Wind Load Analysis on High Rise Chimney using Computational Fluid Dynamics

Sarvesh Kumar [1], Dr. Sunil Kumar[2]

[1]Research Scholar, Department of Civil Engineering, HBTU Kanpur
[2]Professor, Department of Civil Engineering, HBTU Kanpur

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Abstract - *The industrial chimneys are tall structures used to remove gases and fumes boilers. These structures are used in power plants, chemical plants. The objective of this research is to investigate the effect of fluid flow across chimney. Different chimney designs and materials are investigated using CFD technique. The CAD modelling and CFD simulation is conducted using ANSYS CFX software. The critical regions of chimney which are susceptible to high stresses are determined. From the CFD analysis it is evident that the chimney mid-section region is weakest part as compared to base and top. The use of chamfered edges can significantly reduce induced pressure on chimney and is thus beneficial.*

Key Words: *Aerodynamics, chimney design, Drag force*

1.INTRODUCTION

Industrial chimneys are vertical constructions created to reduce the impact of greenhouse gases and other industry substances on its immediate surroundings. This stonework (brick), concrete, or steel structures are used to eject gases generated by industries after completing their production processes. The objective is to reduce the impact these sub-products have on the environment and on humans. Some reduce levels of pollutants while others reduce gas the temperature of the gas. A chimney is a tall, slender structure through which waste gases are discharged into the external atmosphere at a sufficiently high height through the chimney effect. Chimneys are typically vertical or as close to vertical as possible to ensure that the gases flow smoothly, under the influence of what is known as the stack effect or stack effect. The space inside the chimney is called the flue. The height of the chimney significantly affects its ability to remove flue gases to the outside environment through the chimney effect. The function of a chimney is to convey and discharge combustion or flue gases away from the operating area of the industry as well as the human occupancy. The cross section of the chimney is generally hollow circular, from aerodynamic considerations, and tapered, from considerations of structural economy and aesthetics. The chimney is subject to gust buffeting in the along-wind direction due to drag forces, and also to possible vortex shedding in the across-wind direction.

2. LITERATURE REVIEW

YOGANATHAM et. al. [1] have conducted research on RCC chimney using FEM simulation software. The research findings have shown that geometric parameter ratio has significant effect on deformation, natural frequency.

SREERATH S et. al. [2] have conducted research on design and analysis of high rise structure using IS code. The structure is also analysed under earthquake and wind loads. The lateral forces have significant effect on structure deformation and base shear. It was found that “the investigation along and across wind behaviors of the structure is needed for slenderness of the structure” [2].

LEONARDO et. al. [3] have conducted research on 9 different chimneys located at Chile. The simplified analytical method is prosed by the researcher to determine the natural frequency, lateral deformation and shear force. The chimneys were analysed by considering three effects flex ion, shear and rotational inertia. The research findings have shown that number of elements no longer influences the estimated responses.

K. ANIL et. al. [4] have conducted research on industrial chimney under seismic and dynamic loading conditions. The loading conditions included wind speed of 55m/s i.e. for zone II and zone III conditions.

M.G. SHAIKH et. al. [5] have conducted research on reinforced tall chimney made of concrete material. The wind load analysis is conducted on chimney by “peak factor” method and “gust factor” method along with random response method. The method used for seismic analysis is response spectrum. At the end the maximum value obtained in wind analysis and seismic analyses are then compared. And the designing value is decided. The effect of “wind forces is quite significant as compared to earthquake forces over 220m height RCC chimney. The geometry of chimney deflection of chimney at the top is within permissible limits” [5].

M. SHIVAJI et. al. [6] have conducted research on RCC chimney using MSC/Nastran software. The response spectrum analysis is conducted on chimney to investigate the base soil structure interaction. The structure soil coupling is investigated to determine fundamental frequency. The research findings have shown that it's better to consider soil structure interaction for seismic analysis of the structure.

