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Thermal insulation — Test method for
thermal diffusivity — Periodic heat
method

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Foreword

This Japanese Industrial Standard has been established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by Japan Testing Center for Construction Materials (JTCCM)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act.

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Thermal insulation — Test method for thermal diffusivity — Periodic heat method

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 21901** : 2021, Edition 1, by incorporating the corresponding parts (scope, normative references, terms and definitions, symbols, principle, test specimen, apparatus, procedure and test report) without any modifications of the technical contents, but also adding some **JIS** specification contents (calculation of thermal diffusivity) that are not given in the said corresponding International Standard.

The vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies a periodic heat method for measurement of the thermal diffusivity of thermal insulation material in the shape of a flat plate.

NOTE The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 21901 : 2021 *Thermal insulation — Test method for thermal diffusivity — Periodic heat method* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative reference

Part or all of the provisions of the following standard, through reference in this text, constitutes provisions of this Standard. For the standard indicated below, only the edition of the indicated year shall be applied and any revisions (including amendments) made thereafter shall not be applied.

JIS A 1412-1 : 2016 *Test method for thermal resistance and related properties of thermal insulations — Part 1 : Guarded hot plate apparatus*

NOTE Normative reference in the corresponding International Standard : ISO 8302 : 1991 *Thermal insulation — Determination of steady-state thermal resistance and related properties — Guarded hot plate apparatus*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions apply.

3.1

phase

quantity that shows the stage of progress in one period of wave motion and other periodic phenomenon

Example In $y = A\sin(\omega t + \varphi_1)$, $\omega t + \varphi_1$ is the phase.

3.2

phase lag

difference between two phases provided by periodic temperature changes measured at two different points on the surface and inside a test specimen

Example When the periodic temperature changes 1 and 2 are given by $y_1 = A_1\sin(\omega t + \varphi_1)$ and $y_2 = A_2\sin(\omega t + \varphi_2)$ respectively, the phase lag between them is $\varphi_2 - \varphi_1$.

3.3

amplitude

half of the difference between the maximum and minimum values of the amount of displacement in a periodic temperature change

Example A in a sine wave given by $A\sin(\omega t + \varphi)$ or $A\exp[i(\omega t + \varphi)]$ is the amplitude.

3.4

amplitude ratio

ratio of two amplitudes provided by periodic temperature changes measured at any point on the surface and inside a test specimen

Example When the periodic temperature changes y_1 on the surface and y_2 inside the test specimen are given by $y_1 = A_1\sin(\omega t + \varphi_1)$ and $y_2 = A_2\sin(\omega t + \varphi_2)$, respectively, the amplitude ratio between the two amplitudes is A_2/A_1 .

3.5

period

reproduction interval of a periodic phenomenon (or a periodic function)

Note 1 to entry When the time interval is constant, the period f is given by $f = 1/\nu = 2\pi/\omega$, where ν is the frequency and ω is the angular frequency.

3.6

frequency

number of repetitions of the same state within a certain time interval of any temporal periodic phenomena

Note 1 to entry It is expressed as $\nu = 1/f$, where f is the period.

3.7

angular frequency

rotation angle per second

Note 1 to entry Angular frequency ω is obtained by multiplying the frequency ν by 2π ($2\pi\nu$) or by multiplying 2π by the reciprocal of the period f ($2\pi/f$).

4 Symbols

The symbols used in this Standard are given in Table 1.

Table 1 Symbols

Symbol	Name	Unit
a	Thermal diffusivity	m^2/s
c	Specific heat capacity	$\text{J}/(\text{kg} \cdot \text{K})$
D	Difference between the true thermal diffusivity (input value) and the nominal thermal diffusivity (calculated result) when L/d of test specimen is changed	%
d	Thickness of test specimen (total thickness of the two pieces when two stacked test specimens are used in measurement)	m
f	Period	s
i	Imaginary unit	—
k	Damping coefficient	1/m
L	Length of one side of test specimen	m
l	Distance from periodic heating surface ($d - x_m$)	m
m	Mass prior to measuring thermal diffusivity (prior to grooving)	kg
V	Volume prior to measuring thermal diffusivity (prior to grooving)	m^3
x	x coordinate	m
x_m	Location of temperature measurement point inside a test specimen when heat dissipation surface of test specimen is taken as original	m
ε	Phase lag on $x = 0$ surface	rad
η	Arbitrary phase	rad
θ	Temperature	$^{\circ}\text{C}$
λ	Thermal conductivity	$\text{W}/(\text{m} \cdot \text{K})$
ν	Frequency	1/s
π	Circular constant	—
ρ	Density, bulk density	kg/m^3
φ	Phase lag at $x = x_m$ cross section	rad
ω	Angular frequency	rad/s

5 Principle

5.1 General

The periodic heat method is a method for obtaining thermal diffusivity by measuring the temperature at two different points in a test specimen, when periodic temperature changes are given to the test specimen. Thermal diffusivity is evaluated by the phase lag between two phases provided by periodically changing the temperature of one side surface of the test specimen. Here, those temperatures are measured at any point on the heating surface and inside (the internal plane perpendicular to the direction of

thermal diffusion) the test specimen.

