Excerpt from the Proceedings of the COMSOL Conference 2008 Hannover

Investigation of natural convective air flow field through comb channels

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Abstract:
This study should support a new development of a radiator. This new radiator has instead of trapezoidal convector plates a package of combs to gain a larger area for heat exchange. The main aim is to find the optimal comb diameter for this special case. To solve this problem CFD (computational fluid dynamics) with the Software Comsol Multiphysics is used.
Based on simulations of single combs with different diameters in 2D, to get a first appraisal, some more simulations in 3D were conducted. Due to the solutions of 2D, the 3D simulations were continued with different diameters. Now these simulations include also the mutual impact of the single combs in a package. With these findings a chart which shows the radiator power was produced. This chart includes the radiator power for different radiator temperatures and different radiator heights.
A validation of these findings were made with the aid of measures of a conventional radiator, to be sure that the settings of the CFD are correct.
Finally, referring to the results, a commendation is given, which diameter the combs in the package should have for the prototype.

Keywords: radiator, heat exchanger, heating, comb, optimization

1. Introduction

Main emphasis of the investigations was on finding an optimum for comb channel air heating without artificial convection under variation of the comb diameter. Despite of the normal use of fins the investigations shall proof the potential of backside mounted combs, which are made of aluminum on a heating radiator. The aim of this work is to find the best geometry of one single comb to achieve the best performance in usage as a big comb package.

In the limits of the balance area several parameter studies with the same cross sectional area are investigated. Thus these boundary conditions a comparison between the different comb diameters is possible.

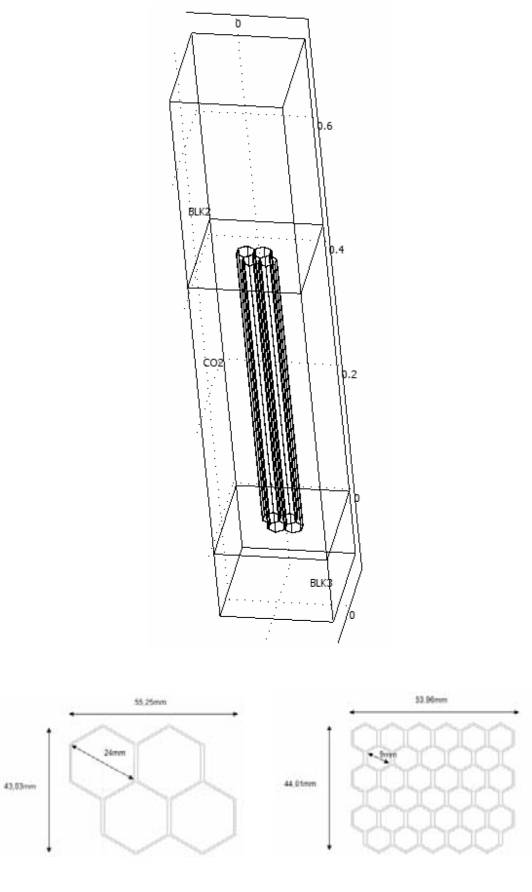

Figure 1: Schematic drawing of the model and comb packages with two different diameters

2. Use of COMSOL Multiphysics

A coupled physics of two COMSOL models is used for our problem. On the first hand we use the model weak compressible Navier – Stokes and on the other hand we implement the standard heat convection and conduction model. The detail for the air with all dependency of viscosity, density is integrated with the COMSOL software.

The heated comb package is installed in a pipe with square surface area. In- and outlet of air have in each case the boundary condition with the defined pressure (no viscose tension with 1 bar). Thus the airflow comes off only by the density variation of air.

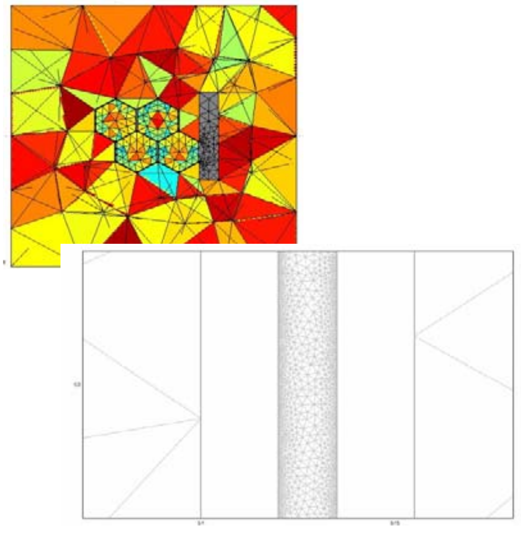

Figure 2: Examples for the cells in the combs

For a correct simulation it is essential to have enough cells in the combs and around the radiator. This is very complex by the simulation of such a case because there are a lot of small gaps, the plate is very thin and the essential simulation room is comparatively very wide.

