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THEORETICAL STUDY OF THERMAL CONVECTION AND THERMAL RADIATION

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Abstract: *In this article we have discussed the most significant steps performed in experimental research for developing technical solutions associated with the principle schemes using mathematical analysis of heat transfer between the active elements and ambient heat by convection and radiation.*
Key words: *convection, radiation.*

1. INTRODUCTION

Thermal convection is the fundamental process of heat transfer that occurs between a wall and a fluid moving relative to it, under the action of temperature differences between wall and fluid.

Convection involves the combined action of thermal conduction in the fluid boundary layer near the wall, internal energy accumulation and movement of fluid particles mixture.

Thermal radiation is energy emitted by matter in the form of electromagnetic waves (or photons where the photon) as a result of the modification of the electronic configuration of atoms and molecules.

2. THERMAL CONVENCTION

The intensity of convective process depends on the movement of the fluid mixture. The heat transfer involves the phase change of the fluid is also considered convection due to the fluid motion induced during the process of evaporation and condensation.

The basic equation of thermal convection is Newton's equation:

$$\dot{Q} = \alpha \cdot S \cdot (t_p - t_f)\,[W] \qquad (1)$$

where α is the convection coefficient, $[W/m^2 \cdot K]$, S is the surface area of heat exchanger $[m^2]$ and t_p and t_f are wall temperatures , respectively of the fluid .

Convection coefficient α is not a property of the fluid. Its value depends on a number of factors (flow regime, the nature of the fluid surface geometry).The flow regime - is characterized by the Reynolds criterion.

Depending on its value are distinguished the following flow regimes:
- Laminar if the value is in the Reynolds: Re [0 ÷ 2320];
- Transient, if the value is in the Reynolds: Re [2320 ÷ 10000];
- Turbulent, if the value is the Reynolds: Re> 10000.

Remark: In the laminar regime, is done mainly by convection heat conduction in the fluid; movement intake is very low. In the turbulent regime occurs by convection of boundary layer thermal conduction and mass transfer and fluid mixture.

The physical properties of the fluid.
Heat transfer by convection is affected by:
- Thermal conductivity: λ [W / m.K];
- Specific heat c [J / kg.K]
- Density ρ [kg / m3];
- Thermal diffusivity [m2 / s];
- Kinematic viscosity [m2 / s].

Remark: All of these physical properties depend on the temperature and to a lesser extent, pressure.

The shape and dimensions of the heat exchange surface

- Heat exchange surface geometry (planar, circular, single, the beam);
- Heat exchange surface orientation to the direction of flow.

The common values of the coefficient of convection are shown in Table 1:

Approximate values of the coefficient of convection
Tab.1.

Common values of the coefficient of convection.	α [W/m$^{2\cdot}$K]
Free convection, gaseous substances	2-25
Free convection, liquid	10-1000
Forced convection gas	25-250
Forced convection liquid	50-20000
Boiling and Condensation	2500-100000

The convection coefficient α are all factors which are encompassed by the convection process: type of movement, flow regime, the physical properties of the fluid, the shape and orientation of the heat exchange surface.

$$\alpha = f(l, w, t_p, t_f, \lambda, c_p, \rho, \nu, a....) \quad (2)$$

2.1 Methods for the determination of the coefficient of convective.

In order to determine the coefficient of convection, α, can be use the following methods:

- exact mathematical solutions of the boundary layer equations;
- analysis approximate boundary layer integral methods;
- experiment and dimensional analysis.

Solving analytical boundary layer equations is difficult and can only apply to certain types of flow; approximate analysis of the boundary layer, which uses simplified equations for velocity and temperature distribution, relays that relationships do not always provide for the calculation of the coefficient of convection. The most common method to determine the coefficient of convection is experimental. It starts by creating an experimental (using similarity theorems) on which will be achieved a program of experiments. Form equation criteria characterizing the phenomenon are obtained by dimensional analysis and exponents and constants are determined from experimental data.

