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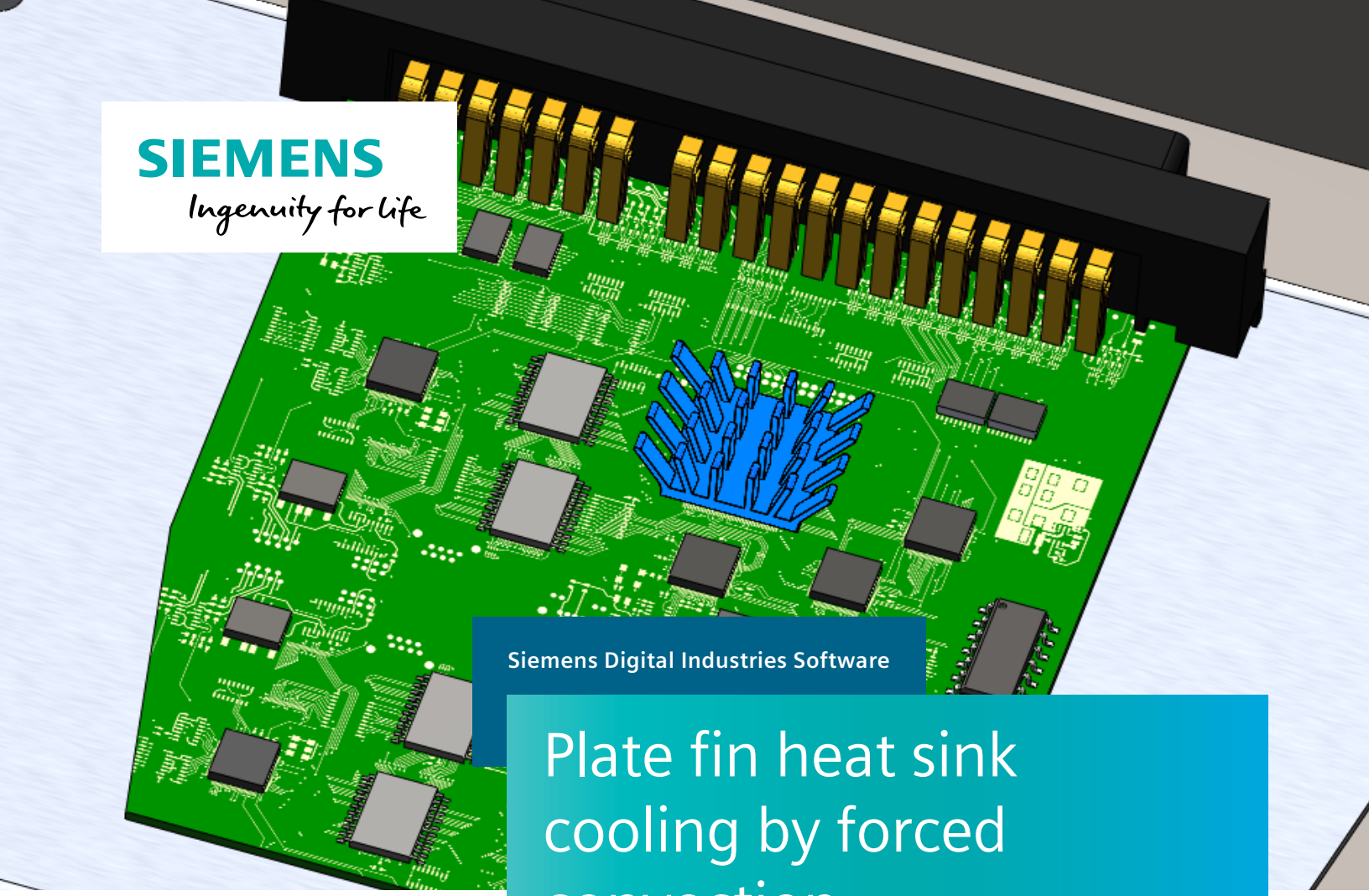

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Plate fin heat sink cooling by forced convection

Simcenter FLOEFD validation example 13

This validation example demonstrates Simcenter FLOEFD™ software capabilities to simulate forced air cooling of plate fin heat sink placed in a wind tunnel. The calculations are based on the experimental results from reference 1, where several flow regimes were considered.

