A Study on the Effects of Wind on the Drift Loss of a Cooling Tower

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Abstract: In cooling towers heat and mass transfer between warm water and ambient air are performed. The water make-up is required in order to compensate of the water losses due to evaporation, drift loss and blow down. In this study the effects of wind on the drift loss of a cooling tower are considered. The loss involves with external effect (e.g. wind and installation location) to the intake air openings of the cooling tower is focused. Computational Fluid Dynamics (CFD) was used to investigate the aerodynamic problem of the cooling tower. The predicted flow field helps significantly to understand the flow and to improve the design of the towers especially the drift loss. The results showed strongly correspond to the field study. To minimize loss, designers have to clear what kind of modification will mostly effectively improve the flow field since the effects included a variety of secondary flows.

Keywords: Cooling tower, CFD, drift loss, flow patterns, wind effects

Introduction

Cooling towers are traditionally designed based on the exchange of heat between warm water and ambient air. That is by convection between the fine droplets of water and the surrounding air and also by evaporation which is by far the most effective factor. Therefore the process involves both heat and mass transfer.

In general required makeup water is determined from three factors. These are evaporation loss, blow down and drift loss. Evaporation loss in general is about 0.7% of circulation water. Blow down or bleed-off for water range at 5°C is about 0.3% and at 10°C is about 0.7% of circulation water. Drift loss with good drift eliminator, the loss can be lower than 0.2% of circulation water. The first factor is due to heat and mass transfer while the later is due to water quality or chemical effect. The last factor is due to internal design effect of the cooling tower. In this study the effects of wind on the drift loss of a cooling tower are considered. It is considered as the external effect because the weather and installation location of the cooling tower are the major factors to the drift loss especially at the air inlet of the tower.

Weather climate in Thailand and cooling towers installation

The transfer of heat in the cooling tower is formed the direct contact between air and water. Both sensible heat and latent heat of vaporization are used to transfer of heat to the atmosphere. For each kilogram of water that a cooling tower evaporates, it removes somewhere near 2,501 kJ's from the water that remains. The more evaporation takes place, the more heat is removed. Additional heat is taken away by the air by virtue of its temperature increase but this sensible heat exchange is minor compared to the latent component provided by the water's phase change. [1].

The weather in Thailand is high humidity and temperature with annual mean of RH = 71% and 25°C [2]. This is effect to the cooling tower performance. When RH increases more air is required to cool the same amount of heat. To ensure satisfactory year around operation, the highest anticipated values are selected. This means that structure of the tower is increased. The tower structure can obstruct the wind and effect to air flow inlet to the cooling tower opening.

The wind speed in Thailand is rather small. The wind speed and direction are shown in Fig 1. From January to May the wind blows from the south to the north at speed of 2.3-4.7 m/s. While in June to August the wind blows from the south-west to the north-east at speed of 3.4-3.5 m/s. The wind blows in opposite direction in October to December at speed of 1.9-2.4 m/s. Only in September, the wind blows eastward at the speed of 2.2 m/s [2].

Numerical simulation

Numerical studies dealing with the effects of wind flow over the cooling tower were carried out by Chumkwun et al [3]. The finite volume second order accuracy code was employed. The details about the code can be found in [3]. The present work focuses on how case study in CFD can be used to develop and reinforce understanding of complex flow physics.

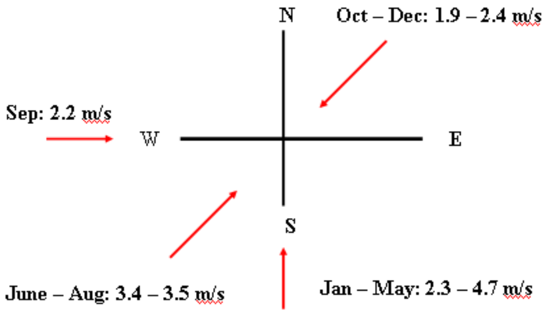


Fig 1 The wind speed and direction in Thailand [2].

The results are shown here to draw attention to some characteristics in the flow around cooling towers, as the wind speed is increased (or the Reynolds number) and its direction to the tower. A single cell cooling tower geometry used in the present work was obtained from Thai Cooling Tower Co.,Ltd [4] with height×wide×length of 2.4 m×2.4m×4.0m of fan stack diameter of 2.4m. The flow is described in a Cartesian coordinate system in which the inlet (or tower inlet air opening) rotate about the perpendicular axis; see Fig 2.