Said Elias et. al. [7] have conducted research on soil structure interaction of chimney. The chimney structure has Distributed multiple tuned mass dampers (d-MTMDs) installed. They did the "Comparison for peak responses for the chimney installed with the single tuned mass damper (STMD), distributed multiple tuned mass dampers all controlling the fundamental modal responses (d-MTMDs-1), arbitrarily distributed tuned mass dampers (ad-MTMDs), and distributed tuned mass dampers (d-MTMDs) subjected to wind with different wind speeds. They found that the soil type greatly affects the design parameters of the STMD, d-MTMDs-1, ad-MTMDs, d-MTMDs, and wind response of the chimney with flexible foundation. When total mass of the TMD the d-MTMDs is consider equal d-MTMDs are more effective than the STMD, d-MTMDs-1, and ad-MTMDs" [7].

3. OBJECTIVES

The objective of this research is to investigate the effect of fluid flow across chimney. Different chimney designs and materials are investigated using CFD technique. The CAD modelling and CFD simulation is conducted using ANSYS CFX software.

4. METHODOLOGY

The methodology of wind load analysis involves applying wind load in the form of air velocity. The methodology process involves designing, simulation and post-processing stage.

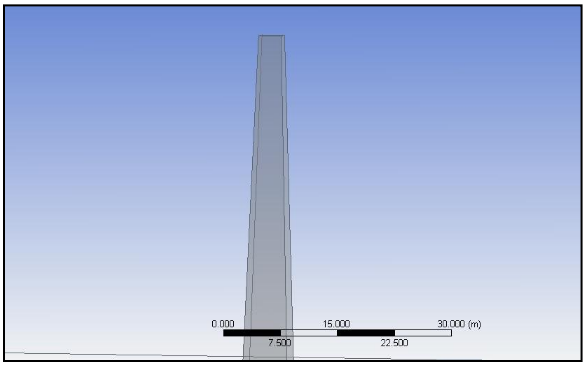

Figure 1: CAD design of chimney

The model of chimney structure is developed with specific tools in design modeller of ANSYS software. The model of chimney is enclosed with enclosure which enables to limit the computational domain. The computational domain is defined by specifying dimensions across length, width and height.

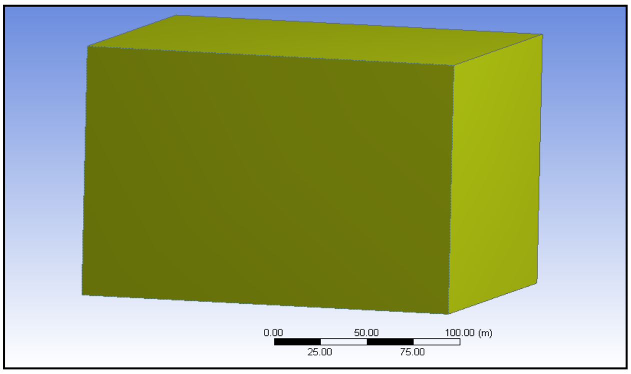

Figure 2: Enclosure modelling of chimney

The dimensions along x and z direction is taken as 100m and dimensions along y direction is 80m.

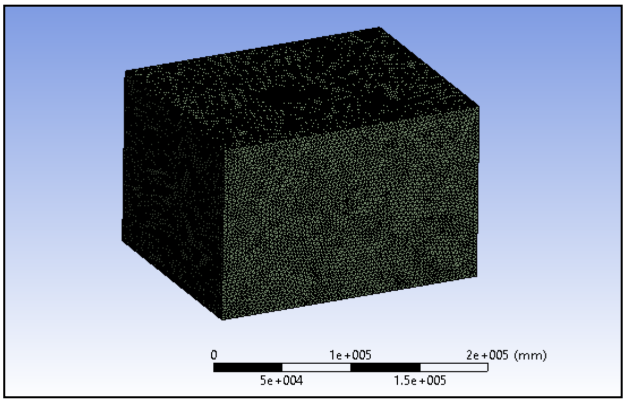

Figure 3: Meshed model of chimney

The model of computational domain is discretized. The discretization is based on geometry type, topological consistency. For meshing, the relevance is set to linear order, solver preference is set to CFX. From meshing, the number of nodes generated is 111458 and number of elements generated is 605432. The mesh settings are shown in figure 4.