Heat sink geometry with its main dimensions is shown in figure 1. The dimension values were set as follows: fin height (H) of 10 mm, thickness of 1.5 mm and fin-to-fin distance (δ) of 5 mm while the heat sink width (B) and length were 52.8 mm and the base thickness was 3 mm. The wind tunnel width (CB), height (CH) and length were 160 mm, 15 mm and 200 mm respectively.

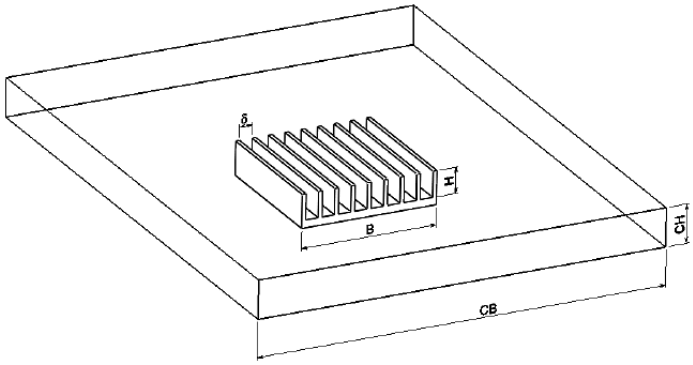

Figure 1. Geometry model of the heat sink.

The model of heat sink is made of solid aluminum (thermal conductivity 200 W/(m·K)). It is heated by MINCO Thermofoil™ electrical heater with a heat load of 10 W. The bottom of the heated foil is insulated with a 25 mm Polystyrene brick (thermal conductivity 0.033 W/(m·K)). The heat sink is placed in a rectangular wind tunnel duct with the walls made of Plexiglass (thermal conductivity 0.2 W/(m·K)). It is mounted in such a way that the fin base is flush with the duct wall as shown in figure 2.

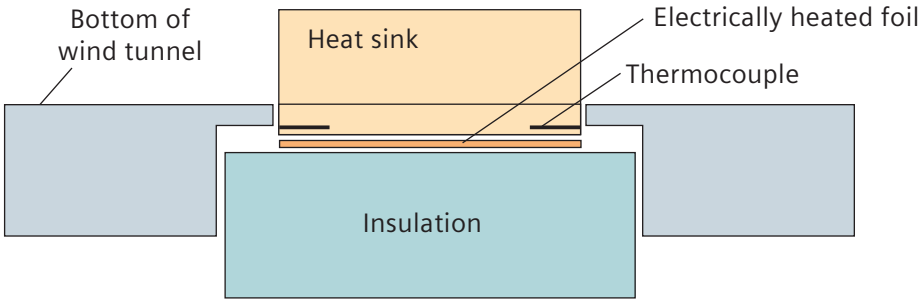

Figure 2. Vertical cut view of heat sink.

The performance of the heat sink is estimated by a thermal resistance defined as $R_{th} = \frac{T_{hs} - T_0}{q}$, where T_{hs} is the temperature of the heat sink base, T_0 is the temperature at the wind tunnel inlet and q is the total power input of the heat source (10 W). In reference 1, the T_{hs} value was measured by averaging the reading of four thermocouples (two of them can be seen in figure 2) placed symmetrically at the corners of the heat sink base.

