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Experimental study on the effects of wind break walls on top of the natural dry draft cooling towers

A. Molavi*, M. H. Kayhani**
**Faculty of Mechanical Eng., Shahrood University of Technology, Shahrood, Iran, E-mail: amir_molavi61@yahoo.com*
***Faculty of Mechanical Eng., Shahrood University of Technology, Shahrood, Iran, E-mail: h_kayhani@shahroodut.ac.ir*

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Nomenclature

a – velocity ratio; C_p – pressure coefficient; Fr – froude number; g – gravity acceleration, m/s^2; h – height from bottom of the tower, m; H – cooling tower height, m; P_θ – perimeter pressure at pharynx of the model tower, Pa; P_∞ – pressure of the air flow on the tower, Pa; Re – Reynolds number; V_i – average velocity in the pharynx of the model tower, m/s; V_W – wind velocity above tower, m/s

Greek symbols

ρ – air flow density above tower, kg/m^3; ρ_∞ – air flow density inside tower, kg/m^3; $\Delta\rho$ – difference between air density and average air density inside tower, kg/m^3; θ – perimeter angle around tower, deg; υ – kinematic viscosity, m^2/s

1. Introduction

Cooling systems in power plants can be performed directly and indirectly by water or air with respect to outlet vapor condensation. Dry cooling towers are sometimes used in water shortage conditions and also waste of water. In areas far from rivers, lakes and other natural water sources, dry cooling towers are more important. Iran is classified as a dry climate region and so using the dry cooling towers as well as converting the wet cooling systems to dry ones are in the center of attention.

Ambient temperature and wind speed are two important factors affecting the dry cooling tower performance. These factors can have negative effects on tower performance and decreases the efficiency of the power plant significantly. The quality of the phenomenon (wind cover) interaction and the quantity of the above mentioned effects is an important field of study. Despite extensive works on the subject, no comprehensive solution is provided for this problem.

In 1976, Holder studied the various configurations of the exchangers in inlet section of the natural convection cooling towers on internal flows of the tower and the sensitivity to side winds [1]. Farell also studied the upper elements installed on parabolic cooling towers on side pressure distribution. As the upper elements installed on external side of the tower increase, negative side pressure decreases [2]. In 1983, Yoshhiro studied the wind pressure distribution in design of parabolic cooling towers [3].

In 1988, Kasperski studied the effects of wind on performance of natural convection cooling towers and evaluated the inside and outside pressure of the towers [4]. In 1992, Kroger and Preez performed some case studies in cooling towers of the Kendal power plant in south Africa and studied their results numerically using phoenics software [5].

Wei and Zheng studied the unfavorable effects of wind of efficiency of the dry cooling tower and came into conclusion that the tower efficiency decreases due to inappropriate distribution of pressure at inlet and destruction of ascending warm air bulk [6].

In 2001, Fu Song studied the inverse effect of wind on heat transfer of two tandem towers numerically and came into conclusion that cross winds destroy the radial air flow into tower [7]. Behnia and Al—Waked also recommended the use of wind break wall in the lower section of the tower to improve the performance of the towers [8].

Here, we develop a model of the dry cooling tower of the Shazand- Arak power plant and investigate the distribution of velocity and pressure in the pharynx of the tower by using wind tunnel and also we improve its performance using wind breaking walls.

2. Conditions, presumptions and modeling

Field study and experimentation on large structures such as dry cooling towers is a cost-intensive, time-consuming and sometime impractical. The researchers are compelled to make a smaller model and investigate it in a wind tunnel.

To use the test results for the main sample, it is necessary to make a geometric resemblance and kinematic between the real model and the smaller one. In order to perform this test, we need three important similarity parameters:

$$Re = \frac{V_i H}{\nu}; \tag{1}$$

$$Fr = \frac{V_i^2}{(\Delta\rho / \rho) g H}; \tag{2}$$

$$a = \frac{V_w}{V_i}. \tag{3}$$

Since in this test, a mechanical fan has been used for making internal flow and also since the outlet temperature from the tower have not remuneration on wind cover at the tower top side, there is no need for making Froude resemblance.

