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A CFD Analysis of Smoke Movement in Steel Industry Sheds

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ABSTRACT: *The problem has taken from a steel making industry which is situated at Wardha, Nagpur. There is a furnace in the shed where smoke is generated and some smoke is passed through the duct and removed by the blower, situated at the base of the chimney but remaining smoke is moving inside the furnace. Due to this, the workers in the shed were not working properly or even they could not see towards each other. A model similarly with the physical shed has designed by work bench. This model mainly covers the analysis of smoke movement, distribution of shed temperature, pressure, and calculation of mass flow and capacity of blower. Results predicted by the model are compared with the experimental results by NPFA charts.*

Keywords: *Ansys Fluent, CFD, NPFA chart, Smoke movement.*

I. INTRODUCTION

Smoke may be simply defined as a cloud of well mixed gases and unburnt solid particles which are a product of combustion. Smoke generation is greatly influenced by the amount and type of fuel and the air available for combustion.

Smoke control techniques are used to manage smoke movement in buildings and to direct smoke away from escape routes. Smoke control can involve passive and/ or active means to modify and direct the passage of smoke to minimize its harmful effects on occupants and property.

The amount of smoke generated can be estimated by NFPA 92B as

m =0.071K (2/3) Q (1/3) Z (5/3) + 0.0018Qr

Where m= mass flow rate of smoke at height z, kg/sec
K=wall factor
Q=heat release of fire, kW
Z=height of smoke
Qr =convective heat release rate of fire, kw =0.7Q

II. DEFINATION OF PROBLEM.

The problem has taken from a steel making industry which is situated at Wardha, Nagpur. There is a furnace in the shed where smoke is generated and some smoke is passed through the duct and removed by the blower, situated at the base of the chimney but remaining smoke is moving inside the furnace. As a result after few hours, there are huge amount of smokes, moving inside the shed. Due to this, the workers in the shed were not working properly or even they could not see towards each other.

Now my aim is to modify and direct the passage of smoke to minimize its harmful effects on occupants and property. Before analyzing, I have assumed various parameters such as

Geometry has considered in 2dimensional.
The furnace is located at the middle of the shed
Smoke distributions has been considered to be 2dimensional in nature
There is no effect of wind on the shed.

III. PROBLEM FORMULATION

The problem is formulated in two parts. In the first part, the smoke movement in the shed was analyzed by CFD approach. In the second part of problem formulation, the capacity of induced blower is calculated.

IV. CFD MODELLING

4.1 Introduction:

Based on control volume method, 2-D analysis of smoke movement inside the shed is done on fluent software

4.2 Geometry part:

The geometry of the model is done using workbench.

Specification of shed-

Width (B):40m
Height (H):30m

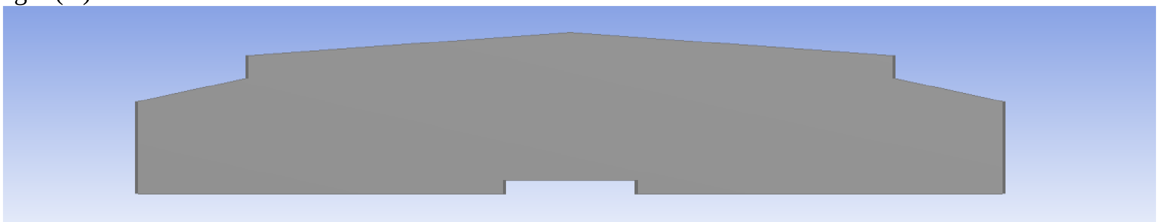

Figure4.1 Geometry of the model in workbench

4.3Meshing part

The geometry is modeled in workbench and the mesh is fine meshed to cope-up the thermal and velocity boundary layer formation as shown in figure.

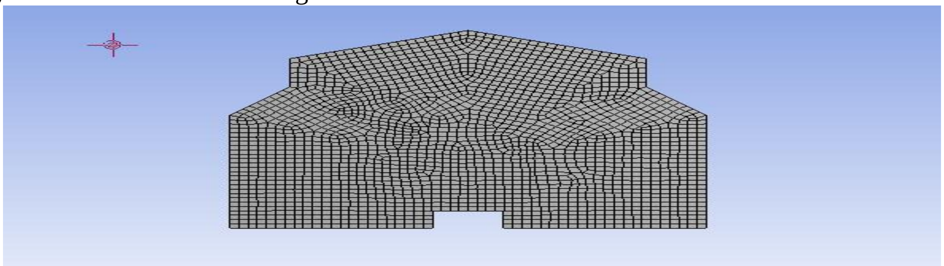

Figure4.2Mesh of geometry

Nodes-2157 Elements-2066

4.4 Fluent part

A.PROBLEM SETUP

1. General 1. a. solver (i) Type-pressured based
(ii) Velocity formation-absolute
(iii) Time-steady
(iv) 2d space-planner
1. b. Model -k-epsilon
-Standard
-Standard Wall Functions-
-Model constants table

Table4.1Model constants table

Cmu	.09
C1-Epsilon	1.44
C2-Epsilon	1.92
TKE Prandtl Number	1
TDR Prandtl Number	1.3
Energy	0.85
Wall	0.85

B.SOLUTION

1. a. Solution method (i) Scheme-Simple
(ii)Pressure-standard
(iii) Momentum-2nd order
(IV) energy- 2nd order
b. Solution control- Relaxation factors are taken to be default values

Table4.2Relaxation factors table

Pressure	0.3
Density	1
Body force	1
Momentum	0.7

Turbulent kinetic energy	0.8
Turbulent dissipation rate	0.8
Turbulent viscosity	1
Energy	1

V. RESULTS

5.1. Initial Smoke flow simulation

In this section, the initial smoke flow simulation has analyzed. The initial velocity and temperature of smoke is taken as 1m/s and 400K respectively. The simulation shows that the smoke generated at the periphery of furnace are moving inside the shed.

