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Drag Force Coefficient for Various Shapes of Cooling Tower Subjected to Wind Load

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Abstract**—** Hyperbolic cooling tower is a tall structure with thin shells subjected to dead load, wind load and ground motion. In absence of ground motion, wind becomes the major factor. In this study three models with different profiles were modelled using Catia and analyzed in Ansys to find drag force and drag coefficient. The results of the models were compared with conventional hyperbolic profile cooling tower. It was found that CT – 2 (Part of the structure has hyperbolic profile and other part is parallel to the vertical axis) has less effect due to wind. The Drag Coefficient of CT – 3 is least when compared to other models but projected area is high, which leads to increase in drag force. The drag force of CT – 2 is 83.2% of conventional cooling tower. Therefore CT – 2 profile is recommended when compared to other profiles.

Keywords**—** Hyperbolic Cooling Tower, Static Pressure, Drag Force.

I. INTRODUCTION

Cooling Towers were designed amid the industrialisation of the nineteenth century through the improvement of condensers for use with the steam motor. By the mid twentieth century, propels in cooling towers were fuelled by the quickly developing electric power industry. Where there were territories of accessible land that is in the edges of the city the frameworks appeared as cooling lakes, yet in city zones they were cooling towers, they are for the most part situated on rooftop tops. Cooling towers dismiss warm through the dissipation of water in an air stream inside the cooling tower. The temperature of the air stream increments through contact with the warm water, and this air is then released. The cooled water is gathered at the base of the pinnacle. Towers are partitioned into two fundamental classifications, the first is named as regular draft cooling towers and the other one is named as mechanical draft cooling towers. Normal Draft Cooling Towers influences utilization of the stack to impact of a smokestack over the pressing to incite wind stream up through the pressing in counter-stream to the water. These are colossal structures with thin shells. Cooling towers are subjected to its self-weight and the dynamic load, for example, tremor movement and a breeze impacts.

The characteristic draft cooling tower is a vital and basic part in the warm and atomic power stations. Because of their complexities in geometry and the astounding disappointment of cooling tower at Ferry Bridge in England in 1965, and at Ardeer in Scotland in 1973, have pulled in consideration of numerous scientists all through the world. Without tremor stacking, wind constitutes the principle stacking for the outline of regular draft cooling towers.

Objective of the study

- The primary and main focus of this investigation is to study the variation in drag force of the structure due to change in the profile of the cooling tower.
- More specifically, the investigation has the following objectives:
- To study the variation in drag force coefficient for various profile.
- To identify the profile of the cooling tower which has less effect due to wind.
- To study the variation in static pressure due to change in profile.

II. LITERATURE REVIEW

G. Murali, et al., have studied on Response of Cooling Towers to Wind Loads. His paper manages the investigation of two cooling towers of 122m and 200m high over the ground level. These cooling towers have been examined for wind loads utilizing ANSYS programming by expecting fixity at the shell base. The examination has been completed utilizing 8-noded shell component. The vertical dissemination of film powers and twisting minutes along 0° and 70° meridians and the circumferential circulations at base, throat and best levels have been examined for both the cooling towers. Different diagrams were plotted like Vertical Distribution of standardized layer power and bowing minute at 0° meridian and furthermore for 70° meridian. They have presumed that these standardized bends can be utilized by the architect to assess the outline film powers and twisting minutes without doing definite limited component investigation of these hyperboloid cooling towers (Further examination is justified).

N Prashanth et al., has studied “The effect of seismic and wind loads on hyperbolic Cooling Tower of varying dimension and RCC shell thickness”. For the motivations behind examination, a genuine pinnacle from one of the warm power station was considered as the Reference Tower. They contrasted the current CT 1 and CT 2 and CT3. The measurements of CT 2 was diminished and the shell thickness was expanded. In CT 3 the general measurements was expanded and the shell thickness was diminished. The limited component investigation of the cooling towers was done utilizing ANSYS V.10. The examination has been completed utilizing 8-noded shell component. Initial fifty regular frequencies and relating modular shapes was acquired. The principal characteristic recurrence is 1.022 cycles/second. It has been inferred that CT 2 has less effect because of wind and seismic burdens i.e. by expanding the shell thickness and diminishing the general measurements the impact of wind and seismic loads on cooling tower can be decreased.

Athira C R, et al., have studied on “Linear and Nonlinear Performance Evaluation and Design of Cooling Tower at Dahej”. In their undertaking, programming displaying, examination, outline and estimation of a cooling tower was improved the situation a site in gas terminated power plant for M/S Torrent Energy at Dahej, Gujarat. They have contemplated the impact of varieties in the pinnacle stature and shell thickness. Structures were demonstrated utilizing STAAD Pro V8i and examined utilizing SAP 2000. The whole shell is isolated into limited components of measurement 0.5m × 4m. They have inferred that impact of shell stature and shell thickness, tallness apparently has the best effect on the free vibration reaction, with increment stature altogether expanding relocations. If there should arise an occurrence of shell thickness variety, it doesn't influence the best hub dislodging altogether. So we can derive that shell thickness does not have much impact in general uprooting of shell.