Study of Froude and Reynolds number shows that simultaneous installation of these two parameters in a small model is not possible. For establishing similar Froude and Reynolds in the model and the main sample, speed in Reynolds parameter should be changed inversely proportional to the model scale, while speed at Froude parameter should be changed proportional to square root of model scale. For example if the speed of exit air from tower pharynx be 1 m/s and model scale be 0.01 of main tower, in order to make this Reynolds number, V_i must be 100 m/s in the model, and velocity must be 0.1 m/s to reach that Froud number.

Reynolds number at main tower is in order of 10^7. If we want to get this Reynolds amount, the speed at pharynx of model tower should reach 1 km/s that creates a supersonic flow that is impossible to reach this speed due to our wind tunnel limitations in Shahrood University of Technology. Since the inlet air into the main tower after pass from radiator awing and fins have a complex regime, making exact Reynolds resemblance inside the model tower is not necessary and if the passing flow from model tower inside be complex one, then it has a same flow regime to main tower.

Since in this experiment we do not fallow effective forces on internal surfaces tower, the installation of such flow regime in the tower model brings us close to our goal and do to create the inside flow by a mechanical fan, passing air from tower inside is absolutely complex.

Study of Fu and Zhai at 2005 [9] has mentioned that if the Reynolds value exceeds 3×10^4 then the air flow becomes independent from Reynolds parameter which was the case in our experiment.

Just have engaged in wind effects at top side of tower and since the air enters the tower and passes through a line toward top side of tower, inside velocity profile turn out to be uniform. Each phenomenon can be analyzed individually.

3. Experimental apparatus

The experimental study has been performed in Shahrood University of technology low speed wind tunnel. The tunnel, of the open circuit type, is constructed mainly in steel. The air enters the tunnel through a carefully shaped inlet and in order to control air velocity a motor controller was used. The test section is of plexiglas giving full visibility and the various models are supported from both of the sidewalls. The test section is square shape and 80 cm wide, 80 cm high and 200 cm long and supported by a steel framework. The longitudinal free stream turbulence intensity is no greater than 2% at its lowest speed (5 m/s) and 0.5% at its highest speed (30 m/s) over its speed range, and the velocity non-uniformity in the central portion of the test section, outside the test section wall boundary layers, is no greater than 0.5%. Fig. 1 shows schematic of the tunnel and installed test object.

The free stream conditions are obtained with a Pitot-static probe, a thermocouple and a hot wire sensor which sits on a transversing mechanism. This allows the location of the hot wire to be adjusted perpendicular to the free stream flow. A micrometer on the mechanism allows for accurate position measurements. From this information, the free stream air density, viscosity, and velocity can be obtained.

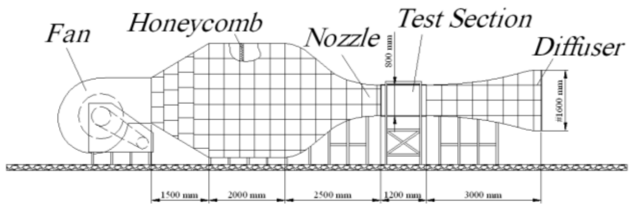

Fig. 1 A schematic of shahrood university low speed wind tunnel with installed test cylinder

Wind tunnel data are acquired with a computer (with a 2-GHz Intel Pentium 4 processor) and a PCI-6031E 16-bit high-speed data acquisition board. The system is controlled by "virtual instruments" written in the LabVIEW programming language. The signals from the all instruments are digitally sampled for a period of 20 s at a rate of 500 Hz.