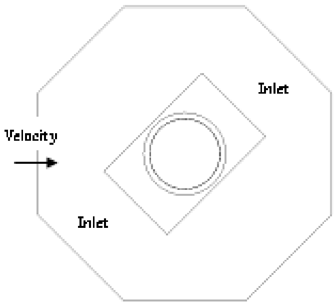
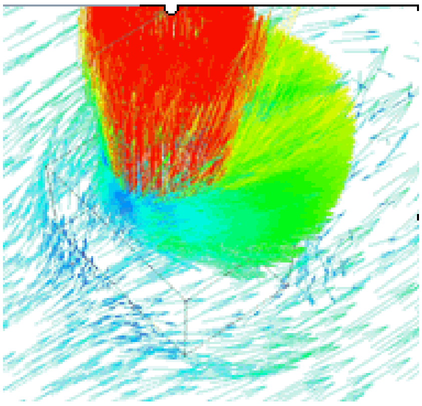


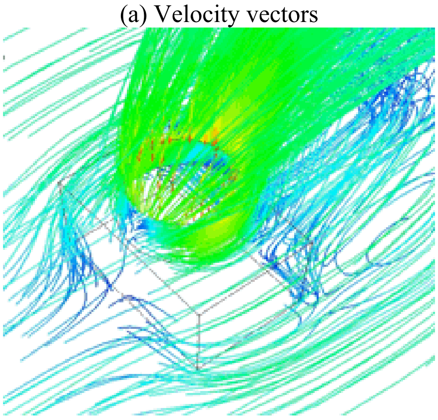
Fig 2 Flow and cooling tower configuration.

The velocity vector and streamline with wind velocity of 4 m/s and varies its' direction are shown in Fig 3 -4.

In Fig 3 when the wind is in the direction parallel to the inlet (or perpendicular to the tower's wall). The simulations indicated that streamwise vorticity is formed behind the tower. Anyhow the result shows no significant effect on the flow at the inlet opening.



(a) Velocity vectors

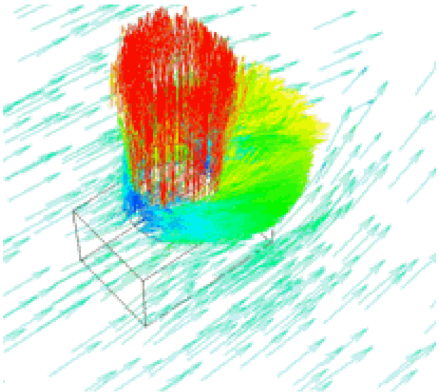


(b) Streamlines

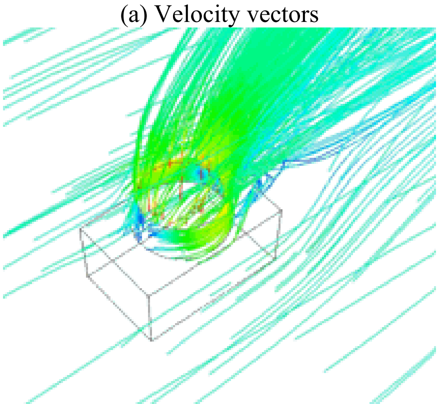
Fig 3 Flow around the cooling tower when wind direction parallel to the inlet air opening

In the case when the wind is flow toward to one of the inlet opening (or parallel to the tower's wall), the flow around the cooling tower behave differently from that show in Fig. 3. Fig. 4 both in term of vector field and streamlines are clearly visible that the outside air wind flow into the one inlet opening through the tower and flow out at the other inlet opening. Only the contour of recirculation downstream behind fan stack is observed.

If we assume that the fine droplet of water in the cooling tower can be carried away by air velocity vectors especially at the inlet openings since there is no drift eliminator. Therefore the velocity vectors at the inlet openings are indicated to the drift loss. If the velocity vectors direct outward from the opening (instead of flow inwardly) this means that the water droplet flow in that direction too. The drift loss is getting high if the velocity's magnitude is high. The result can be concluded that the effect of wind on the drift loss shows no significant when it is in the direction perpendicular to the tower's wall. On the other hand result show significant effect on the drift loss when wind is in the direction perpendicular to the tower's louver or air inlet opening. In this case it is not only that drift is high but also the tower performs poorly since retained time between water and air is decreased.



(a) Velocity vectors



(b) Streamlines

Fig 4 Flow around the cooling tower when wind flows directly to the inlet air opening

Field study

To validate the code, a set of cooling towers in one power plant is selected. The towers specification is:

Water flow rate = 11,000 m^3/hr
Water inlet temperature = 42 °C
Water outlet temperature = 32 °C
Air wet bulb temperature = 28.5 °C
Cooling capacity = 24,000 RT
Size 16.1m × 44.4m × 13.4 m

The installation plane and tower model are shown in Fig 5 and 6 respectively. The yellow lines indicate the 3-cells cooling tower and white area indicates a lawn.