Table 1 shows air inlet flow conditions specified for the calculations, inlet temperature is constant and equal 20 degrees C. To perform the calculations, five cases are considered, each with a different inlet velocity u_{in} that was determined as follows: $u_{in} = \dot{V}/A$, where $A = 24 cm^2$ is wind tunnel cross sectional area; $\dot{V}$ is volumetric air flow rate at standard conditions defined as

$$w = \frac{\dot{V}}{A - A_{front}}, \quad Re_{dh} = \frac{\rho \cdot w \cdot d_h}{\mu}$$

where w is average air velocity; $A_{front} = 1.4 cm^2$ is front area of the fins; Re_{dh} is the Reynolds duct number; dh is hydraulic diameter of the wind tunnel; μ is dynamic viscosity of air; ρ is density of air.

Table 1 – Inlet boundary conditions

Case	u_{in}, m/s	Re_{dh}
1	0.903	1740
2	1.287	2480
3	1.583	3050
4	1.899	3660
5	3.633	7000

The outlet static pressure is set to 1 atm.

The heat exchange between the outer duct surfaces and the ambient medium with the temperature of 20 degrees C is defined by a Newton's law of cooling with the heat-transfer coefficient of 3 $W/m^2 \cdot K$.

Since the geometry model has a symmetry plane, only a half of the model is used to generate the computational mesh.

The automatically generated mesh with RRL = 3 contained approximately 26 000 cells for cases 1-4 and with RRL = 5 contained approximately 109 000 cells for case 5. Figure 3 shows the mesh generated in the fluid region in one of the heat sink cross-sections. One can see that there only about 3-4 cells generated between two adjacent fins.

The values of thermal resistances predicted by Simcenter FLOEFD and the corresponding values measured experimentally are shown in figure 4. According to this plot, the difference between the calculations and the experimental measurements is less than 10 percent. This indicates that the sufficient accuracy of the results is maintained even on a coarse mesh generated inside the narrow channels.

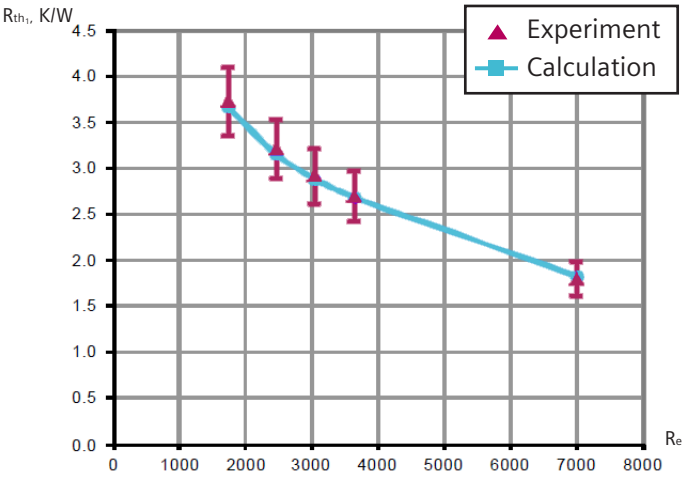

Figure 4. Thermal resistance of the heat sink versus Reynold number in comparison with the experimental data (reference 1).

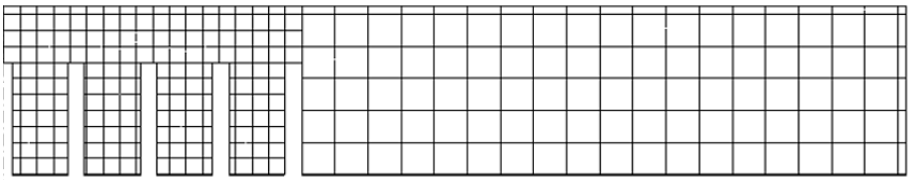

Figure 3. The computational mesh (cases 1-4).

References

1. Jonsson, H., Palm B., Thermal and Hydraulic Behavior of Plate Fin and Strip Fin Heat Sinks Under Varying Bypass Conditions, Proc. 1998 Intersociety Conf. On Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm '98), Seattle, May 1998, pp. 96-103.

Siemens Digital Industries Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Unit 901-902, 9/F
Tower B, Manulife Financial Centre
223-231 Wai Yip Street, Kwun Tong
Kowloon, Hong Kong
+852 2230 3333

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