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INVESTIGATION OF FLOW CHARACTERISTICS OF HELLER-TYPE COOLING TOWERS WITH DIFFERENT COOLING DELTA ANGLES

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Abstract

In the Heller-type dry cooling towers, the heat exchangers are arranged circumferentially at the bottom of the cooling tower. Two cooling columns constitute a cooling delta, in which the cooling columns represent two sides of a three-sided prism, and the third side of this prism is equipped with louvers in order to control the air flow through the cooling delta. The angle between the cooling columns within a cooling delta is called cooling delta angle. The cooling delta angle affects the flow pattern through the heat exchangers, and thereby influences the thermal and economic parameters of the cooling tower, too.

The aim of this article is to summarise the investigation of the flow characteristics of cooling deltas with different delta angles. The analyses are based on FLUENT 5.5, a Computational Fluid Dynamics software. Four cooling delta angles were investigated using two-dimensional computational models, and in each case the air side pressure drop was also altered in order to model cooling columns with different depths.

Keywords: dry cooling, cooling towers, CFD.

1. Introduction

In the Heller-type dry cooling towers, the heat exchangers are arranged circumferentially at the bottom of the cooling tower. Two cooling columns constitute a cooling delta, in which the cooling columns represent two sides of a three-sided prism, and the third side of this prism is equipped with louvers in order to control the air flow through the cooling delta (see *Fig. 1*).

2. Building the Geometry

The calculations were performed by FLUENT 5.5, a Computational Fluid Dynamics software. Recommendations regarding the setting up a computational model were taken from the software documentation [1]–[10]. We applied the following simplifying conditions:

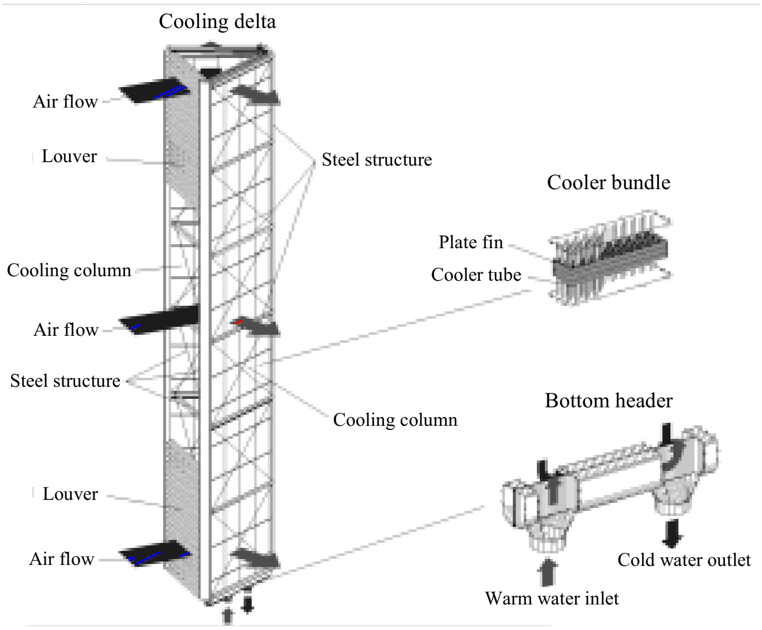

Fig. 1. Cooling delta – Forgó-type water-to-air heat exchangers

- it is enough to create a two-dimensional model, because the height of the cooling deltas is usually 15 or 20 m, so the flow parameters (pressure, velocity) can be considered as constants in the vertical direction;
- the energy equation is not solved, because we will not evaluate the temperature field;
- while the base diameter (> 100 m) of the cooling towers is much more greater than the size of cooling deltas, the cooling delta model is considered to be a part of a cooling tower with infinite base radius ($R = \infty$);
- the flow is considered to be steady.

The cooling delta geometry was built up based on plans of real projects. In the case of a certain cooling delta angle, the grid is illustrated in *Fig. 2*.

Because of the complexity of the geometry, we applied quadrilateral mesh elements and an unstructured meshing scheme near by the cooling delta during mesh generation. Farther on structured quadrilateral mesh was generated.

