SIMULATION OF INTERNAL SURFACE CORNER HEAT TRANSFER USING THE RADCON MODULE

Content

1. Introduction 1
2. The global internal surface heat transfer coefficient according to EN ISO 6946. 1
3. The reduced internal surface heat transfer coefficient according to EN ISO 10077-2...1
4. Internal surface heat transfer simulation using the RADCON type BC_SKY 2
5. Comparing results: BC_SIMPL versus BC_SKY. 4
6. Discussion 5
7. References...5
8. ANNEX 6

1. Introduction

To simulate internal surface heat transfer by convection and radiation most standards define a global surface heat transfer coefficient. To take into account the lower radiation heat exchange in corners, a locally reduced global surface heat transfer coefficient is often used (for example in EN ISO 10077-2 and in EN ISO 13788).
The RADCON module (available in the 2D & 3D Physibel software) allows a separated analysis of radiation and conduction or convection. The radiation heat exchange is simulated in a physically correct way, and therefore a more precise corner effect heat transfer simulation is possible.

2. The global internal surface heat transfer coefficient according to EN ISO 6946.

In annex C of the standard ISO 6946: 2017, the radiative and convective parts of the global internal heat transfer coefficient in case of plane surfaces are given (see Figure 7 in annex of this document).

For the radiation a surface heat transfer coefficient value that is a function of the mean temperature is used. This corresponds to 'linear' radiation as explained in Physibel Knowledge Base[1]. For a mean temperature of 20 °C, the black-body radiative coefficient h_{r0} = 5.7 W/m^{2}K. Using the default emissivity of 0.9, the radiative coefficient h_r = 5.1 W/m^{2}K.

For the convective surface heat transfer coefficient 3 values are given, depending on the heat flow direction. For horizontal heat flow the convective coefficient h_{ci} = 2.5 W/m^{2}K.

The global internal heat transfer coefficient h_i = 7.7 W/m^{2}K used for vertical plane surfaces is the sum of the radiative and the convective part.

3. The reduced internal surface heat transfer coefficient according to EN ISO 10077-2.

Figure 1 shows schematically the radiation heat transfer between an internal environment and a window frame with an insulation panel or glazing. The radiation striking the plane wall and the frame front surface (A) isn't affected by the frame (radiative coefficient h_r = 5.1 W/m^{2}K). The frame surface perpendicular to the glazing surface, receives radiation from the interior (B), but because it is warmer than the glazing surface, it also sends radiation to that glazing surface (C).

[1] THERMAL SIMULATION OF NON-VENTILATED CAVITIES USING THE RADCON MODULE.pdf

As a result, the net radiation received in the corner zone is lower (radiative coefficient $h_r < 5.1$ W/m^{2}K).

Therefore a lower global heat transfer coefficient is justified. EN ISO 10077-2 uses $h_i = 5.0$ W/m^{2}K in the corner zones (Figure 2).

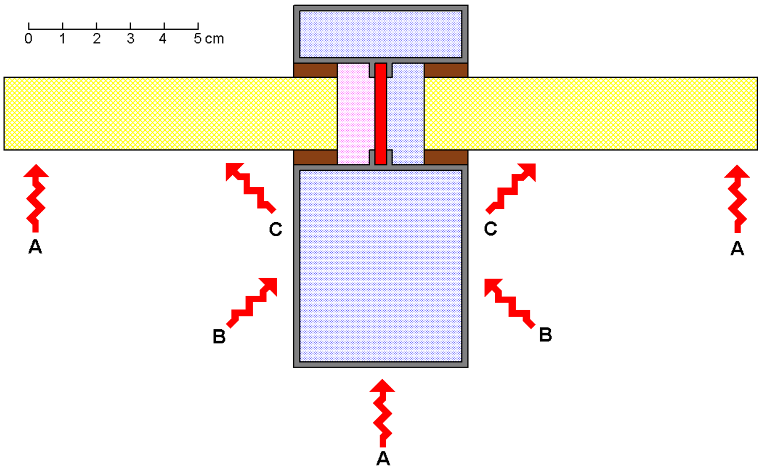

Figure 1. Radiative heat transfer at plane surfaces and corners.