The uncertainty of the measurement in the field is very large, and the flow around the tower is unstable. Therefore only the visualization is compared. The average wind velocity of 3.36 m/s flow to the north-east direction is measured in the field study.

The predicted streamline is shown in Fig. 7. Lateral vortices are formed at the right side inlet opening of the tower. Fig 8 plots the velocity vectors in the horizontal plane from 1 m – 13 m above the ground. The contour of the recirculation downstream of the tower is also clearly visible. The vortices on the right side inlet opening of the tower are clearly visible in these pictures especially at y= 5 m (middle of the inlet opening). The re-attachment is also shown at the rear of the tower. This is caused by vortices generated in the shear layer on the lateral sides of the tower.

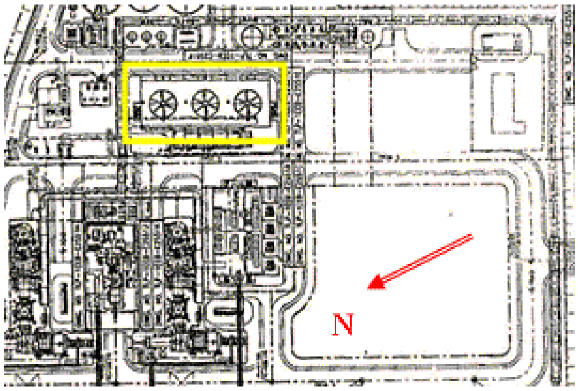


Fig 5 Installation plane of the 3 cells cooling tower

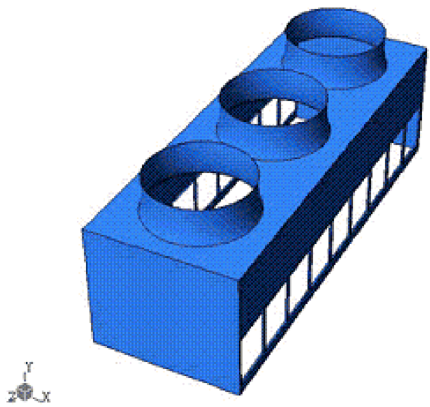


Fig. 6 Three-cell cooling tower configuration

The velocity vectors on the vertical plane (x-y plane) from front to back of the tower are shown in Fig. 9. At z = 1m (on the front wall of the tower), the stagnation point can be seen on the left hand side in the middle of the wall. The imbalance at the inlet opening is shown at z = 11 m. It should be noted that air flow toward the left opening with angle about 45° into the basin. On the right opening, the air flow outward to the atmosphere. This flow is severely of the imbalance at z =21 m. and gradually decreased near the back of the tower (z > 40 m). The outflow of air may carry moisture with it. This is drift loss. Behind the back wall of the tower (z = 51 m), the horseshoe vortex and the secondary vortex behind the wall can be noticed.

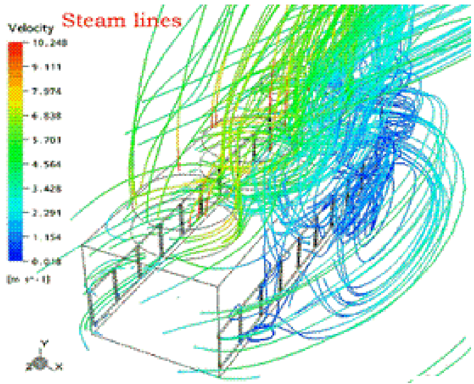
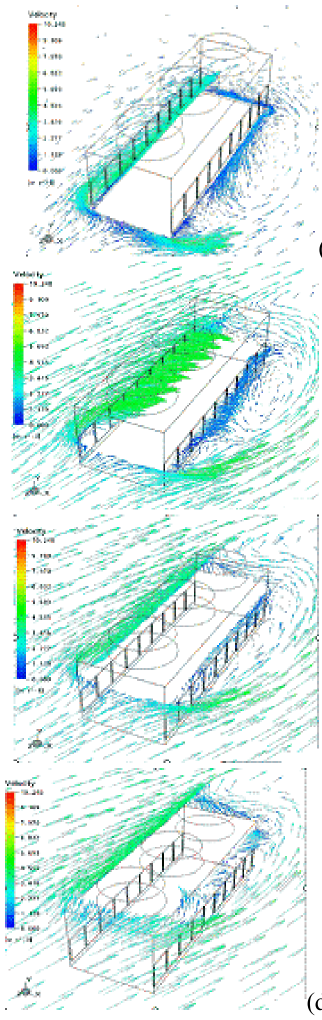