For measuring velocity and pressure at cooling tower pharynx, we use a cooling tower located in Arak – Shazand power plant that its dimensions are as follows:

Tower height:	130 m
Tower down diameter:	110 m
Tower pharynx diameter:	62 m
Exchanger height:	20 m

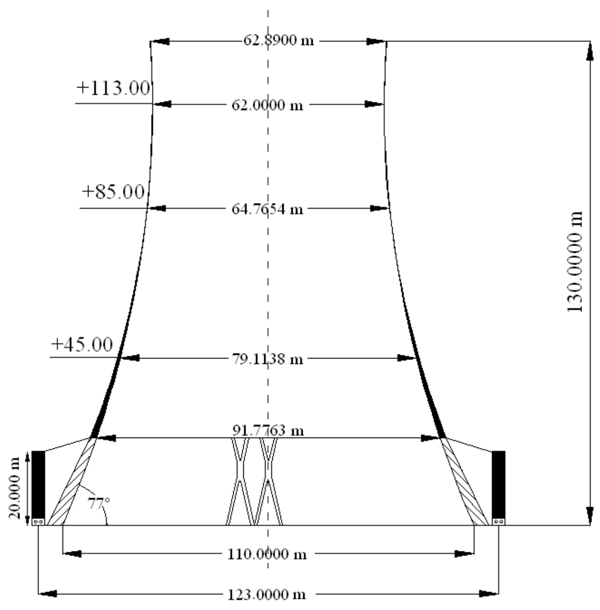

Fig. 2 Arak – Shazand power plant cooling tower

A view of the tower together with its sizes has been shown in Fig. 2. We made this model out of the earthenware matter in the scale of 1/640 compare to the actual size of the tower. We set the model on a wooden base and put it in the wind tunnel that is far from floor and walls boundary layer. By using a channel connected model tower end to a mechanical fan.

In order to study velocity distribution in pharynx, we use a one-dimensional probe. We put the probe parallel to flow direction inside the tower and opposed so that wire flow meter be perpendicular to flow, as it shown in Fig. 3. the recorded velocity by hot wire flow meter is the absolute output flow from the tower's vent. By using of transmission move mechanism, we transferred probe toward the direction of wind in the tunnel from the front vent to the back vent in the pharynx of the model. The velocity changes at the output vent in the model is negligible in direction of perpendicular diameter to wind flow and the main change occurs in direction of parallel diameter to the flow.

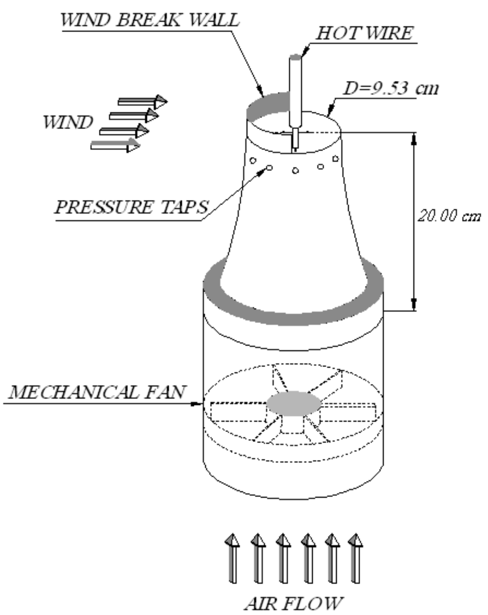

Fig. 3 Schematic of experiment arrangement

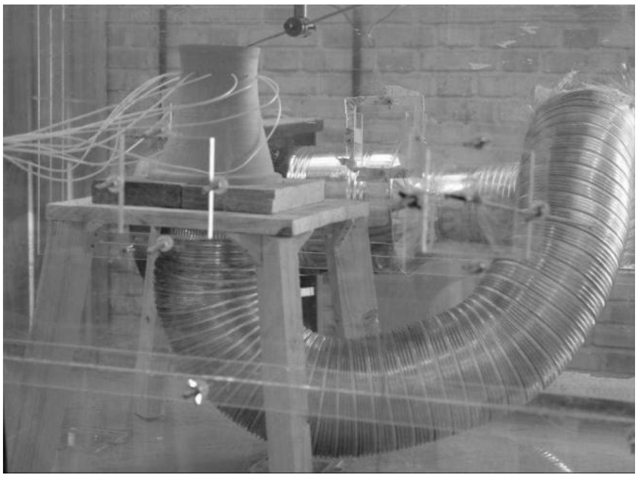

Fig. 4 A view of experiment arrangement

In order to study pressure distribution inside the tower pharynx, we used 12 pressure measuring tubes around outside area with 30° to the central line. In order to study the effect of wind break walls on dry cooling tower, we used a hemi cylindrical shape wall made out of plastic matter with height 10, 15, 20, 27 and 30 mm that stands exactly in direction of the wind flow and its shape came from arrangement of tests shown in Figs. 3 and 4.

