Design and Analysis of Cooling Tower

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***Abstract* - Cooling towers are recirculating water systems used to remove heat from building air conditioning equipment and industrial processes. The objective of current research is to investigate the effect of external air velocity on stability of cooling tower. The CAD modelling of cooling tower is developed in Creo design software and CFD analysis is conducted using ANSYS CFX software. From the fluid structure interaction study, the critical regions of cooling tower are identified where the stresses and deformation are high. The shear stress at the base of structure is observed to be maximum and needs to be further strengthened.**

Index Terms - Cooling tower, CFD, Fluid Structure Interaction.

1.INTRODUCTION

The cooling tower systems employs water for extraction of heat from system. This heat is then rejected into the atmosphere by evaporation. The cooling tower system comprises of 3 major components which are cooling tower, heat exchanger and recirculating pump.

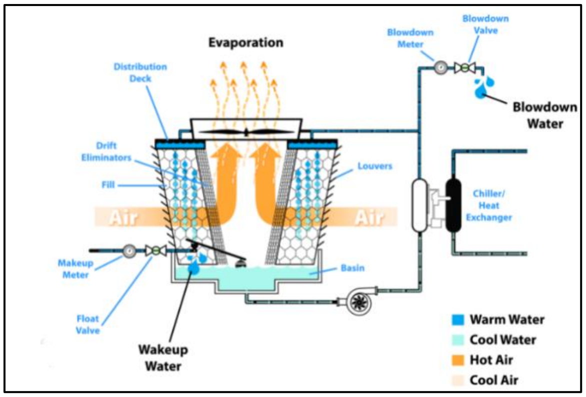

Figure 1: Schematic of cooling tower

The process schematic is shown in figure 1 above in which “the water passes through a heat exchanger where it absorbs heat which is then distributed over the top of the cooling tower where air travels past the warm water causing a portion of the water to evaporate” [8]. This heat is then transferred to air stream which increases the air temperature and its RH value. The water stream temperature reduces and is pumped back and the cycle repeats.

2. LITERATURE REVIEW

Louis et al [2] have worked on operating characteristics of fluidized bed cooling tower used for industrial water-cooling purpose. The research findings have shown that “the FBCT produces heat and mass transfer rates much higher than in conventional fixed-bed towers and concluded that water can be cooled using fluidized spherical packing in a model FBCT equipment with the view of designing a full-scale model” [2]. The size of FBCT is smaller than conventional fixed bed tower.

Seetharamu et al. [3] have worked on different configuration of packing materials used in Fluidized Bed Cooling Tower (FBCT). The research findings have shown that performance of cooling tower depends upon shapes of packing materials. The spherical shape of packing materials is not preferred for FBCT.

N. Sisupalan [4] et al. have investigated on fluidized bed cooling tower using experimental techniques. The FBCT investigated was 3 phase type and bed height for most efficient performance of FBCT is 11cm to 13cm.

Hamid Reza etl al. [5] have investigated the performance of fluidized bed cooling tower using numerical techniques involving computer simulation package. The analytical model is also presented by the author which was based on mathematical equation which could predict the volumetric mass transfer coefficient of the tower.

Ram Gopal Seth et al. [5] have investigated the forced draft dry cooling tower using experimental techniques. The small inert particles in the tower “stabilizes the fluidization of smaller particles and enhances the fluidization and heat exchange effect thereof”. [6]

Alper et. al. [7] has presented an analytical method to predict performance of cooling tower performance of using logarithmic mean enthalpy method (LMED). The results obtained from LMED method was in close agreement with experimental results. The conventional analytical methods under predicted the temperature of cooling tower and therefore its less accurate as compared to LMED.

3. OBJECTIVE

The objective of current research is to investigate the effect of external air velocity on stability of cooling tower. The CAD modelling of cooling tower is developed in Creo design software and CFD analysis is conducted using ANSYS CFX software.

4. METHODOLOGY

The CFD methodology involves 3 major steps which are preprocessing, solution and post processing. The CAD model of cooling tower is developed in Creo is converted in Para solid file format which is then imported in ANSYS design modeler as shown in figure 2 below.

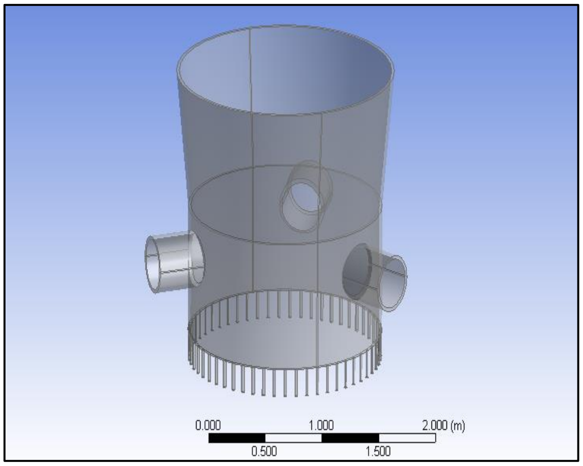

Figure 2: Imported CAD model of cooling tower

The cooling tower design is checked for geometric errors like hard edges, surface patches etc. An enclosure surrounding cooling tower is then developed as shown in figure 3.