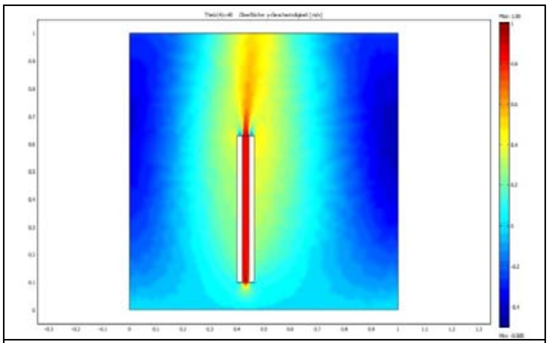

Figure 3: Velocity profile of one comb

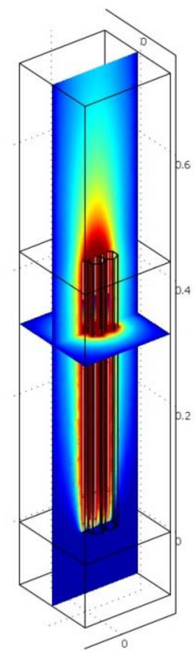

Figure 4: Example for the temperature profile of a comp package

3. Results

The result of this study is that a larger comb diameter, concerning to the thermal output, is better than a smaller one. The reason for this is that the smaller combs have a larger air resistance and therefore more drag effects occur. Thus no so high convection velocity speed will be achieved, which we see in lower energy transfer rate. The comb package with a large diameter achieves a power output about 21,8% more with a heating temperature of 40°C and an ambient temperature of 20°C, than the package with a small comb diameter. In comparison with a conventional radiator with trapezoidal convector plates the power output is event between 40 and 50% higher.

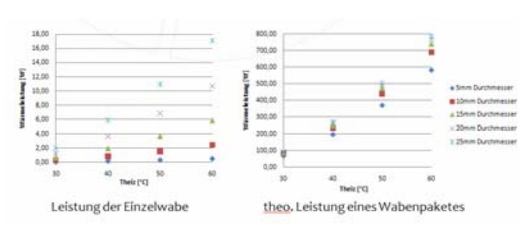

Figure 5: Power of different single combs and packages by different temperatures

Single combs with a wider diameter have definitely a better energy transfer rate. The reason for that is that wider diameters have got less friction loss. But with a smaller diameter you have more combs in the same area. This has the effect that the increase of the energy transfer rate by the comb packages decreases with the rising of the diameter. In the present case the best diameter will be about 25mm.

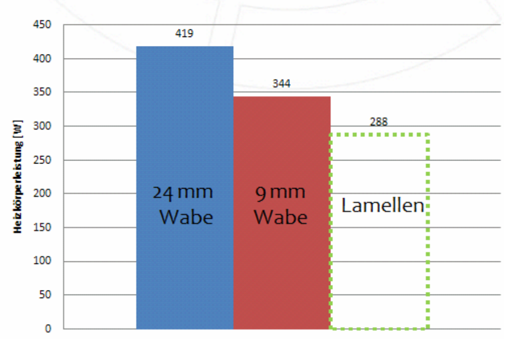

Figure 6: Comparison of the power of two different radiators with different comb diameter with a conventional radiator by the same size

The results show that radiators with different length but same heating temperature, same high and same convector plates have already the same heat transfer rate per square meter surface. But an increase of the surface thought higher convectors or more convector plate surface results that this value decreases. This effect also confirmed with literature as well.

4. Validation of the results

To validate the results an experimental rig with a common radiator was build. The Temperature profiles and air velocity at fixed places wear measured by different heating temperatures. The test arrangement was simulated with Comsol.
These data (temperature profiles, air velocity and heat transfer rate) agreed very well to the simulations and therefore we can run our simulations for further predictions.

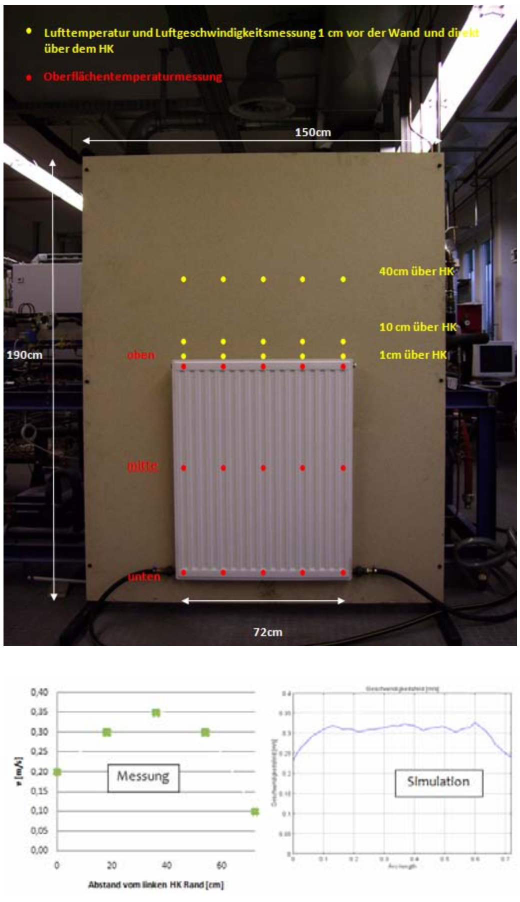

Figure 7: Experimental rig and the comparison of measured and simulated velocities of a simple radiator

5. Conclusion

During this boundary conditions and geometry settings following two effects take occur:

- The air resistance of the comb packages, which comes due to the wall friction. This has influence to the natural convection velocity due to the density variation with the heating up. A substantial factor is therefore the air velocity speed.
- The second effect results from the heat exchange. If the heat exchange surface will be increased, the air temperature at the top of the comb will proportional rise marginal. This temperature difference has medium influence to the energy transfer rate.

The simulations show us that an increased air drag is more significant as a smaller heat exchange surface for the energy transfer rate to the periphery.

6. References

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