3. Boundary Conditions

The boundary conditions were defined as follows:

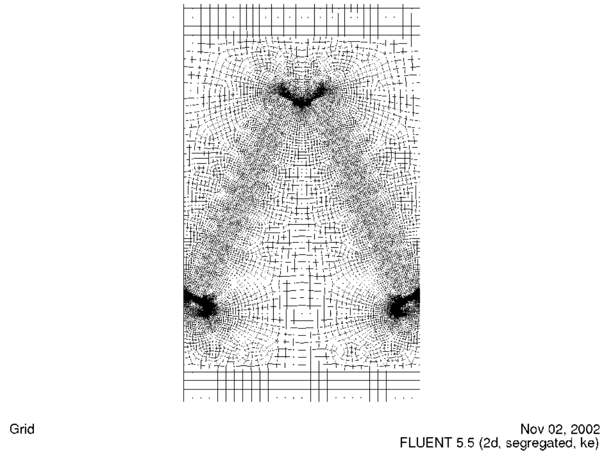

Fig. 2. Detail from the grid near by the cooling delta

- at the velocity inlet boundary we prescribed uniform velocity distribution in the direction normal to boundary, wherein the velocity magnitude was altered in cases with different cooling delta angles in order to hold a typical and constant specific air mass flow rate to the cooling columns (L_1 [t/h,m^2]);
- at wall boundaries a 0.0001m wall roughness was prescribed;
- the pressure loss of the cooling columns is modelled by porous zones, and the parameters required by FLUENT were determined according to equations derived from measurements;
- at the end of the computational model, far enough from the cooling delta, a pressure outlet boundary condition was applied;
- the flow is considered to be turbulent and the k-ε turbulence model was applied; at the velocity inlet boundary the turbulence was defined by turbulence intensity and length scale;
- the model contains only one cooling delta, and at the sidelong boundaries symmetry conditions were applied;
- the control louvers in front of the cooling delta are modelled by porous jump conditions, and their pressure loss is defined based on measurement data.

The boundary conditions are illustrated in *Figs.* 3 and 4.

4. Results

After having converged solutions for these models, we obtained the flow pattern around the cooling delta. In case of a given cooling delta angle, the contours of pressure and velocity magnitude are illustrated in *Figs.* 5 and 6, respectively.

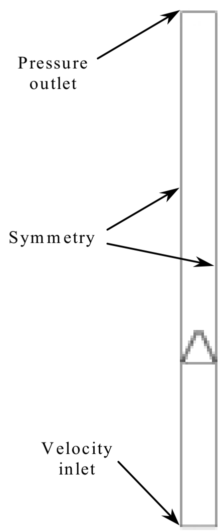

Fig. 3. Boundary conditions in the computational domain

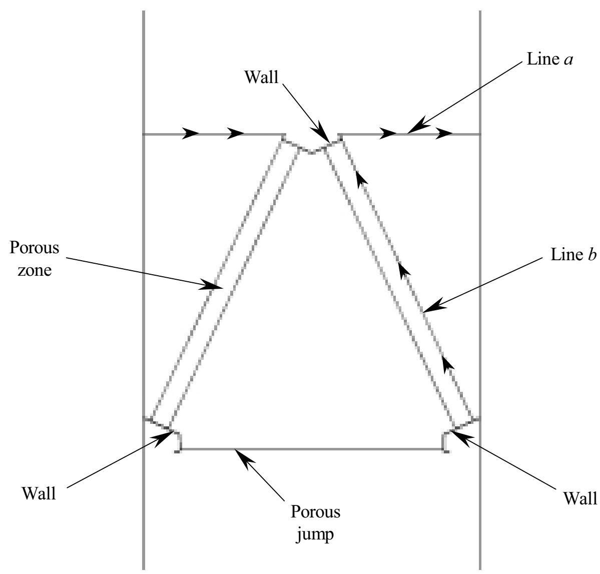

Fig. 4. Boundary conditions near by the cooling delta

During postprocessing, the calculated pressure loss of the cooling columns was in good accordance with the expected values.