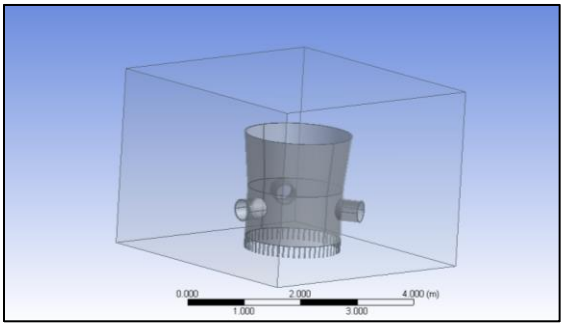

Figure 3: Enclosure model of cooling tower

The cooling tower design is discretized using tetrahedral elements. The tetrahedral elements have 4 nodes with 3 DOF/node. The smoothing is set to medium and inflation set to smooth transition. The transition ratio is set to 0.77 with maximum number of layers set to 5 and growth rate set to 1.2. The number of nodes generated is 202306 and number of elements generated is 1102325. The meshed model of computational domain is shown in figure 4 below.

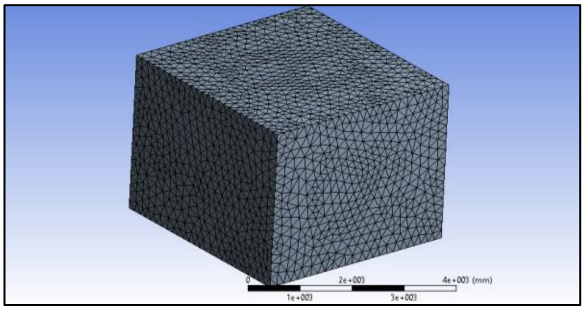

Figure 4: Meshed model of cooling tower

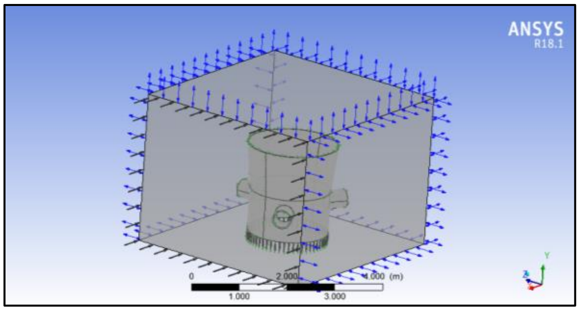

Figure 5: Boundary conditions on cooling tower

The fluid flow boundary conditions are applied on the computational domain as shown in figure 5 above. The inlet velocity of 55m/s is applied and opening type boundary condition is applied on all other face (excluding bottom) as shown in figure 6 and figure 7 respectively. The velocity value is taken from metrological data of coastal regions of India where the air flow is maximum.

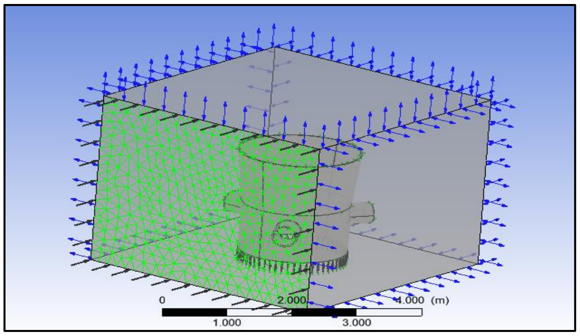

Figure 6: Velocity inlet boundary condition

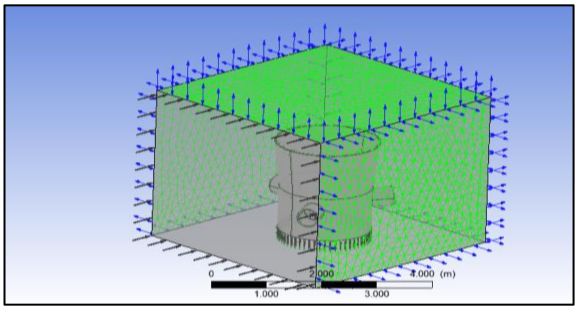

Figure 7: Outlet boundary condition

After running CFD simulation, the static structural analysis is conducted on cooling tower to determine stresses and deformation under external air flow conditions. The base of cooling tower is applied with fixed support and pressure data is imported from CFD analysis results as shown in figure 8 below.

