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Design and Analysis of Cold Rolling Mill Fume Exhaust System

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ABSTRACT: Slender structure exposed to wind may experience large static and dynamic load. The mean part of the response, usually in the along wind direction, is linked with the mean wind velocity, the fluctuating part of the response is caused by the joint action of the oncoming wind turbulence and of the vortex wake. The former produces motion amplitudes, depending mainly on the wind velocity. The bottom portion is the essential element of cross-wind vibrations and constitutes a complex physical phenomenon, especially when it degenerates into lock-in conditions. Large vibration may occur at moderate and frequent wind velocities, structures may undergo a great number of stress cycles that lead to damage accumulation and may determine structural failure without exceeding the ultimate limit states. Design and analysis of cold rolling mill fume exhaust system like chimney has been carried out with the help of finite element methods. Modeling and finite element analysis is to be done with the help of FEA software SOLIDWORKS. Model analysis of fume exhaust system shows the maximum and minimum stress point and deformation point respectively. This project work covers wind load acting on the fume exhaust system and their effect on the foundation.

KEYWORDS: Cold rolling mill fume exhaust system, static and dynamic load, wind load, stress and deflection, Foundation loads.

I. INTRODUCTION

Cold rolling mill produces significant levels of oil mist/liquid particulate, visible emissions, and/or volatile organic compound (VOC) emissions. Emissions occur as a result of coolant evaporation inside mill, and vary by coolant type and quantity used. Mills are required to reduce emissions of any or all of these contaminants to meet regulations. Fume exhaust system is an appliance which is used to capture hazardous chemical vapors, gases, dusts, mists and metal fumes in a work process. Fume exhaust system help remove or lower human exposure to hazardous fumes. A fundamental safety and industrial hygiene principle is to manage exposure to hazards with engineering and administrative controls before implementing personal protective equipment. Primary specification for chimney as: Top diameter 2.36m, Bottom diameter 3.2m, Basic wind speed 47 m/sec and various parameter for Cold Rolling Mill Fume Exhaust System is given below in figure [1].

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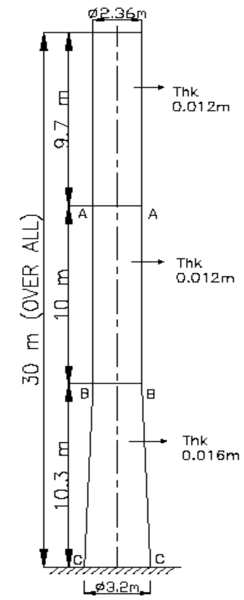

Fig. 1: fume exhaust system chimney.

II. GOVERNING EQUATIONS

1. Importance factor/Topography factor

   $K_1 = 1$ (For Normal occupancy, public or private buildings),

   (Reference: ASCE-7-98 Chapter 6.2, Category selection: II, Class selection: 'B')

2. Scale effect factors/probability factor

   $K_3 = 1$ (for heights up to 50 meters)

3. Velocity pressure explosure coefficient

   $K_2 = 2.5\,(4.6/Z_9)^{2/\alpha}$ for $Z < 4.6$ m, Z = Height and

   $K_2 = 2.5\,(Z/Z_9)^{2/\alpha}$ for $4.6 < Z < Z_9$

   (For Urban and suburban areas, wooded areas, other terrain with numerous closely spaced obstructions having size of single families, dwelling or larger)

   $\alpha = 7.0$, Z_9 (m) = 36, External pressure coefficient (C') = 0.7

   (For the structural element and components of the lateral force resisting structure systems)

4. $V_Z = V_b \times K_1 \times K_2 \times K_3$ (m/sec), V_Z = Velocity of wind with coefficient,
5. $P_Z = 0.6 \times (V_Z)^2$ (N/m^2) , Pressure of wind
6. $P'_Z = C \times P_Z$ (N/m^2), P'_Z = Pressure of wind with coefficient
7. Self weight = $(\pi \times d \times t \times 78.5) \times h \times 1.1$

   $P_d = P'_Z / 9.81$ (Kg/m^2) , P_d = Design pressure

   Force = $P_d \times d \times h$ (Kg)
8. Effective thickness = total thickness – 3 mm (corrosion)
9. Mass = $(\pi \times d \times t \times 78.5) \times h \times 1.1 \times 100$ (kg)
10. M/EI where $E = 2.1 \times 10^{11}$ Pa, $I = \pi R^3 t$, M=Moment
11. Deduced acceleration:

    $\eta_{ij} = (\Psi_{ij}\, \Sigma\, (\Psi_k * P_{S+k} * M_k))/(\Sigma\, \Psi^2_{ik} \times M_{ik})$

    $= \Psi_{ij} \times 39.29$

    Ψ_k = 'X'= Height constant factor, M_k = Mass constant factor, P_{S+k} = Force correspond to design pressure
12. $f = (1/2\pi) \times (g \times \Sigma\, MX)^{1/2} / (\Sigma\, MX^2)$, f= frequency
13. T' =1/f, T= time period

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14. $P_{dyn} = 46.068 \times M_j \times \Psi_{ij}$, $P_{dyn} = 46.068 \times M \times$ 'X', P_{dyn} = dynamic force.
15. Net allowable stress (σ) = Allowable Stress x Corrosion temp.
16. Thickness required (t) = $4M/\pi d^2\sigma$
17. Max. Compression/ meter of circumference = $4M/\pi d^2 + W_S/\pi d$ where W_S = self weight

III. EXPERIMENTAL ANALYSIS

By considering the specification of chimney of cold rolling mill, mentioned above and preformed for estimation of various parameter i.e. static wind loads at different height of chimney, Self weight of the chimney at different section, moment at different section, mass properties, time period, lateral force and bending moment, allowable stresses & thickness. The following results are shown in the forms of tables below, from **table [1-9]**.

Table 1: Calculation of static wind loads (Basic wind properties at different height of chimney)

S. N.	Height Z (m)	Basic wind speed V_b (m/s)	K_1	K_2	K_3	VZ (m/s)	PZ (N/m^2)	C'	P'Z (N/m^2)
1	10.3	47	1	0.901	1	42.347	1075.961	0.7	753.173
2	20.3	47	1	1.094	1	51.418	1586.286	0.7	1110.4
3	30	47	1	1.223	1	57.481	1982.439	0.7	1387.707

Table 2: Self weight of the chimney at different section

Section	Self weight in kN
A-A	74.521
B-B	76.8255
C-C	143.0683
Total self weight	295.4069

Table 3: Calculation of moment at sections (Moment at different section of chimney)

S. N.	Section	Avg. dia.(m)	Pd (Kg/m^2)	Force (kg)	Height at middle of section (m)	Shear at section (kg)	Moment at section (kg-m)
1	A-A	2.36	76.776	1757.556	25.15	1757.556	8524.146
2	B-B	2.36	113.19	2671.2841	15.3	4428.84	48243.9071
3	C-C	3.2	141.458	4662.4696	5.15	9091.309	158784.028

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Table 4: Calculation of mass properties at different section of chimney

Section	Mass M(Kg)	I (m^4)	Moment (Kg-m)	M/EI	'X' at mid height	M x X	M x X^2
A-A (0.007 thk)	5589.075	0.046	27107.01	5.79×10^{-6}, 5.79×10^{-6}	0.008	44.713	0.358
B-B (0.0090 thk)	5761.912	0.046	111807.3	5.96×10^{-6}, 1.64×10^{-6}	0.008	46.095	0.369
C-C (0.013 thk)	11624.299	0.167	288587.6	3.31×10^{-6}	0.001	11.624	0.0116
Total						102.432	0.739

Table 5: Calculation for time period

Zone (a)	Mass(kg) (b)	Ψ_k ='X' at mid point (c)	P_{S+k} = force (kg)(d)	M_k (table 6) IS:6533 (e)	$\Psi_k * P_{S+k} * M_k$ (c x d x e)	Ψ^2_k x M_k (c^2 x b)
1	5589.075	0.008	1757.556	0.65	9.139	0.358
2	5761.912	0.008	2671.2841	0.75	16.028	0.369
3	11624.299	0.001	4662.4696	0.83	3.869	0.012
Total					29.036	0.739

