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Study of the stability and deformation of a RCC chimney and masonry chimney during wind turbulence using ANSYS software

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Abstract: Chimneys are tall structures used in power plants, chemical units and other manufacturing units. The chimney structures are subjected to high wind loads which may cause lateral deformation and increased base shear.
The objective of current research is to investigate the external air flow on high rise chimney structure using techniques of Computational Fluid Dynamics. The modelling and simulation of chimney is conducted using ANSYS simulation package. The fluid flow characteristics i.e. pressure, velocity and drag forces are determined from CFD analysis of chimney. The effect of wind load on chimney structure is evaluated using velocity plot, pressure plot and eddy dissipation. The regions of high pressure and velocity fields are determined from CFD analysis. The variation of pressure and velocity with respect to height is also investigated.

***Key Words**: Chimney, stability, wind load*

1. INTRODUCTION

Chimneys are a symbol of industrial growth in any country. In recent years there has been an increased demand for tall Chimneys due to setting up several large thermal power stations in the country. With increased recognition that fuel gases from large plants such as power stations must be discharged at very high elevations in order to meet the demands of air pollution control the trend is towards constructing taller Chimneys. In early 1960 a 122- metre-high chimney was considered to be very tall and nowadays many chimneys in the range of 220 M height have been built in our country. In the USA, several chimneys in the range of 380 m already exist, and this trend toward constructing taller chimneys will continue. Construction of "such tall Chimneys has been possible with the better understanding of loads acting on them and of the structural behaviour above all with the utilization of Modern construction plant equipment and techniques such as slip form. Reinforced concrete has been the most favoured material for Chimney construction since it has the advantage to resist wind load and other forces acting on them as a self-standing structure"[6].

2. LITERATURE REVIEW

Kalpesh Dhopat et al (2018)[1] have conducted FEA analysis on self-supported steel chimney using staad pro software. A total for 49 different chimney designs are analysed using (IS: 6533 part2) and IS 1893(part 4). The critical regions of high stresses and deformation are identified.

Kalagouda R Patil et al (2017)[2] have conducted FEA analysis on chimney using ANSYS and Staad Pro software. The analysis was conducted using IS codes and main objective of author was to "study the design and constructional aspects of steel stack (with particular reference to steel plant) adhering to the guidelines given in internationally accepted standards/codes"[2].

M. Pavan Kumar et al (2017)[3] have conducted FEA analysis on chimney using Staad pro simulation package. The chimney structure investigated is made of self-supporting steel structure with overall height of 90m and 110m height. The chimney was analysed for different air velocities of 39m/sec, 44msec, 49m/sec.

Nimisha Ann Sunny et al (2017)[4] have conducted analysis on building structure have piled raft foundation using ANSYS FEA v17 simulation package. The wind loads are applied on the structure and soil structure interaction on piled raft foundation system is analysed.

Rakshith B D et al (2015)[5] have conducted wind load analysis of chimney using Staad Pro software as per Indian codal provisions. Two different designs are investigated i.e. with and without manhole. The effect of chimney design parameters on wind loads is evaluated.

3. OBJECTIVE

The objective of current research is to investigate the external air flow on high rise chimney structure using techniques of Computational Fluid Dynamics. The modelling and simulation of chimney is conducted using ANSYS simulation package. The fluid flow characteristics i.e. pressure, velocity and drag forces are determined from CFD analysis of chimney.

4. METHODOLOGY

The design of chimney is developed using sketch and extrude tool of CAD design package. The model is then converted in parasolid file format and imported in ANSYS design modeller. The design of chimney is shown in figure 1 below.

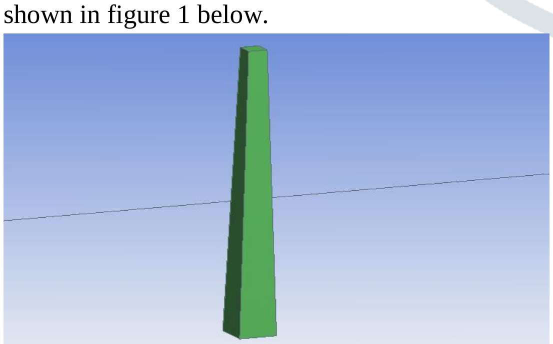

Figure 1: Design of chimney

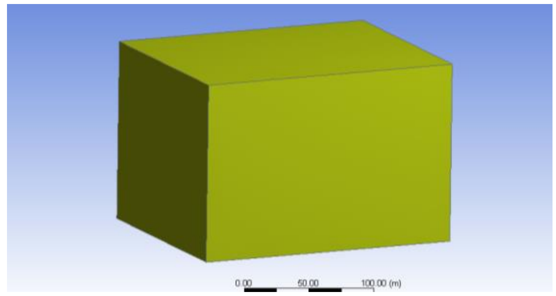

Figure 2: Enclosure modelling

The enclosure is generated after modelling of chimney. The enclosure is modelled with 80m*100m*80m as shown in figure 2 above.

