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Hydraulic fluid power — Determination of derived displacement of positive displacement pumps and motors — Part 2: Zero-pressure intercept method

CD stage

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This document was prepared by Technical Committee ISO/TC 131, Fluid power systems, Subcommittee SC 08, Product Testing.

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Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Two types of components of such systems are the positive displacement pumps and motors. One of the technical parameters of these components is the derived displacement, also known as derived capacity. This document is intended to describe the zero-pressure intercept method for determining the derived displacement of hydraulic fluid power positive displacement pumps and motors. The term derived displacement is preferred over derived capacity.

Hydraulic fluid power — Determination of derived displacement of positive displacement pumps and motors — Part 2: Zero-pressure intercept method

1 Scope

This document specifies the zero-pressure intercept method for the determination of the derived displacement of hydraulic fluid power positive displacement pumps and motors under steady state conditions. A single value for the derived displacement is determined from measurements at a single shaft speed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4409:2019, *Hydraulic fluid power — Positive Displacement Pumps, motors and integral transmissions — Methods of testing and presenting basic steady state performance*

ISO 5598:2020, *Fluid power systems and components — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598:2020 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp
— IEC Electropedia: available at https://www.electropedia.org/

3.1
unit
pump or motor

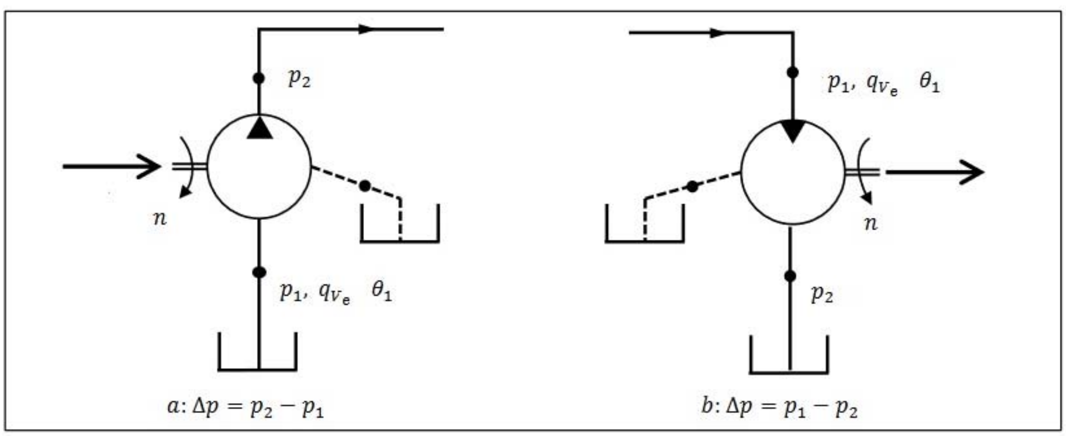
4 Symbols and units

The general symbols used throughout this document are shown in Table 1 based on ISO 4391:1983 (1). Graphical symbols are depicted in accordance with ISO 1219-1 (2).

Table 1 — Symbols and units

Symbol	Term	Unit
k	number of measurement points	-
n	Shaft speed	rev/min
n_{ma}	arithmetic mean of the shaft speed	rev/min
p_1	inlet pressure	bar
p_2	outlet pressure	bar
Δp	differential pressure	bar
Δp_i	differential pressure at measurement point i	bar
p_d	case pressure	bar
q_{V_e}	high pressure flow rate	L/min
$q_{V_{e,i}}$	high pressure flow rate at measurement point i	L/min
q_{V_0}	high pressure flow rate at zero differential pressure	L/min
θ_1	inlet temperature	°C
V_i	derived displacement	cm^3/rev

A diagram showing the use of symbols, subscripts and graphical symbols is shown in Figure 1.



Key

a pump differential pressure

b motor differential pressure

Figure 1 — Example use of symbols, subscripts and graphical symbols for pumps and motors

5 Test procedure

5.1 General requirements

Measurements for positive displacement pumps shall be carried out in accordance with ISO 4409:2019, subclause 5.1, and ISO 4409:2019, subclause 5.2.

Measurements for positive displacement motors shall be carried out in accordance with ISO 4409:2019, subclause 5.1, and ISO 4409:2019, clause 5.3.

5.2 Number of steady-state differential pressures

A minimum of 5 differential pressures Δp are recommended to be used. Δp should be increased in equal increments from minimum Δp to maximum Δp.

5.3 Variable displacement unit

The data for performing the determination of the derived displacement of a variable displacement pump or motor shall be obtained following ISO 4409:2019, subclause 5.2.4., respectively ISO 4409:2019, subclause 5.3.4.

5.4 Unit used as pump or motor

A unit intended to be used as pump shall be tested as pump and a unit intended to be used as motor shall be tested as motor. The derived displacement determined when a given unit is tested as a pump can differ from that determined when the unit is tested as a motor. If both operation modes are considered necessary, the test shall be carried out for both operation modes.