Physics Preference	CFD
Solver Preference	CFX
Relevance	99
Element Order	Linear
+ Sizing	
+ Quality	
+ Inflation	
+ Advanced	

Figure 4: Meshed model of computational domain

The boundary conditions are defined for the computational domain. The domain is defined which in the reference pressure is defined as 1 atm and turbulence model is defined.

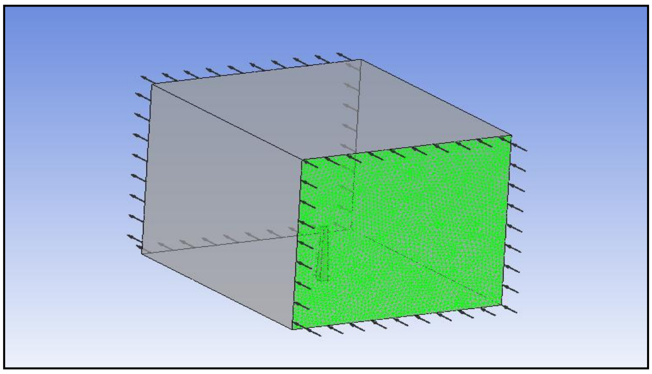

Figure 5: Inlet boundary condition

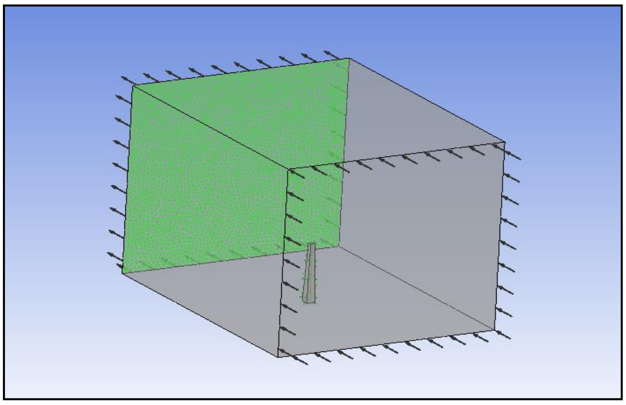

Figure 6: Outlet boundary condition

The inlet and outlet boundary conditions are defined for the computational domain. The air inlet boundary condition includes defining air inlet boundary condition and air outlet boundary condition. The outlet boundary conditions are defined which includes relative pressure difference of 0Pa. The solver settings are defined which include defining iterations.

5. RESULTS AND DISCUSSION

The results are obtained from wind load analysis of chimney using CFD technique. The velocity and pressure plots are generated for sharp edged design and chamfered edge design.

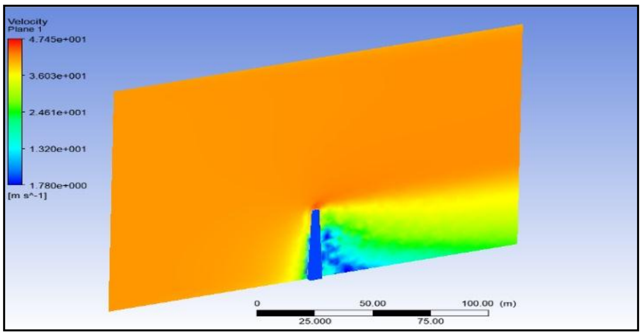

Figure 7: Velocity plot across mid-section plane (sharp edged design)

The high velocity of air is obtained for region above the chimney. The air velocity at the rear region is much low in the order of 13.2 m/s as shown in dark blue and green colored region.

