CALCULATION OF CONVECTIVE HEAT TRANSFER COEFFICIENTS

1. Introduction

The convective heat transfer coefficient can be derived from empirical relations as described in multiple textbooks on heat transfer. Some of these relations were implemented in spreadsheet files allowing the calculation of the convective heat transfer coefficient for typical situations.

2. Internal flow (forced convection)

spreadsheet Convection_Internal_Flow.xlsx

cross section shape

	a	b	hydraulic diameter	section	shape factor	Nu const q	Nu const Θ
	m	m	m	m2		-	-
rectangular	0,200	3,000	0,375	6,00E-01	15	6,49	5,7

fluidum

	temperature	conductivity	density	specific heat	dynamic viscosity	kinematic viscosity	thermal diffusivity	Pr
	°C	W/mK	kg/m3	J/kgK	kg/ms	m2/s	m2/s	-
air	40,0	0,026	1,177	1006	1,85E-05	1,57E-05	2,22E-05	0,71

mean velocity

velocity	volume flow	mass flow	volume flow	mass flow
m/s	m3/s	kg/s	m3/h	kg/h
0,500	0,300	0,353	1080,000	1271,592

results

Reynolds number	flow type	laminar flow case	turbulent flow case	Nusselt number	surface coefficient
-				-	W/m2K
11958	turbulent		heating	36,62	2,56

Figure 1. Spreadsheet for internal flow (example air flow in rectangular duct).

Purpose of the spreadsheet: calculation of the convective surface heat transfer coefficient between a fluidum (air or water) and the surfaces of a circular or rectangular pipe or duct as a function of the fluidum velocity.
Examples.

- Water at 30°C with a velocity of v = 1 m/s flowing through a circular pipe of diameter 18 mm: h_c = 4540 W/m^{2}K.
- Air at 40°C with a velocity of v = 0.5 m/s flowing through a rectangular section (0.2 m x 3 m): h_c = 2.6 W/m^{2}K.

3. Natural convection at a vertical plate

spreadsheets Convection_Natural_Vertical_Plate_a.xlsx
Convection_Natural_Vertical_Plate_b.xlsx
Comparison.xlsx

vertical plate

L	temperature		g
m	°C	m/s2	
3,000	20,0		9,81

fluidum

	temperature	conductivity	density	specific heat	dynamic viscosity	kinematic viscosity	thermal diffusivity	Pr
	°C	W/mK	kg/m3	J/kgK	kg/ms	m2/s	m2/s	-
air	30,0	0,026	1,177	1006	1,85E-05	1,57E-05	2,22E-05	0,71

results

Rayleigh number	Grashof number	Nusselt number	surface coefficient h
-	-	-	W/m2K
2,51,E+10	3,55,E+10	337,762	**2,954**

Figure 2. Spreadsheet A for natural convection at a vertical plate.

Calculation of natural convection heat transfer from a vertical plate

data			
environmental temperature	θ_e =	20,0	°C
surface temperature	θ_s =	30,0	°C
plate height	H_c =	3,000	m
air properties			
mean temperature	θ_i =	25,0	°C
coefficient of expansion	β_i =	0,00335	1/K
density	ρ_i =	1,18	kg/m^3
dynamic viscosity	μ_i =	1,85E-05	Pa.s
kinematic viscosity	ν_i =	1,56E-05	m^2/s
specific heat	c_{pi} =	1007	J/kg.K
thermal conductivity	λ_i =	0,026	W/m.K
thermal diffusivity	α_i =	2,181E-05	m^2/s
Prandtl number	Pr =	0,715	-
air flow results			
Grashof number	Gr =	3,657E+10	-
Rayleigh number	Ra =	2,613E+10	-
Nusselt number	Nu =	308	-
convective heat transfer coefficient	h_c =	**2,67**	$W/m^2.K$
convective heat transfer coefficient EN 1.46 $\Delta\theta^{1/3}$ (CEN_CON)	h_c =	3,15	$W/m^2.K$

Figure 3. Spreadsheet B for natural convection at a vertical plate.

Purpose of the spreadsheets: calculation of the natural convective surface heat transfer coefficient between a fluidum (air or water) and a vertical surface as a function of the surface height, the surface temperature and the fluidum temperature.
For air, 2 spreadsheets are available.

Example.
Air at 30 °C cooled by a surface at 20° of 3 m high: convective heat transfer coefficient values found: h_c = 2.95 W/m²K / h_c = 2.67 W/m²K / h_c = 3.15 W/m²K (Figure 2, Figure 3).

A comparison is made between the given 2 formulas from literature[1,2] and the formula implemented in CEN_CON ($1.46\Delta\theta^{0.33}$): Comparison.xlsx
There is (as far as we know) no standard (CEN, ISO) giving formulas as a function of the temperature difference. Only in EN 13789 are convective heat transfer coefficients explicitly mentioned (fixed values).

[1] Principles of Heat Transfer (7th edition), Kreith, Manglik & Bohn, 2011, CENGAGE
[2] Fundamentals of Heat and Mass Transfer, Bergman (7th edition), Lavine, Incropera & Dewitt (2011), John Wiley & Sons, Incorporated