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# Test method for thermal transport properties to friction materials and brakes

摩擦材料和制动器间的热传导试验方法

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**WARNING – The personnel who uses this document shall have hands-on experience in formal laboratory work. This document does not address all possible security issues. It is the responsibility of the user to take appropriate safety and health measures and to ensure compliance with the conditions which are set by the relevant national regulations.**

## 1 Scope

This document describes test methods for thermal diffusivity, specific heat, thermal conductivity, and coefficient of thermal expansion to friction materials and brakes.

This document applies to the determination of thermal conductivity properties to disc brake linings, drum brake linings and friction materials.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the version corresponding to that date is applicable to this document; for undated references, the latest version (including all amendments) is applicable to this document.

GB/T 4339, Test methods for thermal expansion characteristic parameters of metallic materials

GB/T 5620, Road vehicles - Vocabulary and definition for braking of automotive vehicles and their trailers

GB/T 10295, Thermal insulation - Determination of steady-state thermal resistance and related properties - Heat flow meter apparatus

GB/T 19466.4, Plastics - Differential scanning calorimetry(DSC) - Part 4: Determination of specific heat capacity

GB/T 22588, Determination of thermal diffusivity or thermal conductivity by the flash method

GB/T 32064, Determination of thermal conductivity and thermal diffusivity of building materials: transient plane heat source method

# 3 Terms and definitions

Terms and definitions determined by GB/T 5620 and the following ones are applicable to this document.

**3.1**

**Thermal diffusivity**

α

The rate of heat diffusion inside the friction material when the friction material is heated or cooled.

**Note:** in square centimeters per second ($cm^2/s$). The larger the thermal diffusivity, the faster the temperature diffusion and heat flow through the material.

**3.2**

**Specific heat**

$C_p$

The heat absorbed or released by a unit mass of a substance when the temperature rises or falls under the condition of constant pressure.

**Note:** in Joules per gram Celsius [J/(g·°C)].

**3.3**

**Thermal conductivity**

λ

The time rate of heat flow per unit temperature gradient in the direction perpendicular to the area, through the unit area, under stable conditions.

**Note:** in watts per meter kelvins [W/(m·K)].

# 4 Test methods

## 4.1 Determination method of thermal diffusivity

### 4.1.1 Method overview

The laser flash method is a method used to determine the thermal diffusivity. Expose a test piece of known thickness to an intense laser or xenon flash lamp, to obtain a short

e) recording device;

f) host;

g) probe;

h) sample compartment;

i) thermostat.

**4.1.3 Test piece**

**4.1.3.1 Flash method (method A)**

**4.1.3.1.1** The commonly used sample is a thin disk-shaped sample whose surface area for receiving pulsed energy radiation is smaller than the energy beam spot. The typical diameter of a test piece is 6 mm ~ 18 mm; the optimal thickness of a test piece depends on the estimated thermal diffusivity; this thickness of test piece shall be selected to ensure that the time required to reach the maximum temperature varies within 40 ms ~ 200 ms. A thinner test piece shall be used for high temperature measurements, so as to minimize the heat loss correction. The test piece shall be of sufficient thickness, so that the to-be-tested material is more representative. The typical thickness of a test piece is 1 mm ~ 6 mm. Since the thermal diffusivity is proportional to the square of the thickness of test piece, different thicknesses of test piece should be used in different temperature ranges. The optimal thickness of test piece required for low temperature testing is inconsistent with that required for high temperature testing.

**4.1.3.1.2** Improperly selected thickness of test piece will not only cause unnecessary test failures, but also be the main cause of test errors. Generally, a test piece with a thickness of 2 mm ~ 3 mm can be selected at the beginning; then, the thickness of test piece can be changed based on the obtained temperature recording curve (the signal cannot be observed if the test piece is too thick).

**4.1.3.1.3** The surface of the prepared test piece shall be flat and the parallel error shall be within 0.5% of the thickness. There shall be no surface defects (sandish holes, scratches, streaks) as they would seriously affect the test results.

**4.1.3.2 Plane heat source method (method B)**

**4.1.3.2.1** The effective diameter of the test surface of the test piece shall not be less than twice the diameter of the probe; the surface shall be flat, and the surface material and density shall not be modified.