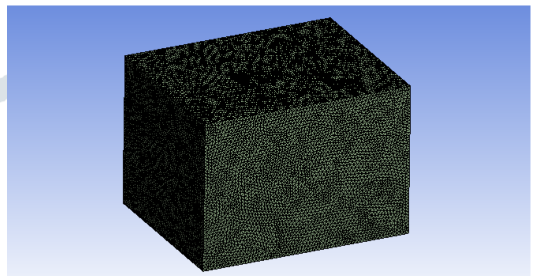

Figure 3: Meshed model of enclosure

The model of enclosure is discretized using tetrahedral element type and fine sizing with adaptive shape function. The number of elements generated is 605410 and number of nodes generated is 111461. The boundary conditions are defined with domain definition, air inlet and air outlet boundary condition. The fluid domain is defined with air as material and solid domain is defined. The air inlet condition defined is 42m/s and air outlet boundary condition is defined with relative pressure difference set to 0.

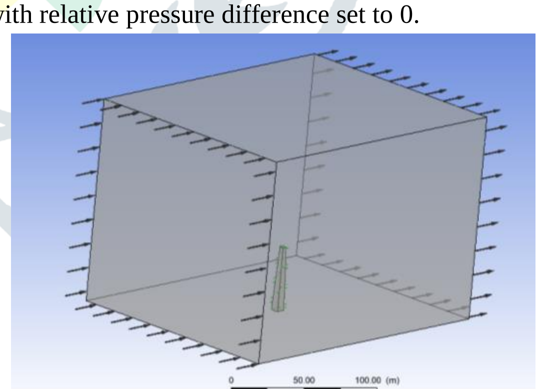

Figure 4: Loads and boundary conditions

The convergence criteria and RMS residual values are set for simulation. The simulation is run using sparse matrix solver type. The solver is run and multiple iterations are carried out to reach convergence.

5. RESULTS AND DISCUSSION

The numerical analysis is conducted on chimney using techniques of CFD. The velocity plot, pressure plot is generated for straight chimney. The velocity plot is higher at the topmost region of chimney. The velocity at this zone is more than 45.42m/s and velocity at the rear end of chimney is less than 12.28m/s as shown in blue colour.

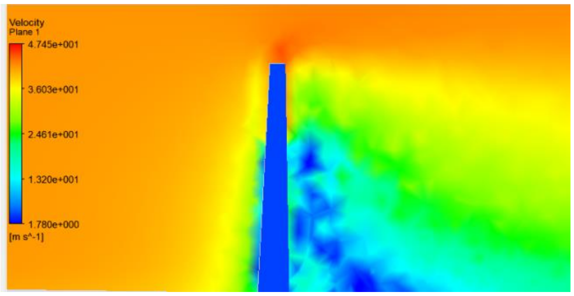

Figure 5: Velocity field across chimney

The pressure field is evaluated across mid-section plane as shown in figure 6 below. The pressure field is maximum at the bottom half region of chimney with magnitude of more than 1072Pa and represented in red colored region and rear side of chimney has lower pressure with magnitude of 531.8Pa. The difference of this pressure causes deformation of chimney across windward direction.

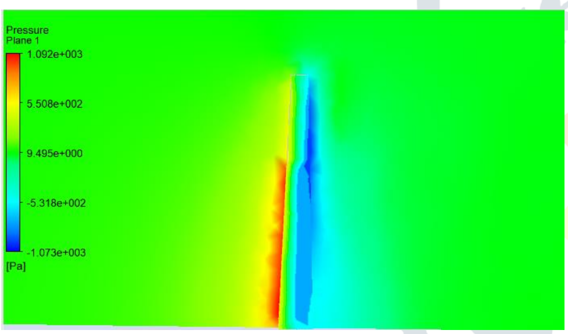

Figure 6: Pressure field across chimney

The variation of velocity with respect to height is shown in table 1 below. The air velocity increases linearly with height upto 5.582m and then increases exponentially and reaches to maximum value at height of 44.978m.