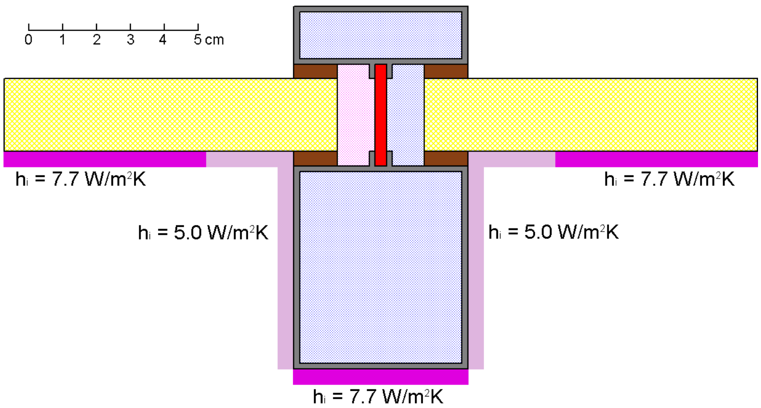

Figure 2. Heat transfer coefficient at plane surfaces and corners according to EN ISO 10077-2.

4. Internal surface heat transfer simulation using the RADCON type BC_SKY

In the Physibel software, the use of the type BC_SKY allows a rather correct physical simulation of the surface heat transfer by radiation and convection.

- The radiation algorithm is based on non-linear or linear view factor based radiation laws (Stefan-Boltzman's law, Lambert's Cosine Law, view factor based heat exchange) (Figure 3). More detailed information is given in Physibel Knowledge Base[2].

[2] THERMAL SIMULATION OF NON-VENTILATED CAVITIES USING THE RADCON MODULE.pdf

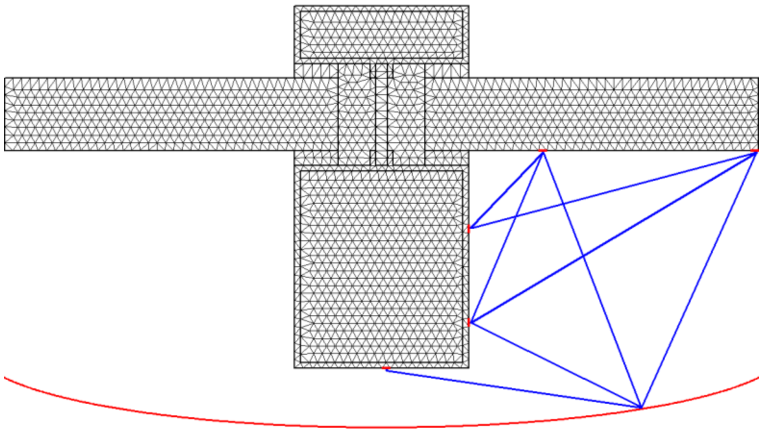

Figure 3. Principle of view factor based radiation heat transfer using BC_SKY

- The convection is simulated using a constant of a temperature difference dependent convective heat transfer coefficient.

Practical implementation in the Physibel software

To simulate the internal* surface heat transfer by radiation and convection physically more correctly the RADCON type BC_SKY can be used as instead of BC_SIMPL.

For this type both the environmental radiation temperature and the air temperature need to be specified. For calculations compliant to EN 6946 and EN ISO 10077-2 radiation temperature = air temperature = 20 °C.

Concerning the radiation, the infrared emissivity of each material (surface) needs to be specified. The default value is e = 0.9. In the calculation parameters, the linear radiation model with a black radiation heat transfer coefficient h_{rb} = 5.7 W/m²K[3] is recommended for calculations compliant to EN ISO 6946 and EN ISO 10077-2. An alternative is to use the non-linear model in combination with external / internal temperatures of 0 °C / 20 °C.

The internal convective coefficient h_{ci} = 2.5 W/m²K has to be used for compliancy with the standards mentioned.

When simulating real situations (external / internal temperatures different to 0 °C / 10 °C) the non-linear model in combination with a temperature difference dependent convective coefficient can be used.

* The BC_SKY model could be used also at the external surface, but because of the dominating forced convection, the difference with the BC_SIMPL is rather small.

