Numerical study of the influence of ambient conditions on the mechanical cooling tower drift deposition in an urban area

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Keywords: Drift deposition, cooling tower, droplets, CFD simulation

ABSTRACT: Drift of small water droplets from mechanical draft cooling tower installations is objectionable for several reasons, mainly due to human health reasons. A computational fluid dynamics (CFD) code including Lagrangian prediction of the trajectory descent of droplets is considered to predict plume rise and surface drift deposition from mechanical draft cooling towers. The influence of psychrometric ambient conditions and wind velocity profiles on the drift is considered. CFD drift deposition calculations are performed for a specific urban mechanical draft cooling tower situation. The data registered of the plume performance and drift deposition in the experimental set-up are employed to validate the numerical results.

1 INTRODUCTION

Prediction of drift deposition is generally resolved by analytic models; however, these codes are less suitable when cooling towers are located midst taller structures and buildings. Other models based on CFD are employed for determining the drift in urban areas. Meroney (2008) developed a CFD model to simulate cooling tower plume dispersion and drift, but do not take into account evaporative phenomena. Under certain ambient conditions, this effect may be important. So, a numerical model to study the influence of psychrometric ambient conditions on cooling tower drift deposition in an urban setting is presented in this work.

The Lagrangian discrete phase model follows the Euler-Lagrange approach. The fluid phase is treated as a continuum by solving the time-averaged Navier-Stokes equations, while the dispersed phase is solved by tracking a large number of droplets through the calculated flow field. The dispersed phase can exchange momentum, mass, and energy with the fluid phase.

2 MODELING

The physical model consists of a mechanical draught cooling tower located on the roof of a building of an urban environment. It contains seven buildings with heights ranging from 9 to 21 m. The cooling tower modeled has a height of 2.6 m, 0.7 m wide and 0.5 m deep. The tower is played on the top of a building or 13 m height, 41 m width and 27 m depth. Several computational domains were created to study the influence of the domain´s boundary conditions and the grid sensibility. Finally, the selected domain dimensions were 800 m long, 800 m wide and 200 m deep whit a 1.7 millions of tetrahedral cells. Boundary conditions selected were symmetry for the roof and lateral sides, a velocity profile for the wind flow intake and outflow for the wind flow outlet. Wind velocity was set (Meyer and Jenkins 1977) to a power-law defined up to 100 m ($v = 0.3523 \cdot z^{0.6781}$), with a constant velocity of 8 m/s above 100 m.

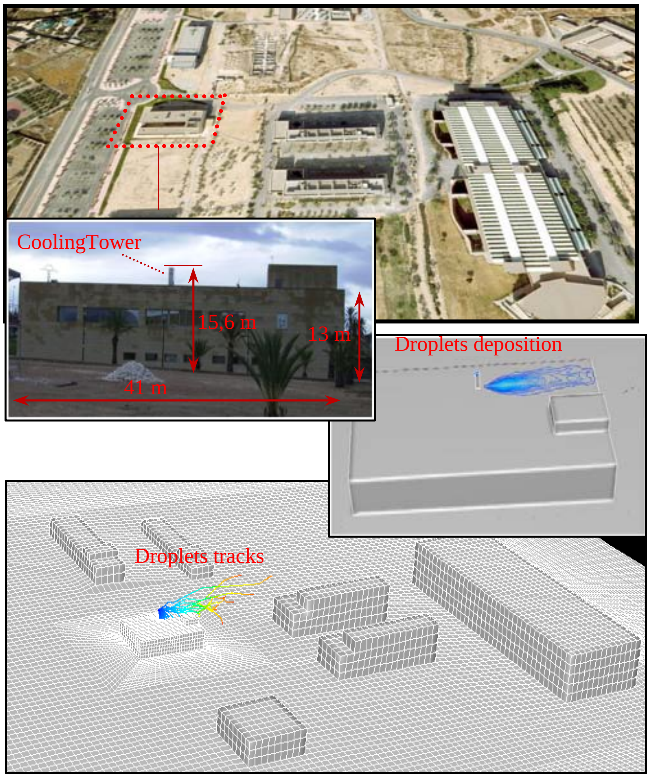

Figure 1: Map of the reference tower, situated at the University Miguel Hernandez, in Spain. Droplets tracks and predicted ground deposition around the cooling tower.

Conditions of air velocity and temperature at the cooling tower exit were set to 3.5 m/s and 315.3 K or 305 K (two levels of dry temperature), in saturated conditions. The exit water mass flow rate was set to 0.000722 kg/s. Droplet size distribution injection was defined as a Rosin-Rammler's distribution (mean diameter = $5{\cdot}10^{-5}$ m; shape factor = 0.65 and spread parameter = 10). Average profiles for the days of summer, winter and spring were selected to be included in the numerical simulation considering meteorological data for the last twenty years.