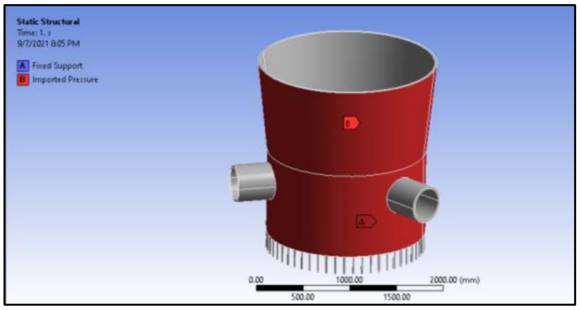

Figure 8: Static structural analysis boundary condition

The simulation is run by setting sparse matrix solver. The process involves setting of element stiffness matrices and assemblage of global stiffness matrix.

5. RESULTS AND DISCUSSION

After running CFD analysis of cooling tower, the pressure plot is generated as shown in figure 7 below. During an external air flow, the windward side of cooling tower has higher pressure generated and leeward side of cooling tower has low pressure generated.

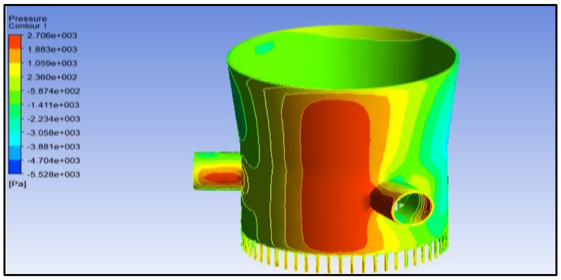

Figure 9: Pressure plot of cooling tower

The contour plot of pressure is shown in figure 9 above. The plot shows high magnitude of pressure at the windward side of cooling tower which is shown in red colored zone with magnitude of 2706Pa and it reduces on leeward side of cooling tower. The pressure on leeward side of cooling tower is below atmospheric pressure causing it to bend.

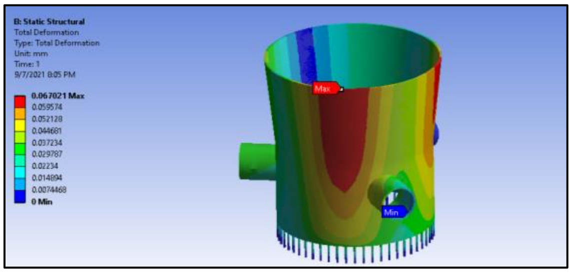

Figure 10: Deformation plot of cooling tower

The deformation plot obtained for cooling tower is shown in figure 10 above. The plot shows maximum deformation on windward side of cooling tower with magnitude of .067mm and is represented by red color. There is small magnitude of deformation observed on support bars at the bottom of tower with magnitude of nearly .03mm and is shown in light blue color.

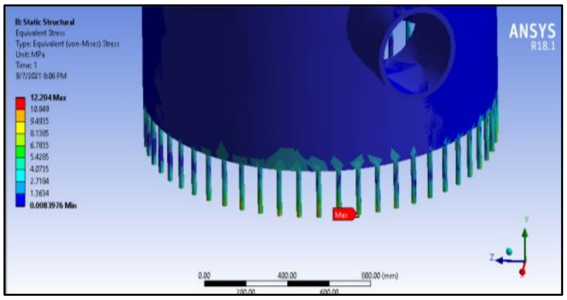

Figure 11: Equivalent stress plot of cooling tower

The equivalent stress plot and shear stress plot of cooling tower obtained from the analysis is shown in figure 11 and figure 12. The maximum equivalent stress obtained from the analysis is 12.204MPa at the bottom of cylindrical support and minimum equivalent stress is observed at the cylindrical zone of cooling tower.

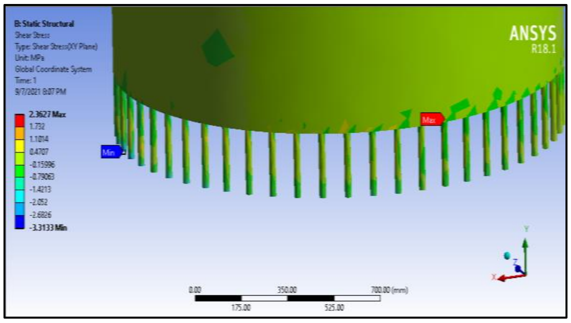

Figure 12: Shear stress plot of cooling tower

The shear stress is minimum at the bottom face of cylindrical support with magnitude of 3.31mm and other region has .04mm deformation.

6. CONCLUSION

The CFD is a viable tool in determining the structural stability of cooling tower subjected to external air velocity conditions. From the fluid structure interaction study, the critical regions of cooling tower are identified where the stresses and deformation are high. The shear stress at the base of structure is observed to be maximum and needs to be further strengthened.

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