Table 1: Velocity vs height

Velocity [m s^-1]	Z [m]
9.43429089	0.658
29.9780197	5.582
31.7350616	10.507
32.9146118	15.431
33.616127	20.356
34.9938545	25.280
36.6470985	30.204
38.3698616	35.129
39.3834648	40.053
40.9726791	44.978

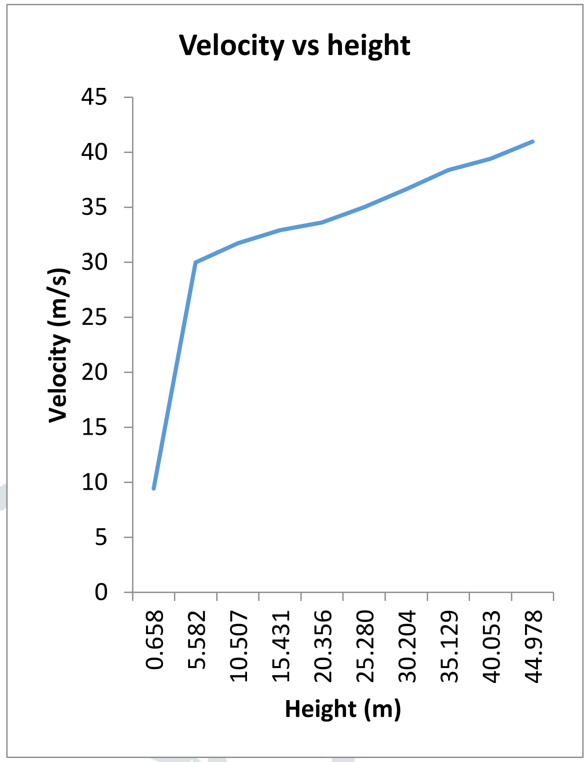

Figure 7: Velocity vs height for chimney

Table 2: Pressure vs height

Pressure [Pa]	Z [m]
498.8	0.66
533.9	5.58
490.3	10.51
433.7	15.43
408.1	20.36
341.8	25.28
251.9	30.20
201.1	35.13
151.5	40.05
76.2	44.98

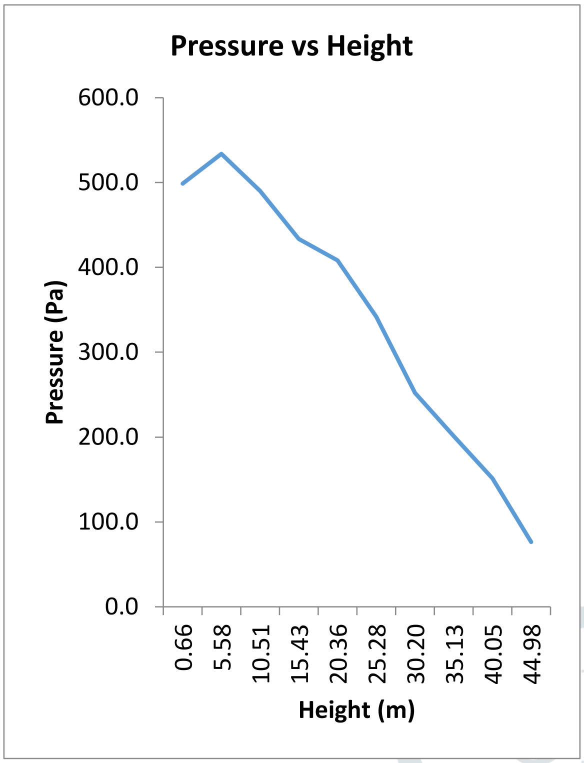

Figure 8: Pressure vs height for chimney

The variation of pressure with respect to height of chimney is determined from CFD analysis and is shown in table 2 and figure 8 above. The pressure increased slightly with height of chimney upto 5.58m and then decreases linearly and reaches to minimum value at 44.98m.

6. CONCLUSION

The use of computational fluid dynamics can significantly reduce time and cost in evaluation of chimney structure subjected to external air flow conditions. The effect of wind load on chimney structure is evaluated using velocity plot, pressure plot and eddy dissipation. The regions of high pressure and velocity fields are determined from CFD analysis. The variation of pressure and velocity with respect to height is also investigated.

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