**4.1.3.2.2** Block samples shall meet the requirements of 4.1.3.2.1, and can be prepared into cylinders, cubes, etc. The thickness of the upper and lower samples shall be the same, and the thickness should be greater than the diameter of the selected probe, but not less than the radius of the probe.

**4.1.3.2.3** Sheet samples shall meet the requirements of 4.1.3.2.1. During preparation, the thickness of the upper and lower samples shall be the same, and the deviation shall not be greater than 0.01 mm.

**4.1.3.2.4** Film samples shall meet the requirements of 4.1.3.2.1. During preparation, the thickness of the upper and lower samples shall be the same, and the deviation shall not be greater than 0.001 mm.

**4.1.3.2.5** The uniaxial anisotropy sample shall meet the requirements of 4.1.3.2.1. During preparation, the test surface of the sample shall be parallel to the plane determined by the x-axis and the y-axis.

**4.1.3.2.6** Dry the sample to constant mass and adjust it to the test temperature; when there are special requirements, the sample shall be adjusted according to the product requirements.

**4.1.4 Test procedure**

**4.1.4.1** The flash method (method A) shall be determined according to GB/T 22588.

**4.1.4.2** The plane heat source method (method B) shall be determined according to GB/T 32064.

**4.1.5 Test report**

The test report shall at least include the following information:

a) sample identification;

b) sample thickness;

c) test temperature;

d) thermal diffusivity, under the test temperature, that is calculated when X = 50% (percentage of temperature rise), $m^2/s$;

e) a statement related to the thermal diffusivity calculated for X = 25%, X = 75% and X = 50%, or a comparison of the data at each temperature in the descending part of the test curve with the theoretical model;

f) report of repeated test results at each temperature;

g) Whether the thermal expansion is corrected, if yes, the thermal expansion data used shall be reported;

h) correction process for heat loss and finite pulse time effects and analysis of errors;

i) environmental conditions around the sample;

$$C_p = \frac{\Delta Q}{m \Delta T} \quad \cdots\cdots (2)$$

Where:

$C_p$ – specific heat, in Joules per gram Celsius [J/(g·°C)];

$\Delta Q$ – heat, in Joules (J);

m – mass of test piece, in grams (g);

$\Delta T$ – temperature rise, in degrees Celsius (°C).

**4.2.2 Instruments and apparatuses**

The instruments and apparatuses required for the determination of specific heat are as follows:

a) DSC instrument: capable of heating or cooling at a constant rate of 0.5 °C/min ~ 20 °C/min; capable of keeping the test temperature constant within ±0.5 °C for at least 60 minutes; capable of sub-programmed heating or temperature rise of other modes;

b) crucible: of good thermal conductivity, capable of being covered and sealed, and capable of withstanding the pressure generated during the measurement process;

c) analytical balance: weighing accuracy of ±0.01 mg.

**4.2.3 Test piece**

Test pieces can be classified as powders, particles, granules, or pieces cut from the sample. Test pieces shall be representative of the test sample and shall be prepared and handled with care. If the test piece is cut from the sample, care shall be taken to prevent the polymer from reorienting or other phenomena that may change its properties from happening when heated. Grinding and similar operations shall be avoided to prevent exposure to heat, or reorientation, or heat history of changing the test piece. For granular or powder samples, two or more test pieces shall be taken. The method of sampling and the preparation of the test pieces shall be stated in the test report.

**4.2.4 Test procedure**

The specific heat shall be determined according to GB/T 19466.4.

**4.2.5 Test report**

The test report shall include the following information:

a) test date;

b) all necessary details for complete description of the test sample, including heat history;

c) manufacturer's model and type (power compensation type or heat flow type) of the DSC instrument used;

d) shape, size and material of the crucible and lid of the sample for test;

e) test atmosphere and flow rate;

f) calibration substances, including information on the printed matter, nature of the material, mass of usage and other characteristics relevant to calibration;

g) shape, size and mass of the test piece;

h) details of sampling and conditioning of test pieces;

i) temperature program parameters, namely: initial temperature, heating rate, final temperature, time interval of isothermal section, and temperature increment in the step-by-step method; if cooling is adopted, the cooling rate shall also be specified;

j) test results, including specific heat and corresponding temperature;

k) other required information.