4. Results

In this section, we present the results of our experiments. Figs. 5-12 show the velocity distribution and average pressure changes in pharynx. Also the way of mass rate flow changes against different flow velocities for different modes and shapes of different wind break walls can be seen in these figures.

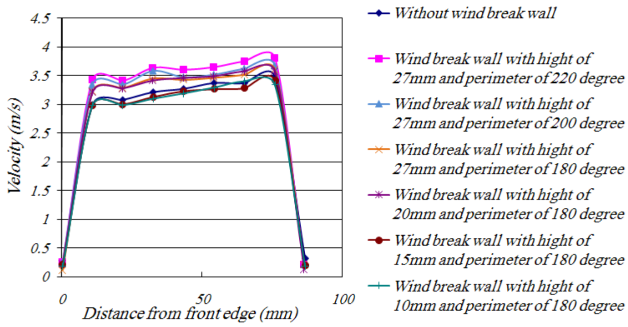

Fig. 5 Velocity distribution at pharynx of model tower influence of wind with velocity of (1 m/s) in tower outlet and using of wind break walls with various dimensions

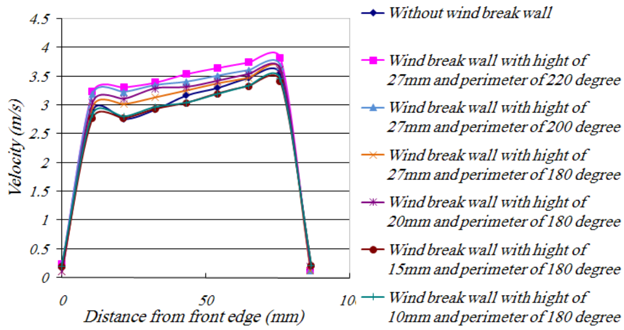

Fig. 6 Velocity distribution at pharynx of model tower influence of wind with velocity of (3 m/s) in tower outlet and using of wind break walls with various dimensions

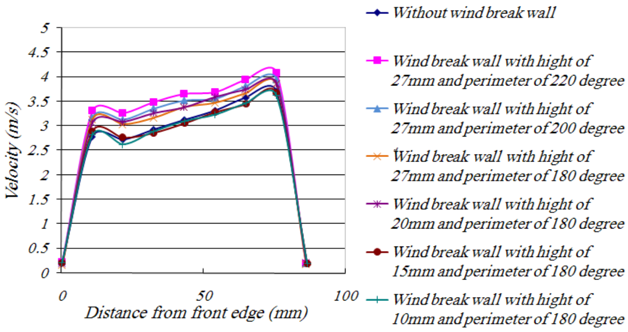

Fig. 7 Velocity distribution at pharynx of model tower influence of wind with velocity of (5 m/s) in tower outlet and using of wind break walls with various dimensions

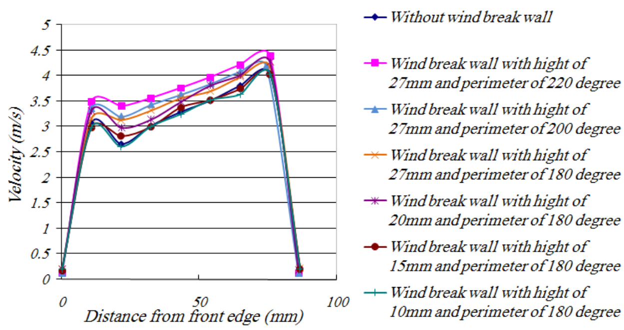

Fig. 8 Velocity distribution at pharynx of model tower influence of wind with velocity of (7 m/s) in tower outlet and using of wind break walls with various dimensions

