6. One-dimensional heat transfer through a wall

1 Introduction

Depending on the system properties the heat transfer can be separated on three main mechanisms. Namely: conduction, convection and radiation. In many cases those three transfer arises simultaneously, however usually one is more dominant than the others. The heat transfer is usually express by one proportionality coefficient which involves a heat transfer mechanism. The heat transfer (heat penetration) is expressed by the amount of energy delivered from the medium inside (w) through a wall to the outer medium (z) (*see figure 1*)

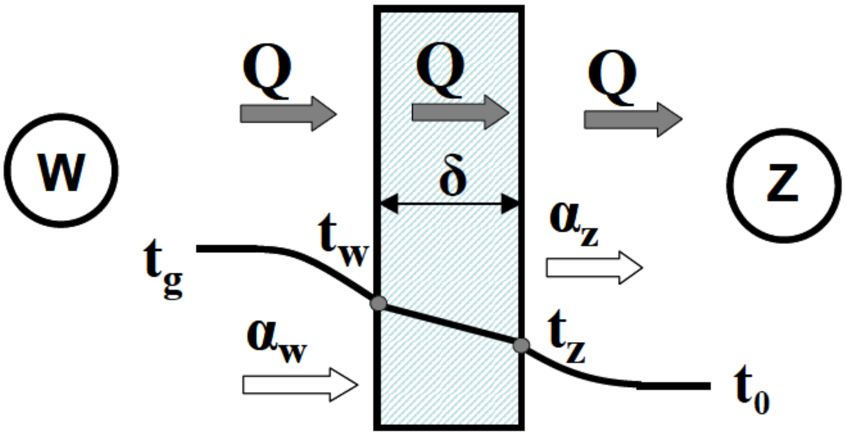

Fig 1 The heat transfer mechanism

Taking single wall (as in figure 1) into consideration the heat transfer mechanism is composed of the heat acquired by the wall from the (w) medium, and heat acquired by the (Z) medium from the wall. In such a case the heat emitted through the wall is characterised by so-called heat transfer coefficient “k” also known as Peclat coefficient and is given by:

$$k = \frac{1}{\frac{1}{\alpha_w} + \frac{\delta}{\lambda} + \frac{1}{\alpha_z}}$$

Where:

k, $W/_{m^2K}$ - heat transfer coefficient,

α_z, $W/_{m^2K}$- outside surface film conductance,

α_w, $W/_{m^2K}$ w - inside surface film conductance,

$\lambda, {}^{W}/_{mK}$ - thermal conductivity.

2 Aim of the experiment

The aim of the experiment is to determine coefficients describing the heat transfer through a wall. There are as follow:

- $\boldsymbol{k}$ - heat transfer coefficient,
- α_{z} - outside surface film conductance,
- α_{w} - inside surface film conductance,
- λ - thermal conductivity.

3 Experiment description

Hot air, with temperature "t_g" goes up along vertical rectangular channel. Walls of the channel are not thermally insulated, and because of this, some portion of heat escapes through the wall from inside to environment with temperature "t_0" (fig.1). Inside of channel, heat penetrates wall in forced convection. Outside, the heat is given up to the environment by means of natural convection and radiation. There are sensors in the test stand to measure necessary parameters as follows: - sensor of heat flux to measure density of thermal flux "q" through the wall, - thermocouples to measure temperature of inside surface of wall "t_w", outside surface of wall "t_z", hot gas inside channel "t_g", ambient temperature "t_o".

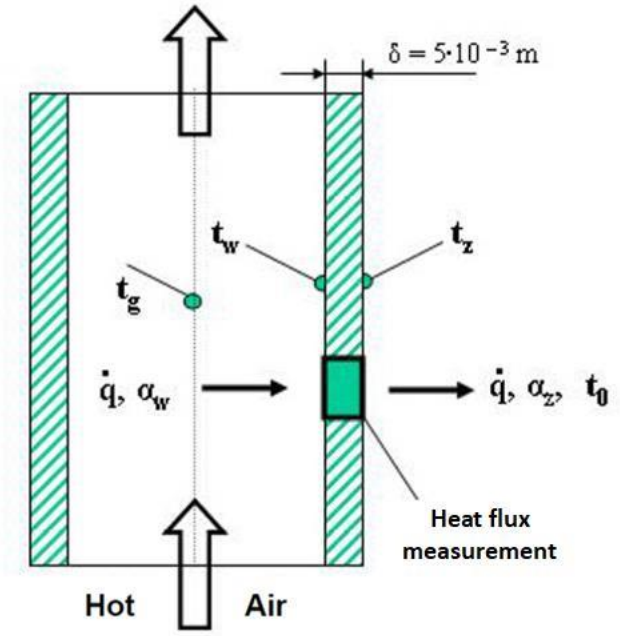

Fig 2. The layout of the test stand

Measurements should be done for two states of the heater. Test data is collected after temperature stabilisation for each of heater positions.

4 Elaboration of test data

1. Determination of $\boldsymbol{k}, \boldsymbol{\alpha_z}, \boldsymbol{\alpha_w}$,

Using the following equations calculate the values of heat transfer coefficient:

$$q = k(t_g - t_0)$$

$$q = \alpha_z(t_z - t_0)$$

$$q = \alpha_w(t_g - t_w)$$

2. Determination of $\boldsymbol{\lambda}$.

Knowing the thickness of the wall ($\delta = 5\ mm$), thermal conductivity λ can be calculated based on the equation below:

$$k = \frac{1}{\frac{1}{\alpha_w} + \frac{\delta}{\lambda} + \frac{1}{\alpha_z}}$$

Group …………………..date: …………………. hour:…………………….

No	Switch positions	10	11	12	13	14	15	16	To calculate			
	State of Heater	$\dot{q}$ mV	t_g mV	t_{w1} mV	t_{w2} mV	t_{z1} mV	t_{z2} mV	t_0 mV	$\boldsymbol{k}$, $W/_{m^2K}$	α_z, $W/_{m^2K}$	α_z, $W/_{m^2K}$	λ $W/_{mK}$
1	1											
2												
3	2											
4												

Thermal flux sensor constant: $q_c = 1000\, W/_{m^2}$ for $\Delta U = 50mV$

Thermocouple characteristic: $t = 23{,}53 \cdot A + 25{,}84 + a$

A – voltmeter indication in mV

a – temperature adjustment in the day of the test: $a = (t_o - 20)$ ℃,