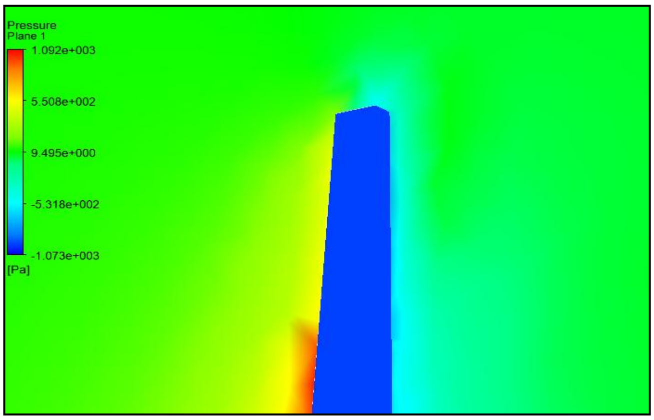

Figure 8: Pressure distribution across mid-section plane (sharp edged design)

The pressure distribution plot is obtained for chimney structure with sharp edges as shown in figure 8. The pressure magnitude on wind ward side is higher as represented by yellow and red colored region. The pressure at this region is more than 550.8Pa.

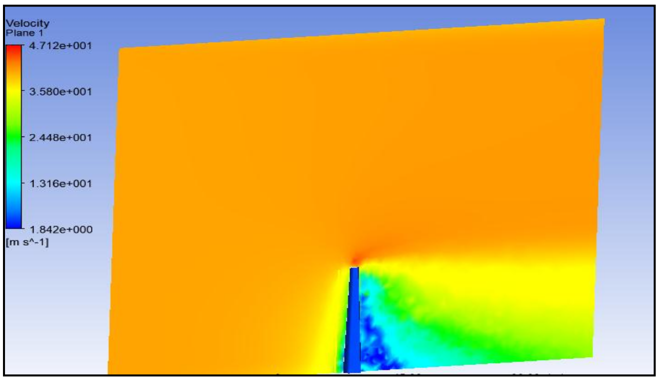

Figure 9: Velocity plot across mid-section plane (chamfered design)

The high velocity of air is obtained for region above the chimney. The air velocity at the rear region is much low in the order of 13.16 m/s as shown in dark blue and green colored region.

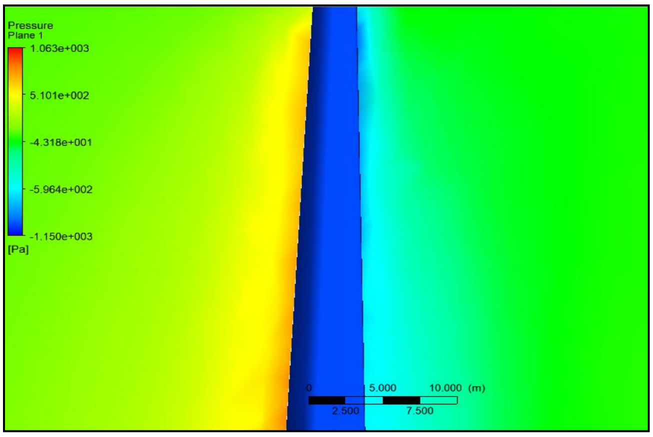

Figure 10: Pressure distribution across mid-section plane (chamfered design)

The pressure distribution plot is obtained for chimney structure with chamfered edges as shown in figure 10. The pressure magnitude on wind ward side is higher as represented by yellow and red colored region. The pressure at this region is more than 510.1Pa.

6. CONCLUSION

The wind load analysis is conducted on chimney to determine the effect of edge treatment on pressure induced and velocity profile. The critical regions of chimney which are susceptible to high stresses are determined. From the CFD analysis it is evident that the chimney mid-section region is weakest part as compared to base and top. The use of chamfered edges can significantly reduce induced pressure on chimney and is thus beneficial.

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