This measurement method uses a solution of the heat conduction equation that is obtained under the condition that the temperature on heating surface of test specimen changes as a trigonometric function of time and the change propagates in a one-dimensional direction, and further, the temperature on the opposite side is kept constant.

The periodical temperature change on the heating surface shall be expressed by a trigonometric function of time.

It is contrary to the measurement principle to generate a distorted temperature change on the heating surface. In addition, in reality, the waveform easily changes in a distorted temperature change during propagation in a test specimen, and this becomes a cause of measurement errors.

5.2 Calculation of thermal diffusivity

The thermal diffusivity is calculated using the following procedure **a)** or **b)** depending on the condition of the heat dissipation surface temperature.

- a) When the temperature of heat dissipation surface of test specimen is constant** As shown in Figure 1, the heat flows downward from the heating surface to the heat dissipation surface (the surface in contact with the low-temperature side heater) of test specimen. The x -axis is taken upward along the thickness direction of a test specimen, and the heat radiation surface is set as the origin of the test specimen having the thickness d , while the heating surface is set at $x = d$. At the heat dissipation surface, when the temperature is kept constant and the temperature of the heating surface is changed periodically based on $\theta_H + \theta_0 \sin(\omega t + \eta)$, Formula (1) can be obtained (see Figure 2).

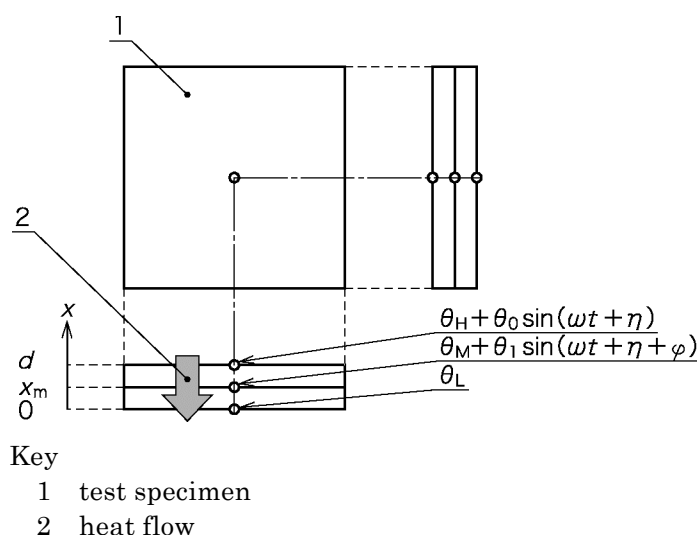
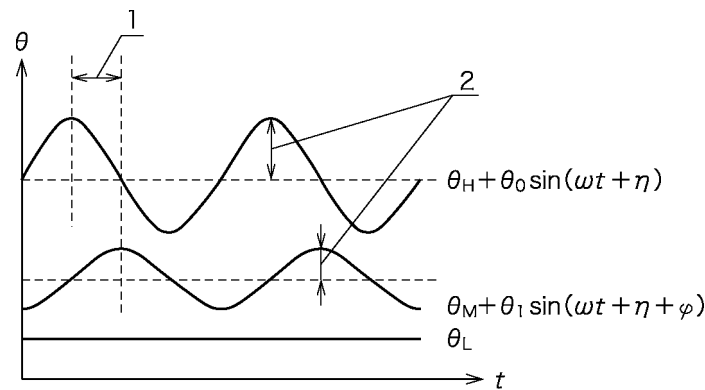


Figure 1 Relation between test specimen and coordinate (heat flow in the case where θ_L is kept constant)



Key

1 phase lag

2 amplitude

Figure 2 Periodic temperature change in the case where θ_L is kept constant

$$\varphi = \arg \left\{ \frac{\sinh[kx_m(1+i)]}{\sinh[kd(1+i)]} \right\} \dots\dots\dots(1)$$

The damping coefficient k in Formula (1) is defined by Formula (2).

$$k = \sqrt{\frac{\omega}{2a}} \dots\dots\dots(2)$$

Also, the angular frequency ω is defined by Formula (3).

$$\omega = \frac{2\pi}{f} \dots\dots\dots(3)$$

The damping coefficient k is obtained using Formula (1) from the phase lag φ between $x = d$ and an arbitrary point $x = x_m$ obtained by the measurement, and the thermal diffusivity a is calculated by Formula (4).

$$a = \frac{\omega}{2k^2} \dots\dots\dots(4)$$

At this time, mean temperature of a test specimen θ_s is calculated by Formula (5).

$$\theta_s = (\theta_H + \theta_L) / 2 \dots\dots\dots(5)$$

When using Formula (1), the temperature on the heat dissipation surface of test specimen shall always be controlled so as to be constant.

- b) **When the temperature of heat dissipation surface of test specimen changes periodically** As shown in Figure 3, if the periodical temperature changes on the heat dissipation surface of test specimen, Formula (6) or Formula (7) can be obtained by solving the one-dimensional heat conduction equation in the same manner as a) (see Figure 4). Formula (6) and Formula (7) are equivalent to Formula (1) when the temperature on the low-temperature side of heat dissipation surface is constant.