Fig. 7 Streamlines around the cooling tower



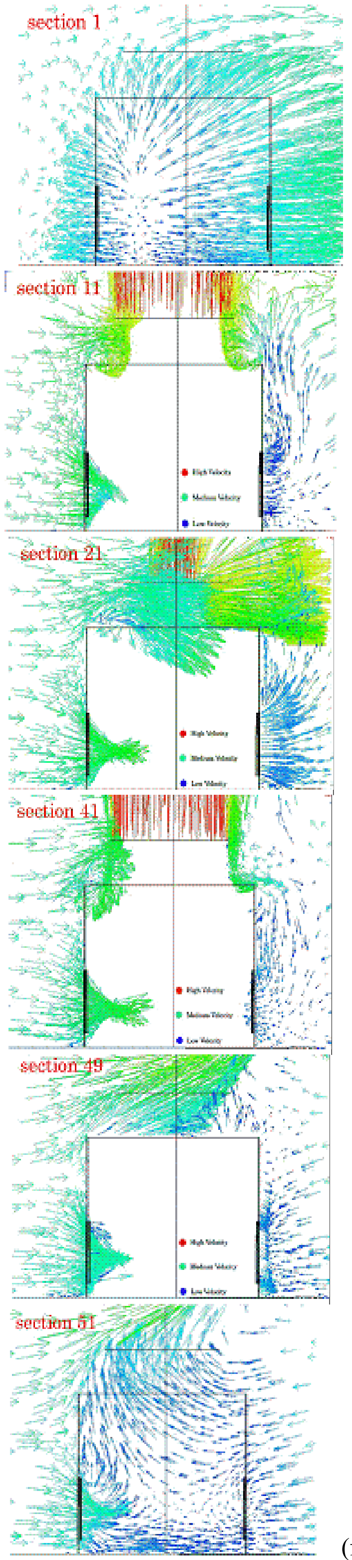
(a) y = 1 m

(b) y = 5 m

(c) y = 9 m

(d) y = 13 m

Fig. 8 Velocity vectors at various horizontal planes



(a)z = 1 m

(b) z = 11 m

(c) z = 21 m

(d) z = 41 m

(e) z = 49 m

(f) z = 51 m

Fig. 9 Velocity vectors at various vertical planes

Comparison results from field study and CFD

The picture of water droplet at the left side of the inlet opening at the front tower is shown in Fig. 10. The flow of the droplets may be used as streamtracers of the air. Comparisons of the flow pattern with predicted velocity vectors that in Fig. 9 as noted previously. Consistent with the visualization in Fig 10, as the air flow into the atmosphere in Fig 8 and 9, principally on the first front cell of the tower. The traces of the water drift loss can be noticed on the ground in the picture.

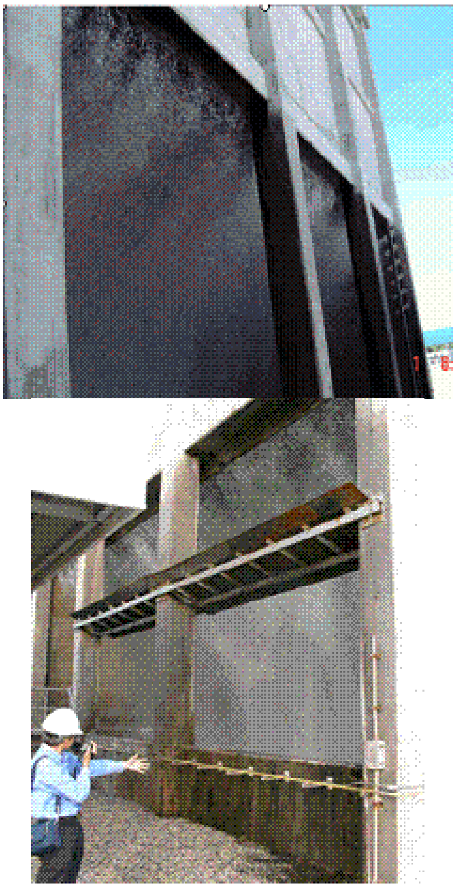


Fig 10 Pictures of the cooling tower with water droplet

Concluding Remarks

This study focused on the aerodynamic problem of the effect of wind on flow through cooling towers. It is found that diverted intake air are at the two corners which are located on windward both on left and right side openings. The flow separation and reattachment occurs on the sides aligned with the flow. The imbalance in the flow rate through the intakes is increased as the wind speed increased. These increase the drift loss of cooling towers.

In summary the apparently improvements included modified tower shape, suppression of corner separation and intake flow imbalanced. Currently work is underway to install wind walls in order to reduce the wind effects to the cooling towers.

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