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

WD stage

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Foreword

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

A list of all parts in the ISO 8426- series can be found on the ISO website.

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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 and at defined, continuous shaft speeds.

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 4409:2009, *Hydraulic fluid power — Positive-displacement pumps, motors and integral transmissions — Methods of testing and presenting basic steady state performance*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 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/

4 Symbols and units

The symbols and units used throughout this document are shown in Table 1.

Table 1 — Symbols and unit

Symbol	Term	Unit
k	Number of measurement points	-
n	Shaft speed	rev/min
$n_{average}$	Arithmetic mean of the shaft speed	rev/min
Δp	Differential pressure	MPa (bar) [a]
Δp_i	Differential pressure at measurement point i	MPa (bar) [a]
q	Flow rate	L/min [b]
q_0	Flow rate at zero differential pressure	L/min [b]
q_i	Flow rate at measurement point i	L/min [b]
V_i	Derived displacement	cm^3/rev

[a] 1 bar = 10^5 Pa = 0,1 MPa; 1 Pa = 1N/m^2.

[b] 1 L = 1 dm^3.

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.

NOTE Attention is drawn to the fact, that the requirements for the accuracy classes with respect to the permissible variation of mean indicated values and permissible systematic measuring instrument errors can vary between ISO 4409:2019 and the previous edition of ISO 8426.

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 units

The data for performing the estimation of the derived displacement of variable displacement pumps and motors shall be obtained following the stipulations provided by ISO 4409:2019, subclause 5.2.4., respectively by ISO 4409:2019, subclause 5.3.4.

5.4 Units used as pump or motor

Units intended to be used as pumps shall be tested as pumps and units intended to be used as motors shall be tested as motors. 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.

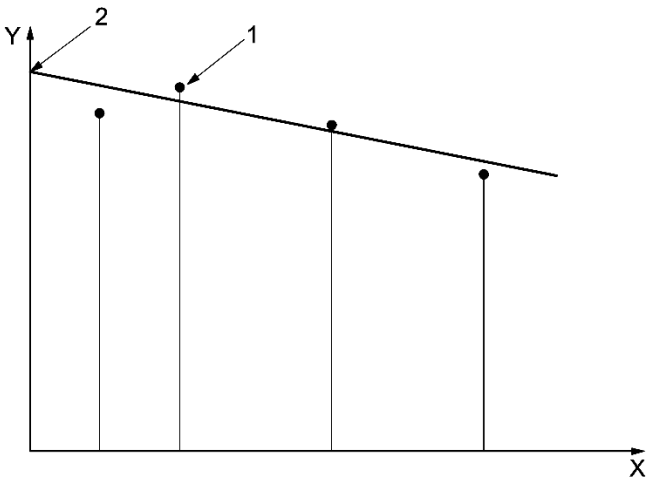
5.5 Pumps for reverse flow and motors for reverse rotation

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 using the zero-pressure intercept method

The derived displacement of a unit is determined from the measured pump outlet flow rate or motor inlet flow rate, q, at a number of pump outlet or motor inlet pressures, p. 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 Δp shall be derived. The flow rate at zero Δp is established as the zero-pressure intercept of the characteristic curve of q versus Δp using linear regression (**Figure *1***).



Key

X pump outlet or motor inlet differential pressure, Δp
Y flow rate, q
1 measured flow rate at Δp_i, q_i
2 extrapolated flow rate when $\Delta p = 0$

Figure 1 — Extrapolation of flow rate at zero differential pressure

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

$$q_0 = \left(\frac{1}{k} \cdot \sum_{i=1}^{k} q_i\right) - \left[\frac{\frac{1}{k} \cdot \sum_{i=1}^{k}(\Delta p_i \cdot q_i) - \frac{1}{k^2} \cdot \left(\sum_{i=1}^{k} \Delta p_i\right) \cdot \left(\sum_{i=1}^{k} q_i\right)}{\left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i^2\right) - \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i\right)^2}\right] \cdot \left(\frac{1}{k} \cdot \sum_{i=1}^{k} \Delta p_i\right)$$

with q_0 the derived displacement is calculated using the following formula:

$$V_i = \frac{q_0}{n_{average}}$$

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

7.1 General

A test report shall be drawn up and shall, at a minimum, include the following:

a) Time and location of the test;
b) Description of the unit under test, including model and serial number, if available;
c) Displacement range if applicable and value of current fixed displacement;
d) Description of the test circuit, including the location of flowmeters and filtration details (see ISO 4409:2019, Figure 1, Figure 2, Figure 3, and 5.1.1);
e) Details of test fluid (i.e., name, kinematic viscosity, mass density);
f) Measurement accuracy class (see ISO 4409:2019, Table 2, Table 4, A.1 and A.2);
g) Nominal ambient temperature of the test area (see ISO 4409:2019, 5.1.1);
h) Nominal inlet fluid test temperature (see ISO 4409:2019, 5.1.4);

i) Nominal shaft speed;
j) Differential pressure operating range;
k) Nominal case pressure, if appropriate (see ISO 4409:2019, 5.1.5);
l) Nominal time interval for flow rate measurements (see ISO 4409:2019, 5.1.6).

7.2 Presentation of the results

The derived displacement of a positive displacement pump or motor forms the basis for the determination of the volumetric and mechanical efficiency of the unit under test in accordance with ISO 4409:2019. As a minimum the following shall be presented:

a) Inlet pressure:
b) Outlet pressure;
c) Differential pressure across the unit;
d) Shaft speed;
e) High pressure flow rate (see ISO 4409:2019, 5.2.1.1, 5.2.1.2. or 5.3.1);
f) Calculated derived displacement.

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

Bibliography

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