Tejas G. Gaikwad, et al., has studied the effect of wind loading on natural draught hyperbolic cooling tower. They have said that the basic reaction to wind is a component of the breeze (e.g., speed and turbulence), the structure, (e.g. firmness, mass, damping) and the breeze structure-communication. Current plan rehearse for cooling tower doesn't take into account dynamic burdens. The code of training demonstrated inadequate in numerous regards for the plan of cooling towers. The static breeze stack is characterized as long haul normal of the fluctuating weight on the cooling tower surface. The appropriation of the mean weight, particularly along the outline, is affected by the Reynolds number, surface harshness and wind profile. Surface unpleasantness lessens the most extreme suction in the sides of the Therefore, extra surface harshness, for example, meridional ribs is gainful. This paper inspects the impact of thickness, stature and arch of cooling tower on unique stacking. It is discovered that the time of vibration diminishes roughly straightly with expanding ebb and flow, yet at high shapes this pattern switches.

III. MODELLING

A. Dimensions of the models

Three profiles were selected including the conventional profile. After finalizing the profile, modelling was done in Catia software. The three models were names as CT – 1, CT – 2, CT – 3.

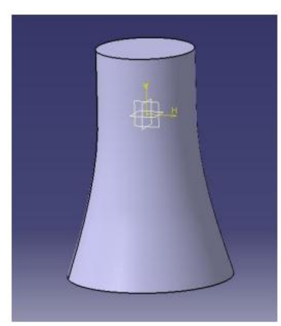
CT – 1 (Conventional)

Ht. of the tower	– 200m
Ht. of throat from bottom	– 142m
Dia. at top rim	– 97.5m
Dia. at throat	– 85.2m
Dia. at bottom rim	– 136m
Equation of the profile	$\frac{2}{1814.76}+\frac{2}{11358.07}=1$

CT – 2 (Modified)

Ht. of the tower	– 200m
Ht. of throat from bottom	– 142m
Dia. at top rim	– 85.2m
Dia. at throat	– 85.2m
Dia. at bottom rim	– 136m
From Bottom rim to throat	– Hyperbolic profile
From throat to top rim	– Straight line
Equation of the profile	$\frac{2}{1814.76}+\frac{2}{11358.07}=1$

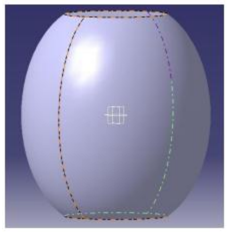
(Valid between throat and bottom rim)



CT – 3 (Modified)

Ht. of the tower – 200m
Ht. of throat from bottom – 100m
Dia. at top rim – 98.32m
Dia. at throat – 140m
Dia. at bottom rim – 98.32m

Equation of the profile $\frac{^{2}}{12100} + \frac{^{2}}{4900} = 1$



All models were created in catia with Geometric Similarity as 1:1000 and all models are undistorted models.

Wind Tunnel Dimension (Ansys)

Length – 0.6m
Width – 0.4m
Cushion at top – 0.1m
Cushion at bottom – 0m
Geometric Similarity 1:1000
Dynamic Similarity 1:1

Tetrahedron meshing was done for both Wind Tunnel and Cooling towers

Properties of the fluid

Density of Air – 1.2 Kg/m3
Laminar Flow
Boundary Conditions at inlet and outlet
Velocity of Air at inlet – 50 m/s
Relative Press. at outlet – 0 Mpa
Walls – Smooth walls
Fluid flow is constant and does not vary with height

IV. Results And Discussion

A. Static Pressure

The variation in static pressure for 50 m/s wind velocity for all three models were obtained using Ansys software package and they are given below.

Table 4.1 Max. Positive and Negative Pressure

Tower Type	Max. positive Pressure MPa	Max. Negative Pressure MPa
CT – 1	1756	2857
CT – 2	1612	2925
CT – 3	1839	3279

The maximum positive pressure is lowest for CT – 2 when compared to other two models. At the same time Max. Negative pressure is high in CT – 2 when compared to CT – 1 but it is less than CT – 3.