Similarity theory

The calculation formulas determined based on a relatively small number of measurements on model (laboratory facilities) can be applied to broad categories of technical processes which have the same mechanism of conducting heat transfer phenomenon. This is possible due to the similarity principle. The principle of similarity shows that the two systems have a similar behavior if their aspect ratio linear forces gear is the same. The similarity in the study of heat transfer processes assumed similarity

- Geometric;
- Mechanical;
- Heat

Similarity has two basic theorems:

Newton's theorem: for similar phenomena, similarity criteria have the same value. (for two similar phenomena (in the laboratory and in practice) criteria Nu, Re, Pr and are equal.)

Buckingham's theorem: integral solutions of differential equations that express two phenomena are also represented by a relationship between the criteria for determining similarity resulting from these equations. Therefore there is a relationship of the form:

$$f(Nu, \Pr, \mathrm{Re}) = 0 \quad (3)$$

2.2 Similarity criteria. Criteria relations

The heat exchange processes certain dimensionless groups, representing the issues that it considers phenomena have become criteria:

Criterion Reynolds (Re) - characterize fluid flow regime and the ratio of inertial forces and the forces of viscosity.

$$\mathrm{Re} = \frac{w \cdot l}{\nu} [-] \quad (4)$$

where: w - the flow rate of the fluid [m/s] ; $l =$ dh – length feature or hydraulic diameter is determined by the relation : $d_h = \frac{4 \cdot A}{P}$ [m] ; A -

flow area; P- wetted perimeter, ν – kinematic viscosity of the fluid, m^2/s.

The criterion Prandtl (Pr) - characterizing the physical properties of the fluid and is the ratio of the velocity distribution and temperature.

$$Pr = \frac{\nu}{a}[-] \quad (5)$$

where: a - thermal diffusivity, is determined by the relation: $a = \frac{\lambda}{\rho \cdot c}\left[\frac{m^2}{s}\right]$.

The criterion Peclet (Pe) is the ratio between the heat flows transmitted by convection or by conduction, at the same difference Δt.

$$Pe = Re \cdot Pr = \frac{w \cdot l}{a} \quad (6)$$

The Nusselt criterion (Nu) - is the ratio of the fluid temperature gradient at the wall surface and a reference temperature gradient.

$$Nu = \frac{\alpha \cdot l}{\lambda}[-] \quad (7)$$

Criterion Stanton (St) - expresses the ratio of heat flux transmitted by convection and heat flux accumulated fluid.

$$St = \frac{\alpha}{c_p \cdot \rho \cdot w}[-] \quad (8)$$

Criterion Grasshoff (Gr) - occurs in free convection processes and characterize the interplay of the forces of buoyancy and viscosity of the fluid.

$$Gr = \frac{g \cdot l^3 \cdot (t_p - t_f)}{T_f \cdot \nu^2}[-] \quad (9)$$

Biot criterion (Bi)- the ratio of indoor thermal resistance (conduction) and outer (the convection) of a body, the heat transfer between it and a fluid.

$$Bi = \frac{\alpha \cdot l}{\lambda_p}[-] \quad (10)$$

Fourier criterion (Fo) - characterize transient heat exchange processes and express heat propagation time.

$$Fo = \frac{a \cdot \tau}{l_c^2}[-] \quad (11)$$

Remark. In practice, convection coefficients α are calculated from empirical equations criteria correlating experimental data obtained by using dimensional analysis. Explicit form of the equations Criterion:

$$Nu = f(Re, Pr, Gr, Pe) \quad (12)$$

and convection coefficients, α, is determined from the relationship:

$$\alpha = \frac{\lambda}{l_c} \cdot Nu\left[\frac{W}{m^2 \cdot K}\right] \quad (13)$$