[3] The black radiation heat transfer coefficient is referred to as "h_{r0}" in ISO 6946 and "h_{rb}" in EN 10077-2

5. Comparing results: BC_SIMPL versus BC_SKY.

BISCO DATA frame_alu_A_BC_SIMPL.bsc frame_alu_A_BC_SKY.bsc
frame_alu_B_BC_SIMPL.bsc frame_alu_B_BC_SKY.bsc
frame_alu_C_BC_SIMPL.bsc frame_alu_C_BC_SKY.bsc
frame_alu_sliding_BC_SIMPL.bsc frame_alu_sliding_BC_SKY.bsc

For 4 cases, the standard method (using BC_SIMPL with a reduced heat transfer zone) was compared to the method using the more precise radiation model (using BC_SKY). Table 1 contains the calculated thermal transmittance U.

The radiosity method of standard 10077-2 was used for the air cavities inside the frame (RADCON type TRANSMAT) with non-linear radiation.

For the cases A, B, and C the BC_SKY method results in slightly higher U-values.

For the case D, a sliding window frame with a more complex internal surface geometry, the BC_SKY method results in a lower U-value.

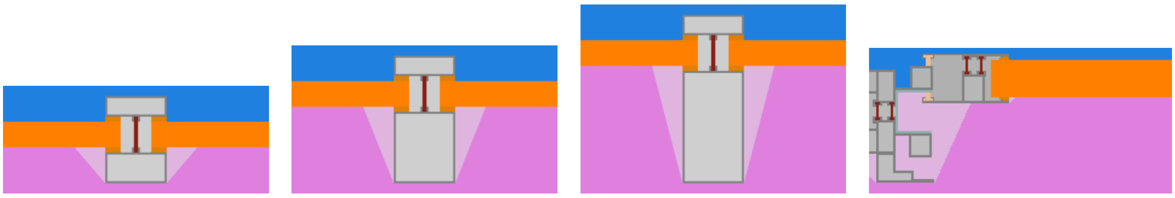

Figure 4. 4 cases for comparing BC_SIMPL with BC_SKY (from left to right A, B, C, D).

U [W/m²K]	BC_SIMPL	BC_SKY linear radiation h_{rb} = 5.7 W/m²K	BC_SKY non-linear radiation
case A	2.515	2.660	2.574
case B	2.695	2.833	2.741
case C	2.796	2.945	2.853
case D	4.496	4.446	4.338

Table 1. Calculated thermal transmittances

6. Discussion

Figure 5 visualises the infrared radiation and temperatures for case C. Though the surface temperatures on the frame (+/-18°C) and on the panel (+/-17°C) are almost constant, a gradient on the infrared radiation can be observed along the interior surfaces. This visualisation justifies the simplified approach of EN ISO 10077-2 with reduced global surfaced coefficient in the standard window frame corners.