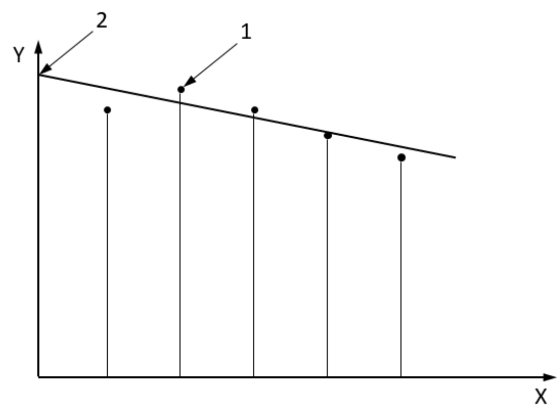
5.5 Pumps for reverse flow and motors for reverse rotation

The derived displacement of a pump may depend on the flow direction and of a motor on the direction of rotation. If the derived displacement is of interest for both flow directions, respectively for both directions of rotation the unit shall also be tested at both flow directions, respectively at both directions of rotation.

6 Calculation of derived displacement

The derived displacement of a unit is determined from the measured high pressure flow rate q_{V_e}, at several differential pressures, Δp. Suspect values shall be re-evaluated at the appropriate conditions to determine if the data were in error or an anomaly in expected performance exists at these specified test conditions.

From the measurement data the flow rate at zero differential pressure q_{V_0} shall be derived. The flow rate at zero differential pressure is established as the zero-pressure intercept of the characteristic curve of q_{V_e} versus Δp using linear regression (Figure 2).



Key

X differential pressure, Δp

Y high pressure flow rate, q_{V_e}

1 high pressure flow rate at Δp$_i$, $q_{V_{e,i}}$

2 Extrapolated high pressure flow rate when Δp = 0, q_{V_0}

Figure 2 — Extrapolation of high pressure flow rate at zero differential pressure

Using the ordinary least squares method for linear regression the flow rate at zero differential pressure is calculated using the following formula:

$$q_{V_0} = \left(\frac{1}{k} \cdot \sum_{i=1}^{k} q_{V_{e,i}}\right) - \left[\frac{\frac{1}{k} \cdot \sum_{i=1}^{k}\left(\Delta p_i \cdot q_{V_{e,i}}\right) - \frac{1}{k^2} \cdot \left(\sum_{i=1}^{k} \Delta p_i\right) \cdot \left(\sum_{i=1}^{k} q_{V_{e,i}}\right)}{\left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i^2\right) - \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i\right)^2}\right] \cdot \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i\right)$$

with q_{V_0} the derived displacement is calculated using the following formula:

$$V_i = q_{V_0}/n_{ma}$$

For each set of test conditions (i.e., shaft speed, test fluid temperature and displacement of the unit under test) the derived displacement shall be determined according to the procedure described above.

7 Test report

A test report shall be written and shall include the following.

General information:

a) Test date and location;
b) Description of the unit under test, including model, serial number, and date of manufacture if available;
c) Shaft speed operating range of the unit;
d) High pressure operating range of the unit;
e) Displacement range if applicable and value of current fixed displacement (i.e. displacement is locked);
f) Description of the test circuit, including the location of flow-meters (see ISO 4409:2019 Figure 1, Figure 2, and Figure 3) and test circuit filtration details (see ISO 4409:2019 5.1.1);
g) Measurement accuracy class (see ISO 4409:2019, Table 2, Table 4, A.1 and A.2);
h) Details of test fluid. This includes, at a minimum, fluid name and the properties of kinematic viscosity and density at the nominal inlet temperature and atmospheric pressure; (see ISO 4409:2019 5.1.3);
i) Nominal inlet fluid test temperature (see ISO 4409:2019 5.1.4);
j) Nominal case pressure, p_d, if appropriate (see ISO 4409:2019, 5.1.5);
k) The time period and data acquisition rate for flow rate measurements (see ISO 4409:2019, 5.1.6);

Measured values & derived quantities:

l) Inlet pressure, p_1;
m) Outlet pressure p_2;
n) Differential pressure Δp;
o) Shaft speed, n;
p) Inlet temperature θ_1;
q) High pressure flow rate, q_{V_e} (see ISO 4409:2019 5.2.1.1, 5.2.1.2. or 5.3.1);
r) Derived displacement V_i;
s) Values of coefficients and correlation coefficients in case a spreadsheet program is used for the linear regression.

A graphical presentation may be added. However, this does not release the editor from presenting the data in written form.

Bibliography

[1] ISO 4391:1983, *Hydraulic fluid power — Pumps, motors and integral transmissions — Parameter definitions and leter symbols*

[2] ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic symbols for conventional use and data-processing applications*