2D THERMAL SIMULATION OF ANGLED AND CURVED SHAPES vs. RETANGLULAR SHAPES: BISCO vs. TRISCO

1. Introduction

The program TRISCO is initially made to simulate block shaped 2D/3D objects. The program uses a rectangular calculation grid.
The program BISCO is limited to 2D but allows objects with any shape. The program uses a triangular calculation grid.
BISCO requires the definition of the 2D object in bitmap format, while TRISCO requires the definition of the 2D/3D object as a set of rectangular blocks (defined in TRISCO format).
Also a bitmap is a set of square pixels, and thus a set of rectangular blocks, and this allows TRISCO to read BISCO data[1]. If the object contains sloped or curved shapes, TRISCO needs relatively a lot of blocks to model the object.
For rectangular 2D objects it can easily be shown that BISCO and TRISCO result in almost identical results.
2 examples are given that show that this is also valid for non-rectangular 2D objects BISCO and TRISCO on the condition that a surface heat transfer correction is applied.

2. Case study 2: sloped square

BISCO data square_45°_bisco.bsc
TRISCO data square_45°_trisco.trc and square_45°_trisco_corr.trc
Trisco2D data square_45°_trisco.tr2 and square_45°_trisco_corr.tr2

Figure 1 shows the BISCO data interface for a 45 ° sloped square object (side length a = 0.1785 m) positioned between an environment at 20 °C with a global heat transfer coefficient of 7.7 W/m^{2}K and an environment at 0 °C with a global heat transfer coefficient of 25 W/m^{2}K.
The heat flow is 1D in this case and can easily be calculated analytically: **Q = 3.36055 W/m**.
Figure 2 shows the isotherms calculated by BISCO. The total heat loss is **Q = 3.3597 W/m** or 0.2 % lower than the reference value.

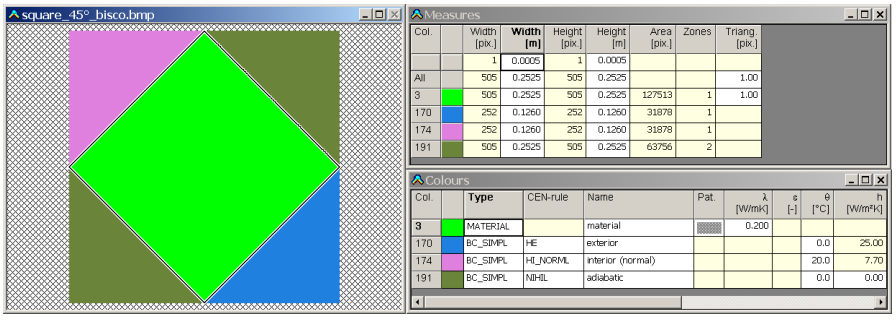

Figure 1. BISCO input interface for the sloped square.

[1] BISCO and bitmap inputs are only possible in the full version of TRISCO, not in TRISCO 2D

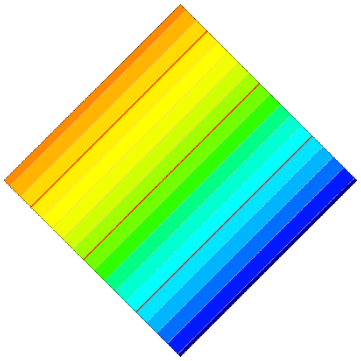

Figure 2. Isotherms (colour increment 1 °C, line increment 5 °C).

When importing the BISCO data in TRISCO (Figure 6), automatically 1009 blocks are created to model the bitmap-based object.
Using a rectangular grid with a maximum size of 0.5 mm (257 048 nodes), the total heat loss amounts to **3.5248 W/m**, 4.9 % higher than the reference value.
The reason for this higher heat loss is an overestimation of the surface heat transfer in TRISCO.
The stepwise-modelled surfaces are a factor $\sqrt{2}$ too large in TRISCO.
By applying lower surface heat transfer coefficients, the larger surface effect can be neutralised:

$h_i' = h_i / \sqrt{2} = 7.7 / 1.414$ W/m^{2}K = 5.44 W/m^{2}K

$h_e' = h_e / \sqrt{2} = 25 / 1.414$ W/m^{2}K = 17.68 W/m^{2}K

Using these corrected values, the total heat amounts to **3.3592 W/m**, only 0.015 % lower than the reference value.