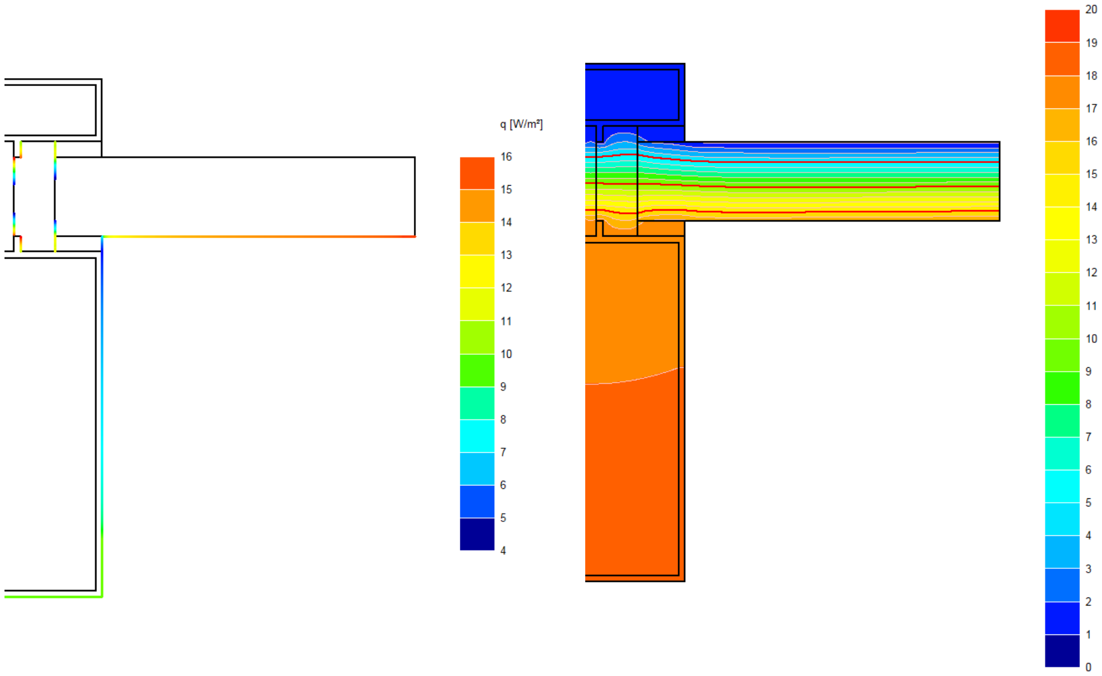

Figure 5. CASE C: Left) infrared radiation (W/m²) and Right) Temperatures (°C)

However, for more complex window frames (e.g. case D, see Figure 6 below) or for non-standard situations (e.g. corner window frames) the simplified approach results in larger discrepancies with the physical reality.
Especially as the revised version of EN ISO 10077-2 allows for detailed infrared radiation calculation in cavities (radiosity method), it can be argued that the detailed calculation of infrared radiation at the surface should be allowed too.

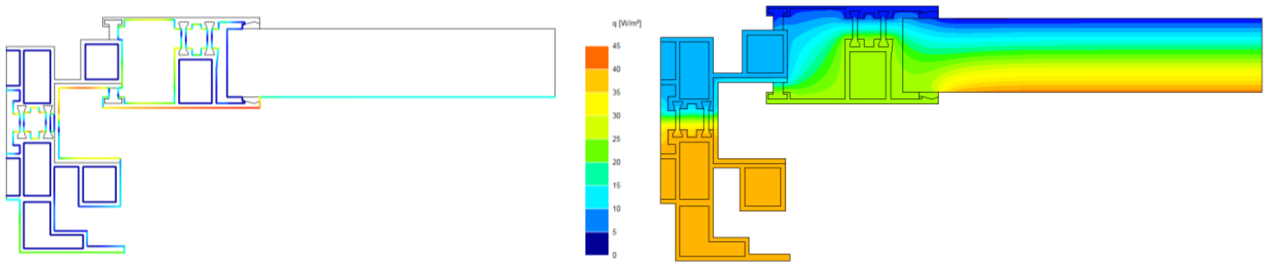

Figure 6. CASE D: Left) infrared radiation (W/m²) and Right) Temperatures (°C)

7. References

EN ISO 10077-2:2017: Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames

EN ISO 13788:2012: Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods

EN ISO 6946: 2017: Building components and building elements — Thermal resistance and thermal transmittance — Calculation method

8. ANNEX

ISO 6946:2017(E)

Annex C
(normative)

Surface resistances

C.1 Plane surfaces

The surface resistance is given by Formula (C.1).

$$R_s = \frac{1}{h_c + h_r} \tag{C.1}$$

where

R_s is the surface resistance, in $m^2 \cdot K/W$;

h_c is the convective coefficient, in $W/(m^2 \cdot K)$;

h_r is the radiative coefficient, in $W/(m^2 \cdot K)$.

and

$$h_r = \varepsilon \cdot h_{r0} \tag{C.2}$$

$$h_{r0} = 4 \cdot \sigma \cdot T_{mn}^{\ 3} \tag{C.3}$$

where

h_r is the radiative coefficient, in $W/(m^2 \cdot K)$;

ε is the hemispherical emissivity of the surface;

h_{r0} is the radiative coefficient for a black-body surface, in $W/(m^2 \cdot K)$;

σ is the Stefan-Boltzmann constant: $5{,}67 \times 10^{-8}$ $W/(m^2 \cdot K^4)$;

T_{mn} is the mean thermodynamic temperature of the surface and of its surroundings, in K.

ε = 0,9 is usually appropriate for internal and external surfaces. Where other values are used, they should allow for any effects of deterioration and dust accumulation with time.

At internal surfaces, or external surfaces adjacent to a well-ventilated air layer (see 6.9.4):

$$h_c = h_{ci} \tag{C.4}$$

Values of h_{ci} are given in Table C.1.

Table C.1 — Values of the convective surface coefficient, h_{ci}

Convective surface coefficient	Direction of heat flow		
$m^2 \cdot K/W$	Upwards	Horizontal	Downwards
h_{ci}	5,0	2,5	0,7

Figure 7. Part of annex C of ISO 6946:2017