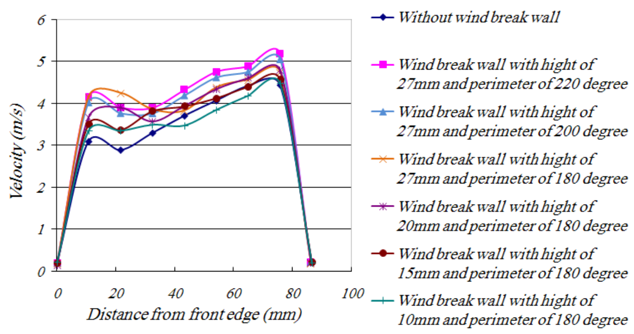

Fig. 9 Velocity distribution at pharynx of model tower influence of wind with velocity of (9 m/s) in tower outlet and using of wind break walls with various dimensions

In these figures, it can be easily seen that the wind cover has made the velocity distribution at pharynx of model tower with output uniform to non-uniform and slop. The velocity close to the front edge is decreased that can reduce exit mass flow rate of tower and destroy the output hot air. By increasing the wind flow velocity at the top side of the tower, this slope is increased.

The effects of placing wind break walls with different heights and perimeter angles are obvious in Figs. 5-9. As it can be seen, using the wind break walls decreases the wind cover and the slope of the velocity distribution.

According to our experiments and using different wind break wall heights against the wind flow, it was practically proven that the optimal height for walls for our case was about 27 mm and using walls with height smaller than 15 mm does not have specific effects on tower performance. Also we show that using the wind break wall with perimeter angle between (200°-220°) gives the best performance.

Mass rate changes passing from model tower under the effect of different wind velocity at the output vent and also applying wind break walls with different dimensions as shown in Fig. 10 show that using the wind break walls cause tower passing rate to increase. For example if we use walls with 27 mm height, the amount of mass rate crossing from tower increases by 14%. Another interesting point in this figure is that wind flow with velocity ratio up to 1.5 causes the mass rate flow to decrease in tower and exceeding this amount will cause the passing mass rate to increase.

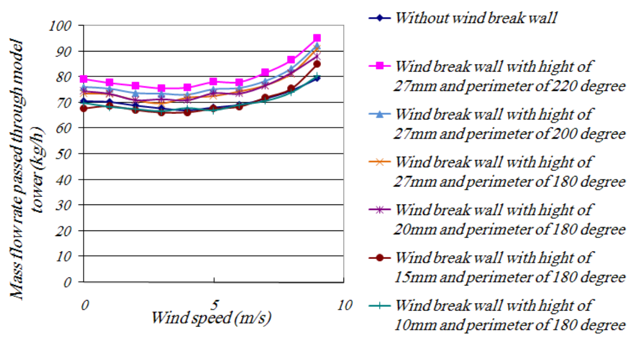

Fig. 10 Variation of mass flow rate passed through model tower versus wind speed at the tower output and using wind break walls with various dimensions

Related curves of average pressure coefficient changes in model tower pharynx versus different wind velocities at top side of the tower model, without and with wind break wall are shown in Figs. 11 and 12. These values have been computed by averaging the measured pressure coefficient in our model pharynx using manometer. Pressure coefficient is:

$$C_p(\theta,h) = (P_\theta - P_\infty)/0.5\rho_\infty Vi^2 . \quad (4)$$

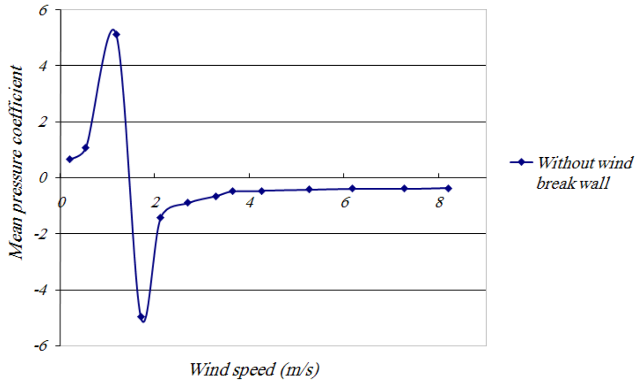

Fig. 11 Variation of mean pressure coefficient at pharynx of the model tower versus wind speed, without wind break wall