Table 6: Calculation of lateral force and bending moment

Zone	Mass (kg)	$\Psi_j = \Psi_k$ =X	P_{dyn}	Height (m)	Shear (kg)	Moment (kg-m)
1	5589.075	0.008	2059.54	25.15	2059.84	9990.224
2	5761.912	0.008	2123.504	15.30	4183.344	22991.41
3	11624.299	0.001	535.494	5.15	4718.84	140112.165

Table 7: Calculation of total lateral force and bending moment

Level(m)	Static wind		Dynamic wind		Total	
	Shear (kg) a	Bending (kg-m) b	Shear (kg) c	Bending (kg-m)d	Shear (kg) a+c	Bending (kg-m) b+d
20.3-30	1757.556	8524.146	2059.84	9990.224	3817.396	18514.37
10.3-20.3	2671.2841	48243.9071	4183.344	22991.41	8612.184	71235.317
0-10.3	4662.4696	158784.028	4718.84	140112.165	13810.149	298896.193

Table 8: Calculation of allowable stresses

Level(m)	h_e(m)	D(m)	h_e/D	T(m)	D/T	Allowable Stress (kg/cm^2) IS: 6533	Corrosion temp. IS: 6533	Net allowable stress (σ)(kg/cm^2)
20.3-30	9.7	2.36	4.11	0.012	196.67	870	0.75	652.5
10.3-20.3	10	2.36	4.2	0.012	196.67	990	0.67	663.3
0-10.3	10.3	3.20	0.01	0.016	200	1390	764.5	764.5

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Table 9: Calculation of thickness (t)

Height level(m)	Diameter (m)	Moment (kg-m)	Required t (mm)	Corrosion allowance(mm)	Total t (mm)	Assumed thickness(mm)
20.3-30	2.36	18514.37	0.649	3	3.649	12
10.3-20.3	2.36	71235.317	2.455	3	5.455	12
0-10.3	3.20	98896.193	4.861	3	7.861	16

IV. MODEL ANALYSIS OF FUME EXHAUST SYSTEM

1. Introduction

Purpose of model analysis in this study is to find out the point at which we get maximum and minimum stress and deformation respectively because of wind velocity. Show in figure 2: (i).

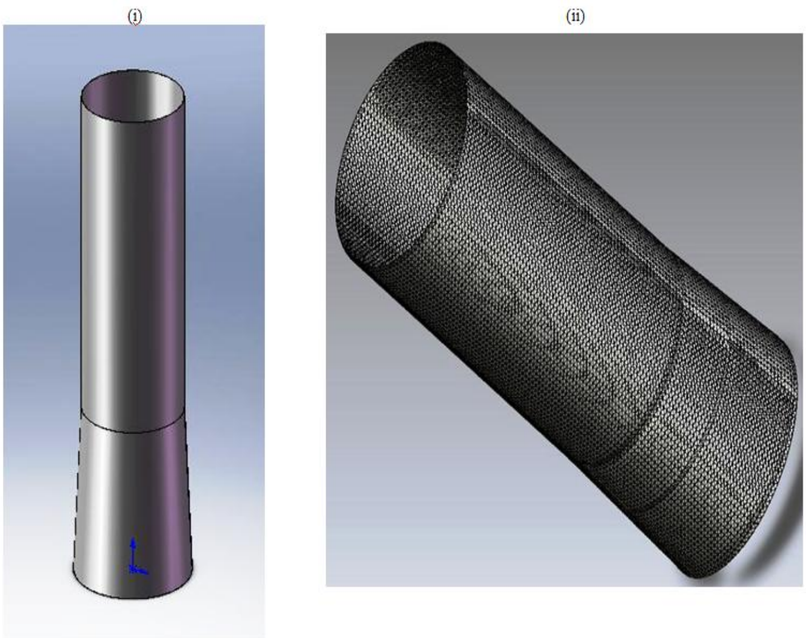

Fig. 2: (i) 3D model of fume exhaust system, (ii) Meshing using tetrahedral element

2. Material property

Each element type had a unique number that defines the element category. In the present work, a structural solid (10 nodded tetrahedral element) was taken.

3. Material name: Alloy Steel
4. Description:

No.	Part Name	Material	Mass	Volume
1	FES	Alloy Steel	55502.5 kg	7.20812 m^3

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5. Material Model Type: Linear Elastic Isotropic and Load & Restraint Information shown in table 10 to 11.