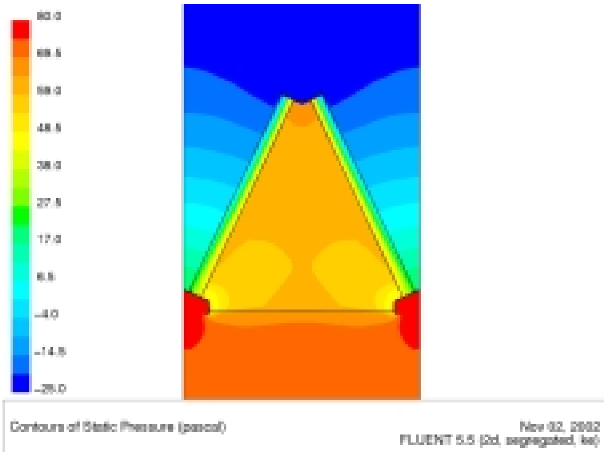

Fig. 5. Contours of static pressure near by the cooling delta, cooling delta angle = 50 °

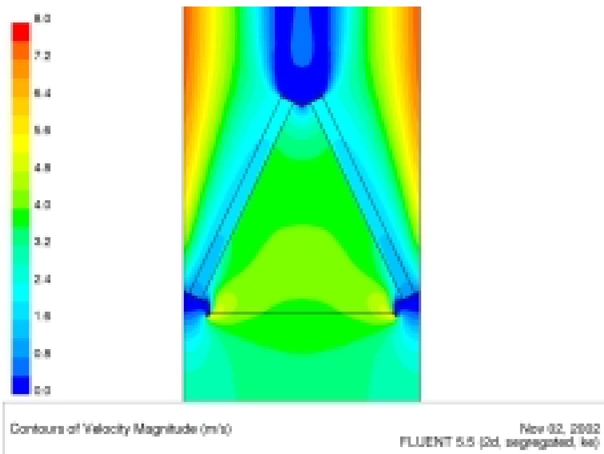

Fig. 6. Contours of velocity magnitude near by the cooling delta, cooling delta angle = 50 °

Fig. 7 shows the contours of stream function. It can be seen that the streamlines are advancing through the heat exchangers in the direction resulting in the shortest path across the finned cooling columns. The computational model of a single cooling delta is mirrored along the symmetry lines.

We have requested the following numerical reports from the program:

- along line a: distribution of velocity components normal to line a (see *Fig.4*)
- along line b: distribution of velocity components normal to line b (see *Fig.4*)

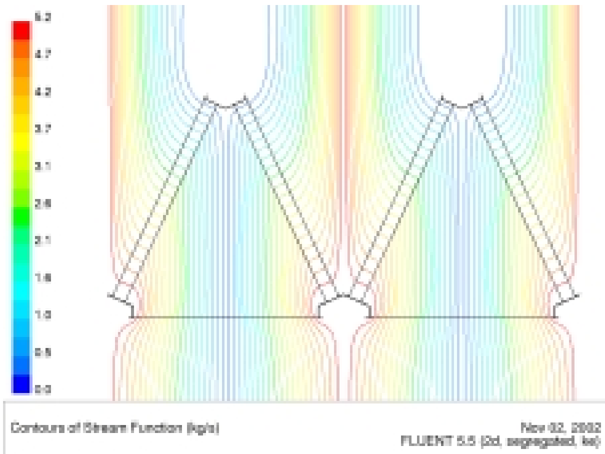

Fig. 7. Contours of stream function near by the cooling delta, cooling delta angle = 50°

These reports are shown in *Figs.* 8 and 9 for a cooling delta angle of 50°. The directions along which the values are plotted can be seen in *Fig.* 4.

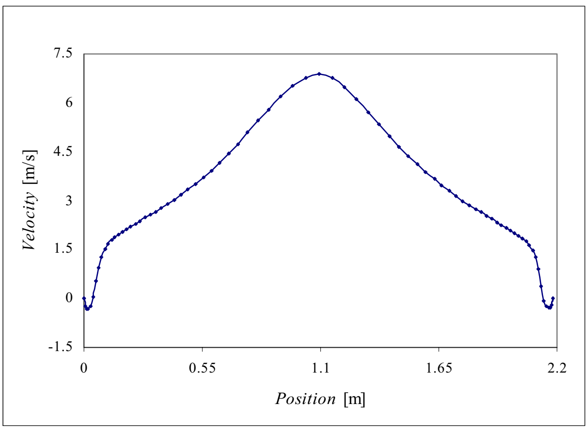

Fig. 8. Velocity distribution along line *a*, cooling delta angle = 50°

The linearised distribution in *Fig.* 9 has the following form:

$$w = C_1 \cdot \text{Position} + C_2, \tag{1}$$

where the constants C_1 and C_2 were obtained by applying the least squares method. By this linearisation, the error between the calculated flow rate using the original and the linearised velocity distribution was less than 0.5%. Let $\mathrm{d}w/\mathrm{d}s = C_1$ denote the slope of the linear approximation of the curve in *Fig.* 9, and let δ denote the