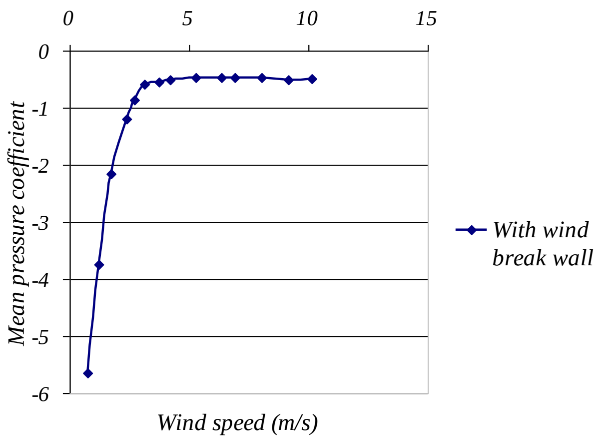

Fig. 12 Variation of mean pressure coefficient versus wind speed at pharynx, with wind break wall

As it is shown in Fig. 11, the value of the positive average pressure coefficient for a tower without wind break at small wind velocity shows that the output air velocity reduces at tower vent and causes pressure to increase while the velocity is decreased at vent is not sent about a tower with wind break wall and the wall prevents vent clogging. Increase of the wind velocity cause the pressure at tower vent is decreased at the created negative pressure cause a suction at the tower that as mentioned before has been caused the rate increase for both a tower with wind break wall and without that.

5. Conclusion

Based on the results, wind causes the passing tower rate decreases by wind cover that is because of the difference between the size of the output hot air movement from tower and the wind flow. Our experiments showed that the using the wind break walls at tower top side and versus majority wind flow causes the wind cover to decrease.

The two effective parameters in a wind break walls performance are:

1. walls height;
2. circumferential area.

The results showed that a hemi cylinder shape wall with a height about 0.135 of the main tower and with circumferential area of 220° will perfume best on decreasing the wind cover.

Acknowledgments

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A. Molavi, M.H. Kayhani

EKSPERIMENTINIS VĖJO PERTVAROS TYRIMAS NATŪRALAUS SAUSOJO AUŠINIMO BOKŠTŲ VIRŠAUS SCHEMOSE

R e z i u m ė

Natūralaus sausojo aušinimo bokštai yra vieni populiariausių elektrinėse, eksploatuojamose sauso klimato zonose. Viena iš šių bokštų problemų yra aplinkos veiksnių įtaka jų eksploatacinėms savybėms. Vėjas yra vienas iš tokių veiksnių. Jis sukuria reiškinį, vadinamą vėjo dangčiu, kuris trukdo pasišalinti išmetamosioms dujoms. Šiame darbe, naudojant aerodinaminį vamzdį ir vielinį anemometrą, tiriama vėjo įtaka bokšto srautų pasiskirstymui. Taip pat tiriama vėjo pertvara, slopinanti šį reiškinį.

A. Molavi, M.H. Kayhani

EXPERIMENTAL STUDY ON THE EFFECTS OF WIND BREAK WALLS ON TOP OF THE NATURAL DRY DRAFT COOLING TOWERS

S u m m a r y

Natural dry draft cooling towers are one of the most popular types of towers in power plants that are being used in dry climate areas. One problem with this type of tower is the impact of environmental factors on their performance. Wind is one of these factors. Wind develops a phenomenon called wind cover that prevents outgoing gasses from escaping. In this work, the effects of wind on flux and distribution of output velocity in tower outlet is studied by using wind tunnel and hot wire anemometer. Also the effects of wind break walls are studied with respect to hampering these effects.

Keywords: Natural dry draft cooling tower; Cross wind, cover effect; Wind tunnel; Hot wire anemometer; Wind break wall.

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