Table 10: Material data input for model analysis

Property Name	Value	Units
Elastic modulus	2.1×10^{11}	N/m^2
Poisson's ratio	0.28	NA
Shear modulus	7.9×10^{10}	N/m^2
Mass density	7700	kg/m^3
Tensile strength	7.2383×10^{8}	N/m^2
Yield strength	6.2042×10^{8}	N/m^2
Thermal expansion coefficient	1.3×10^{-5}	Per Kelvin
Thermal conductivity	50	W/(m.K)
Specific heat	460	J/(kg.K)

Table 11: Load & Restraint Information

Load & Restraint	
Restraint 1	On 1 Face(s) immovable (no translation).
Description:	Bottom of chimney.
Load 1	on 1 Face(s) apply force -1.381e+005 N normal to reference plane with respect to selected reference Right Plane using uniform distribution
Description:	First portion of chimney (0-10.3m)
Load 2	on 1 Face(s) apply force -86122 N normal to reference plane with respect to selected reference Right Plane using uniform distribution
Description:	Second portion of chimney (10.3-20.3m)
Load 3	on 1 Face(s) apply force -38174 N normal to reference plane with respect to selected reference Right Plane using uniform distribution
Description:	Third portion of chimney (20.3-30m)

6. Meshing

Figure [2] (ii) and Table 12 shows the Finite Element meshing, which is the process used to "fill" the solid model with nodes and elements, i.e., to create the FEA model. Remember, you need nodes and elements for the finite element

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solution, not just the solid model. The Solid Model in CAD does not participate in the finite element solution.

Table 12: Mesh Information

Mesh Type:	Solid mesh
Mesher Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Jacobian Check:	4 Points
Element Size:	193.16 mm
Tolerance:	9.6579 mm
Quality:	High
Number of elements:	87889
Number of nodes:	175485
Time to complete mesh(hh;mm;ss):	00:20:46

Table 13: Stress results

Name	Type	Min	Location	Max	Location
Plot1	VON: von Mises stress	417.462N/m^2	(-90.959 mm, 30000 mm, 2778.51 mm)	5.02907×10^6 N/m^2	(-3166.94 mm, 381.481 mm, 97.5722 mm)

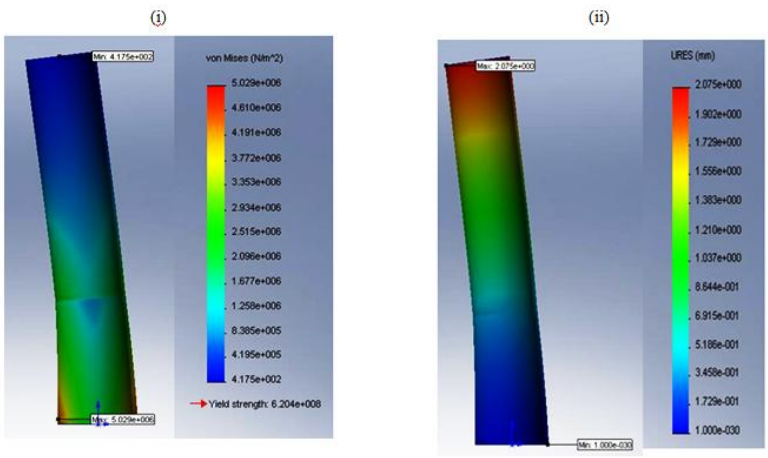

Fig. 4: (i) Stress Distribution & (ii) Deformation Diagram

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Table 14: Deformation/ Displacement results

Name	Type	Min	Location	Max	Location
Plot2	URES: Resultant displacement	0 mm	(-2757.42 mm, -1.95937e-015 mm, 1592 mm)	2.07457 mm	(-2779.6 mm, 30000 mm, 46.9534 mm)

V. CONCLUSION

The Fume exhaust system is a one of the most important units of cold rolling mill. Calculation shows that total thickness is less than the assumed thickness. So we can conclude that our design analysis of chimney for static and dynamic load is safe. Model analysis of chimney shows the maximum and minimum stress point and deformation point respectively shown in figure [3&4] and table 13 & 14. The maximum stress at a point satisfies the allowable bearing stress on concrete foundation.

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