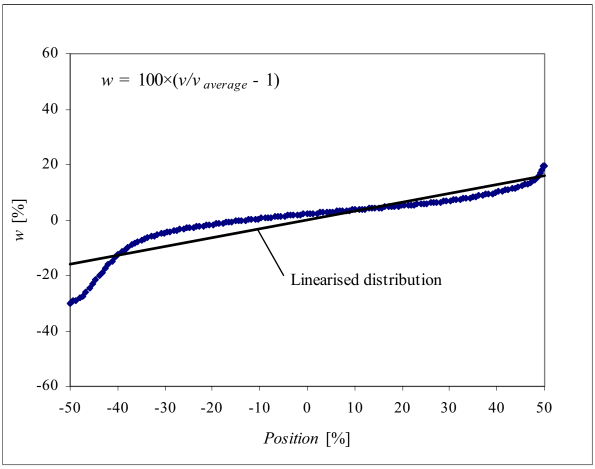

Fig. 9. Distribution of velocity components normal to line b at the outlet of the cooling column (along line b), cooling delta angle $= 50°$

cooling delta angle. The data points obtained from the investigation of four different cooling delta angles were used to derive a relationship for $\mathrm{d}w/\mathrm{d}s$ as a function of δ and the Euler number in the following form:

$$\mathrm{d}w/\mathrm{d}s = A_0 \cdot \delta^{A_1} \cdot Eu_\infty^{A_2}. \tag{2}$$

The constants A_0, A_1 and A_2 were determined by applying the least squares method. The resulting curves can be seen in *Fig. 10*.

These results can be used in further calculations, from which equations can be derived showing the effect of different cooling delta angles on the thermal, flow and economic parameters of the cooling tower. By applying the relevant optimisation criteria, an optimal cooling delta angle can be determined for different cases.

5. Conclusions

The cooling delta angle affects the flow pattern through the heat exchangers, and thereby influences the thermal and economic parameters of the cooling tower, too. In this article the investigation of the flow characteristics of cooling deltas with different delta angles is summarised. The analyses are based on FLUENT 5.5, a Computational Fluid Dynamics software. Four cooling delta angles were investigated using two-dimensional computational models, and in each case the air side pressure drop was also altered in order to model cooling columns with different depths.

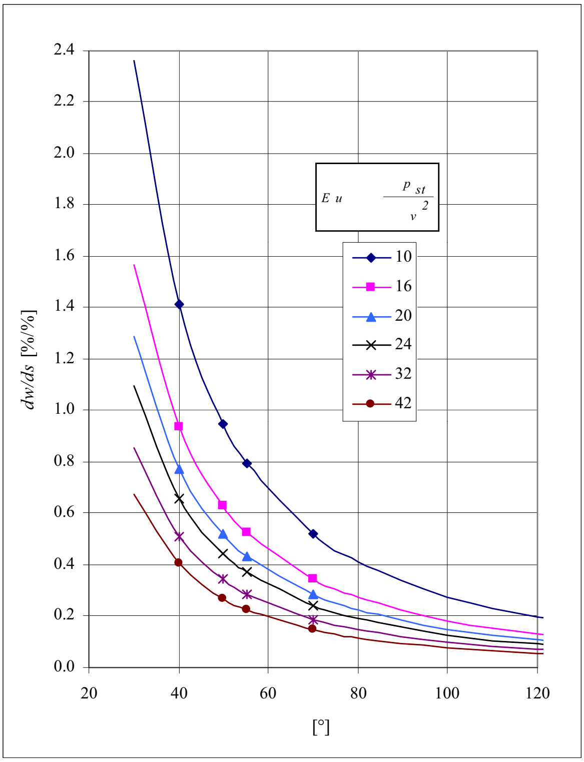

Fig. 10. Variation of $\mathrm{d}w/\mathrm{d}s$ in function of δ and the Euler number

The results can be used in further calculations, from which an optimal cooling delta angle can be determined for different projects.

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