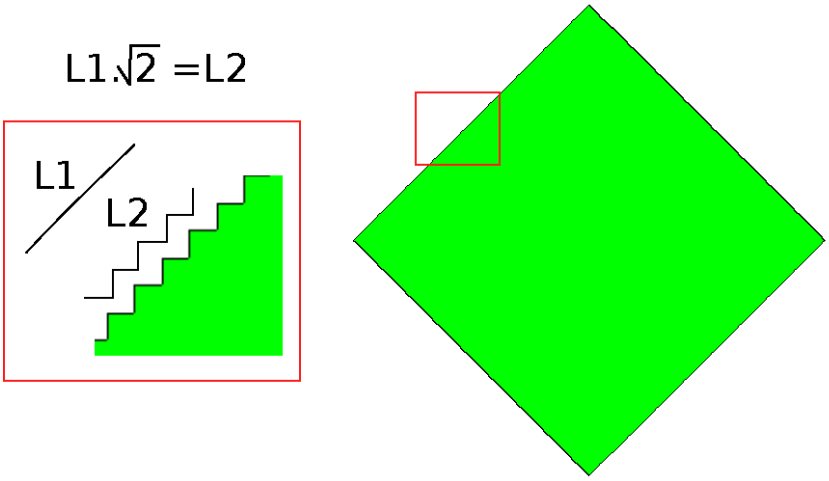

Figure 3. Stepwise modelled surface vs. physical surface.

3. Case study 1: circular tube

BISCO data tube_bisco.bsc
TRISCO data tube_trisco.trc
TRISCO data tube_trisco_corr.trc

Figure 4 shows a quarter of a tube (outer radius 0.5 m, inner radius 0.25 m). Inside the tube an environment at 20 °C with a global heat transfer coefficient of 7.7 W/m^{2}K is assumed. Out of the tube an environment at 0 °C with a global heat transfer coefficient of 25 W/m^{2}K is assumed. The thermal conductivity of the tube is 0.5 W/mK.
For a zoomed part, the figure clearly shows
- the pixel based bitmap format used to define the object in BISCO; the pixel size is 0.5 mm.
- the triangular grid used in the BISCO calculation.

Figure 5 shows the isotherms calculated by BISCO using a grid with 170 469 nodes.
The total heat loss through the pipe quarter is **15.81 W/m** [2].

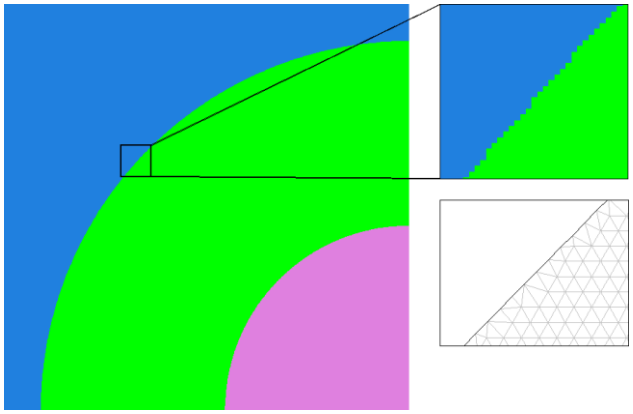

Figure 4. Quarter of a tube

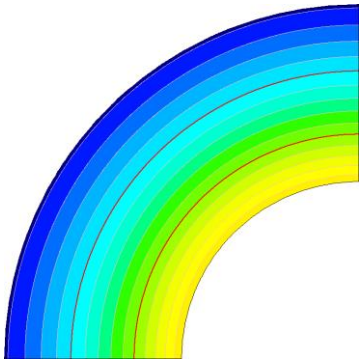

Figure 5. Isotherms (colour increment 1 °C, line increment 5 °C)

[2] For the cylindrical configuration also an analytical calculation can be made. Its result is 15.82 W/m.

