 2011, Sopron. Budapest : Hungarian Chemical Society, 2011. ISBN 978-963-9970-16-8.

[9] J. Pivoňka a kol.: Tekutinové mechanizmy. Praha, SNTL 1987.

[10] STN ISO 1219 (01 3623): 1984-01 : Zásady používania symbolov – Základné symboly a pravidlá navrhovania funkčných symbolov.

[11] Z. Tkáč, G. P. Kangalov, J. Kosiba, Ľ. Hujo, J. Tulík: Analysis of the hydraulic pump flow efficiency. In: Agricultural, forest and transport machinery and technologies. Vol. 1, no. 1 (2014), s. 69-72. ISSN 2367-5888.

[12] J. Turza a kol.: Axiálne piestové hydrostatické prevodníky. Teória a výpočet. Trenčianska univerzita AD, Trenčín 2009. ISBN 978-80-8075-436-5.

[13] J. Turza, B. Kopiláková: Kombinovaný stend pre meranie hydraulických prvkov. In: Riadenie tekutinových systémov 2011, XI. medzinárodná vedecká a odborná konferencia. Máj 11-13,2011, Zuberec, Žilina, Hydropneutech, 2011. ISBN 978-80-968150-9-8. s.119-126.