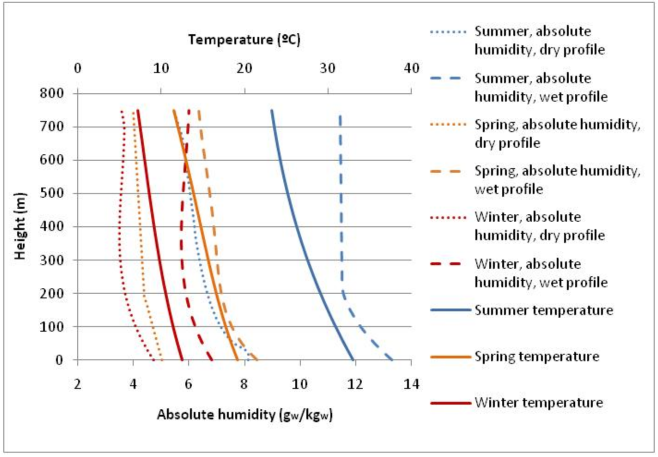

Figure 2: Ambient dry bulb temperature and absolute humidity profiles.

For the absolute humidity, two levels were selected to describe a wet and a dry average day for every season (see Figure 1).

Case	Ambient temperature level	Ambient humidity level	Exit cooling tower water temperature level	Water deposition (g/s)	Affected distance (m)
1	Winter	Wet	High (315 K)	0,1186	19,61
2	Winter	Wet	Low (305 K)	0,1142	18,75
3	Winter	Dry	High (315 K)	0,1010	17,05
4	Winter	Dry	Low (305 K)	0,1004	15,34
5	Spring	Wet	High (315 K)	0,0968	16,19
6	Spring	Wet	Low (305 K)	0,1019	15,34
7	Spring	Dry	High (315 K)	0,0819	14,48
8	Spring	Dry	Low (305 K)	0,0817	14,49
9	Summer	Wet	High (315 K)	0,0782	13,65
10	Summer	Wet	Low (305 K)	0,0787	13,63
11	Summer	Dry	High (315 K)	0,0749	13,61
12	Summer	Dry	Low (305 K)	0,0747	11,93

Table 1: Numerical cases studied. Water deposition and affected distance predicted for each case.

3 COMPUTATIONAL RESULTS AND DISCUSSION

In Figure 3 we note that when the ambient dry temperature increase (from winter to summer conditions), the deposition of water on the floor decreases. This parameter also varies depending on the absolute humidity of the atmosphere. The higher the gap of absolute humidity between saturated air on droplet surface and ambient conditions, the higher the differences of vapour partial pressures and droplet evaporation. In this way, the amount of water deposited on the floor is reduced.

Different levels of deposition were observed for different droplets temperature (low and high). The psychometric results show that the higher the temperature of the droplets, the lower the level of deposition.

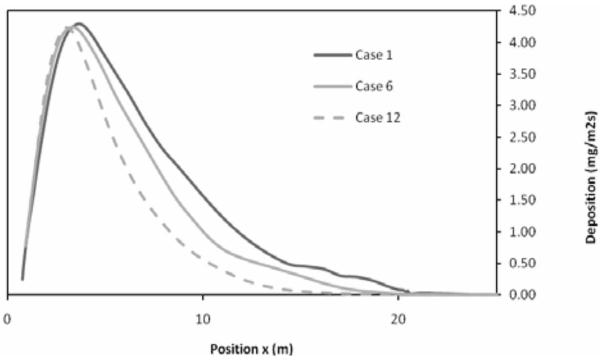

Figure 3: Predicted ground deposition results.

Another aspect considered in this study is the affected distance for each case studied. Its value is very influenced by the ambient conditions. This distance decreases if the difference between droplet temperature and ambient wet bulb temperature decreases. If we compare mechanical draft with natural draft cooling towers in terms of the water deposition/emission ratio (Figure 4), it may be appreciated great differences. The differences in the scale between both configurations cause differences in the droplets residence time and as a consequence, in the mass flow evaporated.

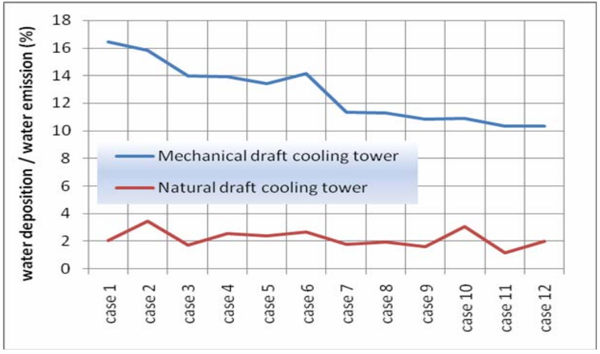

Figure 4: Ratio deposition/emission for a natural draft cooling tower and for a mechanical draft cooling tower.

4 CONCLUSION

A numerical model has been developed to predict plume rise and surface drift deposition from a mechanical draft cooling tower. The influence of ambient conditions and wind velocity on the drift has been analyzed in an urban area. The physical presence of the buildings next to the source of emission of droplets does not strongly affect to the deposition due to the low height of droplets emission and the great distance between buildings in the studied area.

5 REFERENCES

Meroney R. N. 2008, *Protocol for CFD prediction of coolinm-tower drift in an urban environment.* JWEIA, 96, 1789-1804.

Meyer J.H. and Jenkins W.R. 1977, *Cooling Tower Drift Dye Tracer Experiment Surface Weather and Ambient Profile Atmospheric Data*, JHU/APL FY 1977 Final Report.