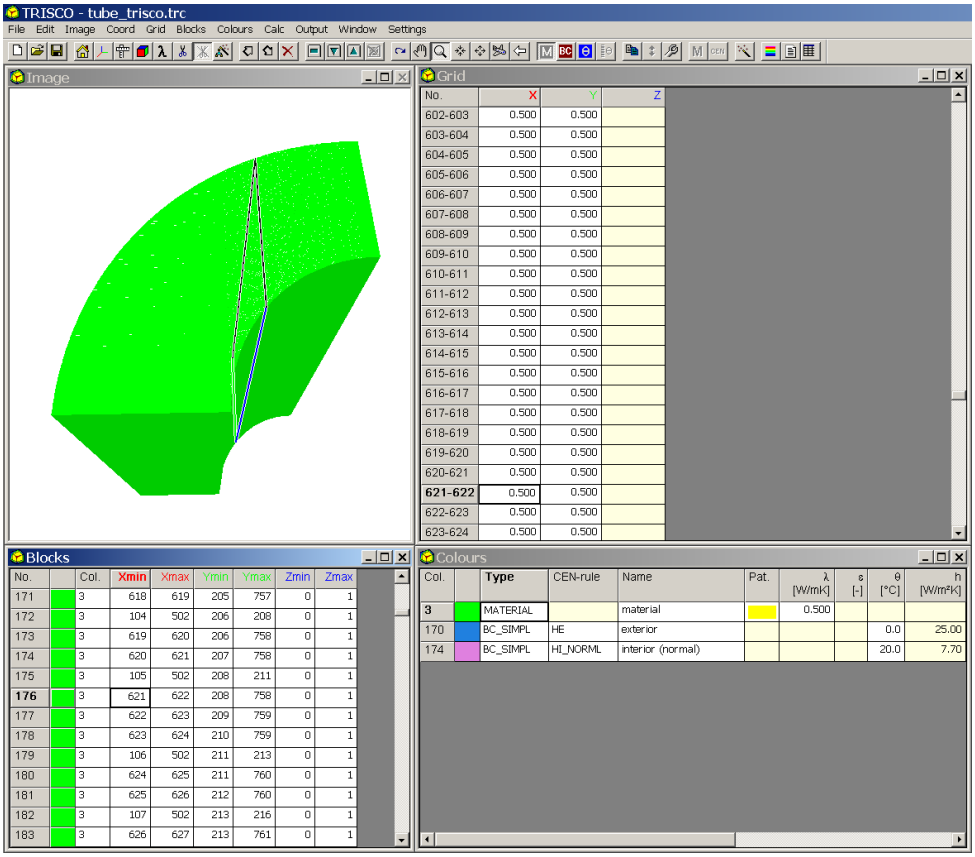

Figure 6. TRISCO input interface after importing the BISCO data

When importing the BISCO data in TRISCO (Figure 6), automatically 1656 blocks are created to model the bitmap-based object.

Using a rectangular grid with a maximum size of 1 mm (807 724 nodes), the total heat loss through the pipe quarter is **16.89 W/m**, 7 % higher than the BISCO result (15.81 W/m).

As in the previous case study the reason for this higher heat loss is an overestimation of the surface heat transfer in TRISCO.

The stepwise modelled internal surface is $2\ r_i = 0.5\ m^2/m$ in TRISCO, but only $\pi\ r_i / 2 = 0.393$ m in BISCO. The stepwise modelled external surface is $2\ r_e = 1\ m^2/m$ in TRISCO, but only $\pi\ r_e / 2 = 0.785$ m in BISCO.

By applying lower surface heat transfer coefficients, the larger surface effect can be neutralised:

$h_i' = (\pi/4)\ h_i = (\pi/4)\ 7.7\ W/m^2K = 6.048\ W/m^2K$

$h_e' = (\pi/4)\ h_e = (\pi/4)\ 25\ W/m^2K = 19.635\ W/m^2K$.

Using these corrected values the total heat loss through the pipe quarter is **15.79 W/m**, almost identical to the BISCO result (15.81 W/m).

Conclusion

The program TRISCO can be used to simulate heat transfer in non-rectangular objects. For sloped or curved environmental surfaces the heat transfer coefficient needs to be decreased by a factor equal to the surface in TRISCO divided by the real sloped or curved surface.