6. One-dimensional heat transfer through plane wall

6.1 Introduction

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

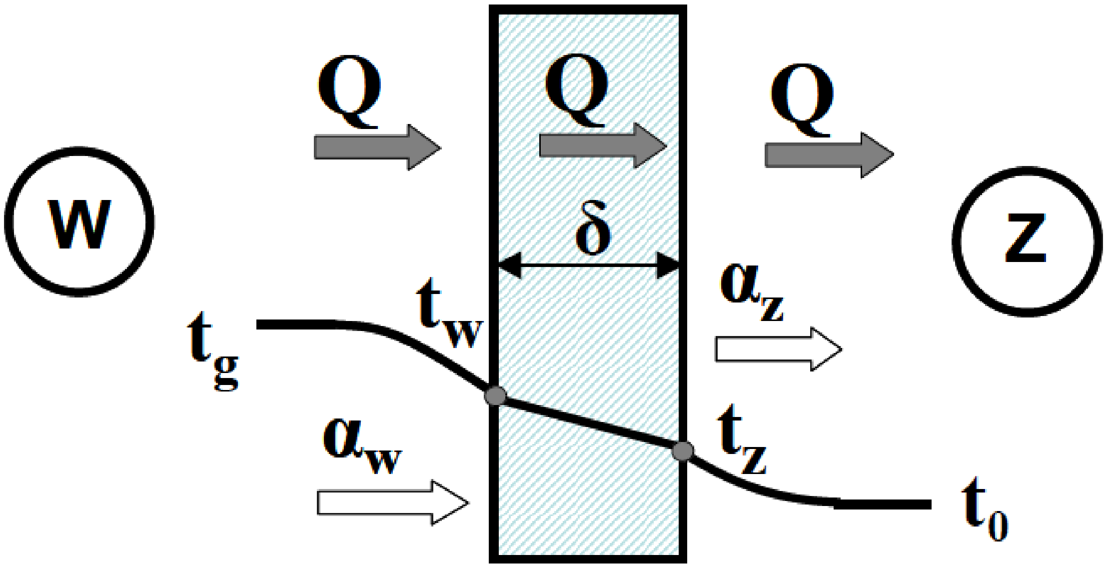

Fig 1 The heat transfer mechanism

Taking single wall (as indicated in figure 1) into consideration the heat transfer mechanism is composed of the heat transmission through to the wall from the "w" medium, the process of heat conduction, and heat transmission from the wall to the medium "z". The heat transfer is characterised by the 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:

$\boldsymbol{k}$, $W/_{m^2K}$ - heat transfer coefficient,
α_z, $W/_{m^2K}$- outside surface film conductance,
α_w, $W/_{m^2K}$ w - inside surface film conductance,
λ, $W/_{mK}$ - thermal conductivity.

6.2 Objective of experiment

6.2.1 The aim of experiment is to determine thermal factors connected with heat transfer through
the wall. There are as follows:

- ***k*** - heat transfer coefficient,
- α_z - outside surface film conductance,
- α_w - inside surface film conductance,
- λ - thermal conductivity.

6.2 Experiment description

Hot air, with temperature "t_g" goes up along vertical rectangular cross-section channel. Walls of channel are non-thermal insulated and because of this some portion of heat goes through the wall in direction from inside to environment with temperature "t_o".(fig.1). Inside of channel, heat penetrates wall in forced convection condition. Outside, the heat is given up to environment by means of natural convection and radiation. There are some sensors in the test stand to measure necessary parameters as follows: - sensor of feat 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". The material property (conductivity) and geometry (thickness) of wall of channel have to know to right carry out test.

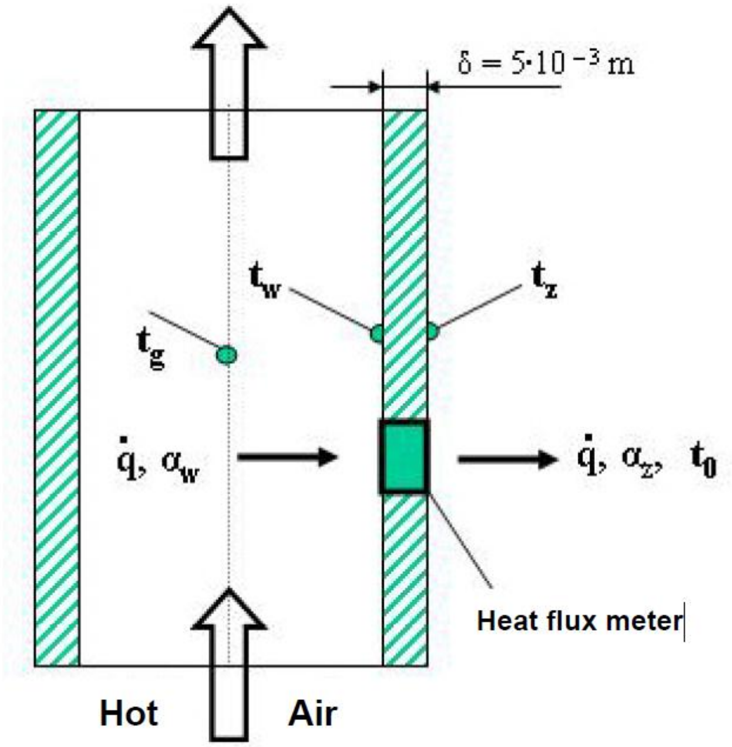

Fig 2 Lay-out of test stand

Measurements should be done for two states of heater (thermo-pressure fan). Test data is collected after temperature stabilisation for each of heater positions.

6.3 Elaboration of test data

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

Taking from tests: density of thermal flux q, temperatures of t_g, t_z, t_w i t_o, and using following equations calculate the values of heat transfer coefficient and thermal conductance for in and out of plane wall

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

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

$$q = \alpha_w(t_w - t_0)$$

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

Knowing the thickness of the wall ($\delta = 5\ mm$), thermal conductivity λ can be calculated based upon q and t_g, t_z, t_w i t_o as well as right transforming the formula.

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

6.3.3. Determination of maximum errors of calculation of factors $\boldsymbol{k}, \boldsymbol{\alpha_z}, \boldsymbol{\alpha_w}, \boldsymbol{\lambda}$

To calculate maximum errors of determination heat factors $k, \alpha_z, \alpha_w, \lambda$ when q is measured with max error 5%, max error for temperature is 0,2°C and error of determination of thickness is 0,5 mm.

An example of test table

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

No	Transducer 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: $q_c = 750 \, {}^{W}/_{m^2}$ for $\Delta U = 50mV$

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

A – voltmeter indication

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