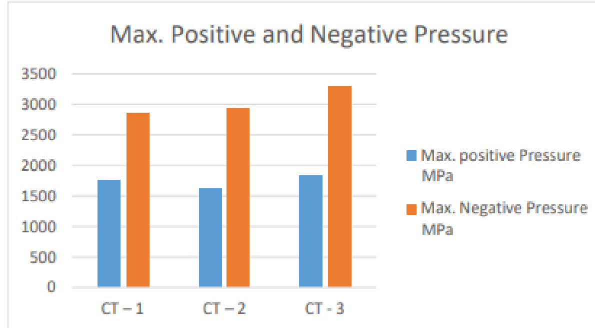


Fig. 4.1 Comparison of Max. Static Pressure

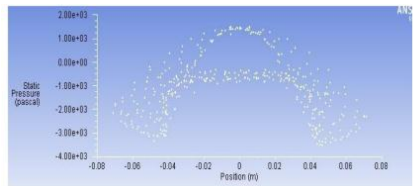


Fig.4.2 Static Pressure Graph of CT - 1

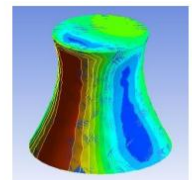


Fig.4.3 Pressure Contour CT - 1

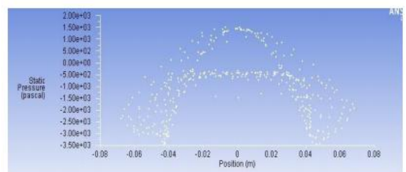


Fig. 4.4 Static Pressure Graph of CT - 2

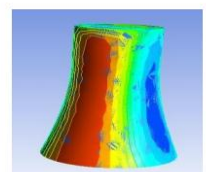


Fig. 4.5 Pressure Contour CT - 2

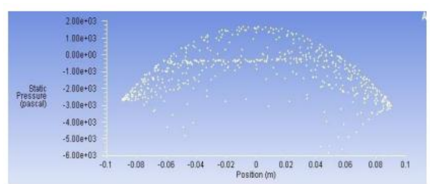


Fig.4.6 Static Pressure Graph of CT – 3

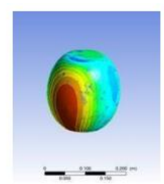


Fig.4.7 Pressure Contour CT - 3

The above graph shows the variation in static pressure with the distance along the axis, which is perpendicular to the wind direction. Pressure variation is shown for all three models and the pressure contour is also shown. Red colour indicates max. positive pressure and blue colour indicates maximum negative pressure.

B. Streamlines

Streamlines are curves that are instantaneously tangent to the velocity vector of the flow. These show the direction in which a massless fluid element will travel at any point in time. When we see the streamlines in CT – 1 we can infer that some part of wind creates backflow which increases the drag coefficient. CT – 1 has more backflow when compared to CT – 2 and CT – 3.

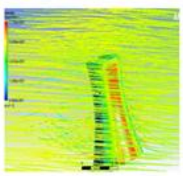


Fig.4.8 Streamlines CT – 1

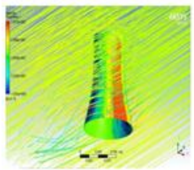


Fig.4.9 Streamlines CT –2

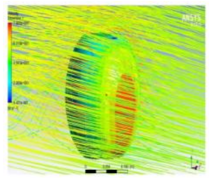


Fig.4.10 Streamlines CT –3

C. Drag Coefficient and Drag Force

Drag Coefficients were obtained from Ansys and Drag Force was calculated manually.

The below table shows the values of Projected area and Drag coefficient for different profile. The projected area given below is the projected area of the model. To get the projected area of the prototype the value can be directly multiplied with 10^6

Table 4.2 Projected Area and Drag Coefficient

Tower Type	Projected Area m^2	Drag Coefficient
CT – 1	0.02148348	0.51
CT – 2	0.019997	0.45
CT – 3	0.03261863	0.36

The below chart (Left) shows that Drag Coefficient. CT – 3 is 30% lower than CT – 1 and 20% lower than CT – 2. The Chart in right hand side of the page shows the projected area of the model, from this chart we can infer that projected area is higher for CT – 3 and Projected area of CT – 2 lies between CT – 1 and CT – 3

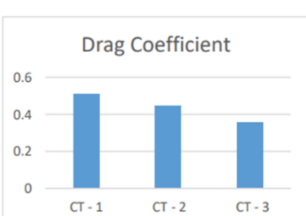


Fig.4.11 Comparison of Drag Coefficient

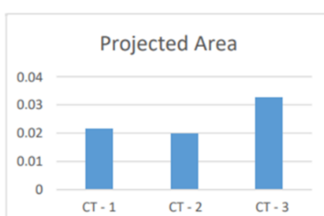


Fig.4.12 Comparison of Projected Area

V. CONCLUSION

Based on the above study, it can be concluded that

- Projected area is high for CT – 3 when compared to CT – 1 and CT – 2.
- Drag coefficient of CT – 3 is 30%lower than CT – 1 and 20% lower than CT – 2.
- Drag Force is high in CT – 3 because projected area is high.
- Drag Coefficient of CT – 2 lies between CT – 1 and CT – 3.
- Therefore, based on the derived values, CT – 2(i.e. part of the profile is hyperbolic and other part is straight line) is recommended.
- Though CT – 3 has least Drag Coefficient it is not recommended because the projected area along the wind direction is high when compared to other cases.

A. FURTHER WORK

Based on the studies carried out, the following areas have been identified for future research

1. Drag Force and Drag Coefficient should be computed for varying wind velocity i.e. velocity of the wind should not be constant throughout height of the structure
2. At the same time velocity of wind should be varied with time and results should be computed and compared with the conventional one.
3. Dynamic behaviour of cooling tower should be studied for the tower subjected to wind force which varies with time and height.

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