2.3 Free convection

The mechanism by free convection heat transfer is the movement of fluid across the free surface of a wall movement caused by the difference in density of the fluid, due to the difference in temperature produced by the heat exchange process. For most fluids encountered in practice the variation of density with temperature is linear. Thus, if the fluid temperature T_f and density ρ_f comes into contact with the hot wall temperature T_p, density of the fluid at a point T temperature boundary layer will be formed:

$$\rho = \rho_f \cdot [1 - \beta \cdot (T - T_f)]\,[kg/m^3] \quad (14)$$

where β is coefficient of volumetric expansion of the liquid. Since $\rho<\rho_f$, the fluid particles with temperature T will act a buoyancy equal to:

$$f_a = g(\rho_f - \rho) = g \cdot \rho_f \cdot \beta \cdot (T - T_f) \quad (15)$$

It seems that The upward force which ensures that the natural motion of the fluid is directly proportional to the acceleration of gravity, coefficient of volume expansion and the difference in temperature. In free convection of thermal and hydrodynamic boundary layers are basically the same thicknesses as velocity gradients are produced by temperature gradients; under these conditions the coefficient of convection and the corresponding relations depend on the geometry calculation.

3. THERMAL RADIATION

Thermal radiation is energy emitted by matter in the form of electromagnetic waves (or photons where the photon) as a result of the modification of the electronic configuration of atoms and molecules. Unlike conduction and convection, radiation does not require the presence of a medium; in terms of thermal effects of interest in the visible and infrared radiation with wavelengths between 0.1 and 100µm. Most solids and liquids radiate heat throughout the wavelength range with a continuous spectrum. Radiations occur in a thin layer on the surface of the body and depend on the nature and surface temperature.

Thermal emissivity material Tab.2

The emissivity of the material at ambient temperature;	
Aluminum foil	0.07
Anodized aluminum	0.82
Polished Copper	0.03
Golden polished	0.03
Silver polished	0.02
Stainless steel	0.17
White Paper	0.92-0.96
Brick red	0.93-0.96
Human body	0.95
Wood	0.82-0.92
Soil	0.93-0.96
Water	0.96
Vegetations	0.92-0.96

The gas radiates heat selectively on certain portions only of wavelength, with a discontinuous spectrum (in whole volume of the gas occurs and depends on the thickness of the gas and its pressure and temperature.) Maximum radiation may be emitted from a surface located at absolute temperature T is given by the Stefan-Boltzmann Law:

$$\dot{Q} = C^0 \cdot S \cdot T^4 \left[\frac{W}{m^2}\right] \quad (16)$$

where C^0 = 5.67 .10^{-8} W/m^2· K Ştefan is Boltzmann constant, S is the area of radiation, and T is the temperature of the body that emits radiant energy, [K]. Ideal surface that can deliver maximum radiation is called black body and the radiation emitted is called black body radiation. The radiation emitted by the actual surface is lower than the radiation emitted by the black body at the same temperature is determined as follows:

$$\dot{Q} = \varepsilon \cdot C^0 \cdot S \cdot T^4 \left[\frac{W}{m^2}\right] \quad (17)$$

where ε is the thermal emissivity of the surface.

Thermal emissivity is a measure of the closeness of a black body surfaces. Values of surface emissivity are shown in Table 2.

4. CONCLUSIONS

Thermal convection depends on the physical properties of the fluid, the shape and dimensions of the heat exchange surface. Methods for the determination of the coefficient of convective, similarity theory, similarity criteria, criteria relations and free convection must be taken in consideration**.**

Thermal radiation must take in consideration the emissivity of the material of ambient temperature.

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Studiu teoretic asupra convecţtiei termice şi radiaţiei termice

In acest articol s-au discutat cele mai semnificative etape ce trebuiesc parcurse în cercetarea experimentală pentru elaborarea soluţiilor tehnice asociate cu schemele de principiu ale soluţiilor de răcire din electronică, folosind analiza matematică a transferului de căldură între elementele termic active şi mediul ambiant, prin convecţie şi radiaţie.

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