### 4.3 Determination method of thermal conductivity

#### 4.3.1 Method overview

The steady-state measurement of heat, or the speed of heat passing through a material, is an important indicator for evaluating the thermal transport of a material. The thermal conductivity is the unit heat transferred through a material of unit thickness under stable heat transfer conditions, and is calculated according to Formula (3):

$$\lambda = \frac{H}{A\dfrac{\mathrm{d}T}{\mathrm{d}x}} \qquad \cdots\cdots (3)$$

Where:

λ – thermal conductivity, in watts per meter kelvin [W/(m·K)];

H – heat flow through the area A, in watts (W);

A – heat transfer area, in square meters ($m^2$);

$\frac{dT}{dx}$ – temperature gradient, in Kelvins per meter (K/m).

c) thickness of the test piece at the time of measurement, and, in the case of a double test piece arrangement, total thickness of the two test pieces; indication of mandatory or measured thickness.

d) method and temperature of conditioning.

e) density of the test piece during measurement.

f) relative mass change during drying or conditioning.

g) relative mass change during measurement, and observed thickness and volume changes.

h) average temperature difference of test pieces that is calculated according to the temperature of the hot and cold plates, and the measurement method.

i) measured average temperature.

j) heat flow density at equilibrium.

k) thermal resistance of the test piece; and, when applicable, thermal resistivity, thermal conductivity, and thickness ranges for which these values are available.

l) type of heat flow meter device used; methods to reduce edge heat loss, ambient temperature around the plate during measurement, and the number and location of heat flow meters.

m) device orientation: vertical, horizontal or other. When the test piece of the single test piece device is not vertical, the position of the hot side of the test piece shall be stated: top, bottom or other position.

n) In the case where a sheet material needs to be inserted between the test piece and the panel of the device or a waterproof vapor cover needs to be used during the test, the nature and thickness of the sheet material or the waterproof vapor cover shall be stated. If a temperature sensor is used to measure the temperature difference, the measurement method shall be given.

o) date of measurement, date of last calibration of the device and type of material used.

p) If it helps to interpret the results, the entire test and the duration of the steady state during the test shall be presented.

q) For the test piece used in the calibration, indicate the type, thermal resistance, date of test piece identification, identification unit, valid date of identification and number of identification tests.

r) It is recommended to state the maximum expected error of the measured heat transfer properties in the report; when some requirements in the standard are not met, it is recommended to include a report of the error estimate.

s) When the determination process described in this document cannot be fully met due to circumstances (or requirements), an agreed exception statement can be made. However, it shall be stated in the report, where the suggested sentence is: "This determination is in full compliance with the requirements for test method in GB/T 10295, except..." For direct-reading devices, there shall also be a calibration of the electronic circuits and equipment or a description of compliance with the standard (including a description of the date and linearity that meets the requirements).

## 4.4 Determination method of coefficient of thermal expansion

### 4.4.1 Method overview

The differential pushrod dilatometers is used to determine the coefficient of linear expansion. The thermal expansion of the test sample is determined from the thermal expansion of a standard reference sample (e.g., quartz). Place two samples side by side in a furnace to heat slowly while pressing two pushrods extending from the furnace to a Linear Variable Displacement Transducer (LVDT) with thermal isolation in order to measure their length change. The difference in expansion between the two samples results in different movements of the pushrod, allowing the determination of the unknown sample's coefficient of linear thermal expansion, which is the ratio of the change in length to the original length at the initial temperature. Use a thermocouple to measure the temperature of the sample. Calculate according to Formula (5):

$$\alpha_m = \frac{\Delta L}{L_0 \Delta T} \qquad \cdots\cdots (5)$$

Where:

$\alpha_m$ – coefficient of thermal expansion, per degree Celsius (°C$^{-1}$);

$\Delta L$ – length change, in millimeters (mm);

$L_0$ – original length of the test piece, in millimeters (mm);

$\Delta T$ – temperature rise, in degrees Celsius (°C).

### 4.4.2 Instruments and apparatuses

The instruments and apparatuses required for the determination of coefficient of thermal expansion is as follows:

**------ The End ------**