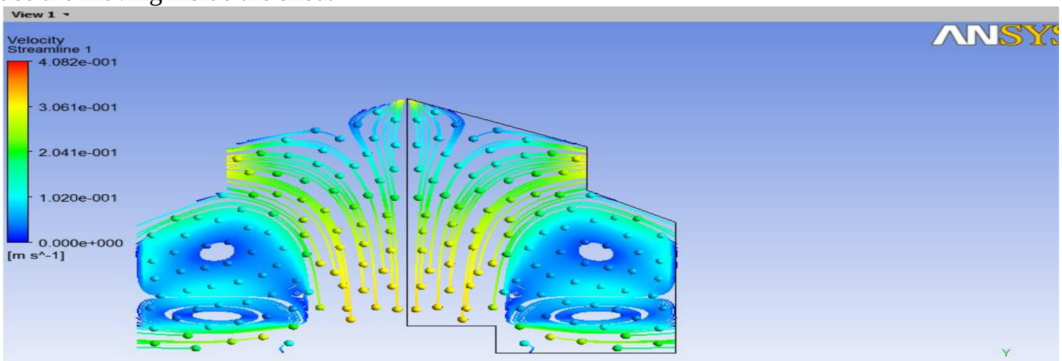

Figure5.1-velocity streamlines at outlet duct pressure 01 atmosphere

5.2. Temperature profile

The temperature is maximum at the bottom of the middle of the shed because the furnace is located at the bottom of the shed. The profile shows that temperature also decreases from bottom to top of the shed as shown below figure.

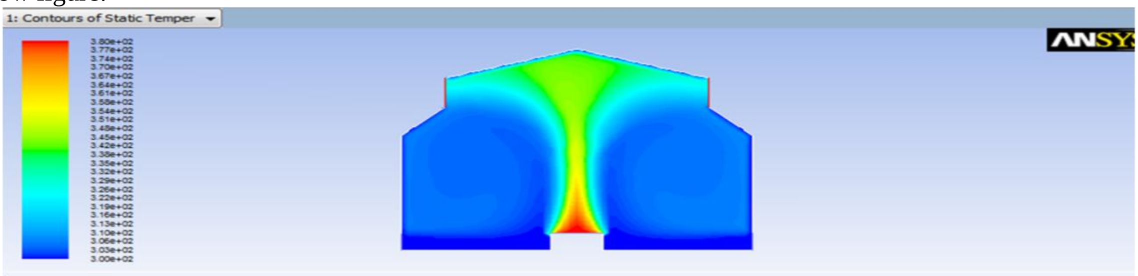

Figure5.2Temperature profile at outlet duct pressure -0.0205 atmosphere

5.3Table-Comparison of temperature with CFD and NFPA CHART

S.No.	Vertical Position from furnace(m)	Temperature(K) (CFD)	Experimental (K) (NFPA chart)	%of error
1	2	380	373	1.84
2	4	378	363	4.76
3	6	350	353	0.85
4	8	330	348	5.45
5	10	328	338	3.04
6	12	320	333	4.06
7	14	318	330	3.77
8	16	315	328	4.12

Table5.1 Comparison of temperature with CFD and NFPA Chart

5.4Validation of temperature

The temperature is maximum at the bottom of the middle of the shed and it also decreases from bottom to top of the shed. The graph between temperatures vs. position has drawn (denoted as blue curve) from CFD data and it almost matches with national fire protection association (nfpa) chart.

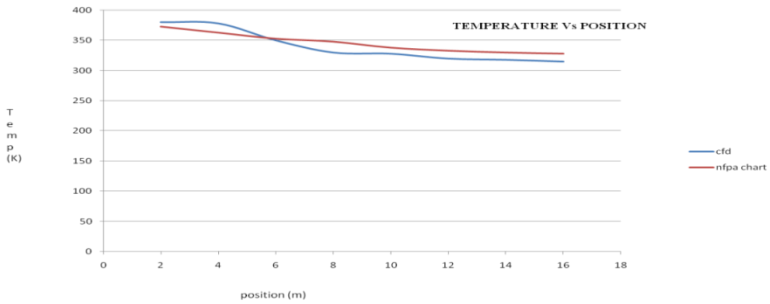

Figure5.4-validation by temperature

5.4 CALCULATION OF MASS FLOW BY NFPA

The amount of smoke generated can be estimated by NFPA 92B as

m =0.071K (2/3) Q (1/3) Z (5/3) + 0.0018Qr

Where m= mass flow rate of smoke at height z, kg/sec

K=wall factor

Q=heat release of fire, kW

Z=height of smoke

Qr=convective heat release rate of fire, kw=0.7Q

m =0.071*1*2000^(1/)*28^(5/3) +0.0018*0.7*2000=**230kg/sec**

5.5 Calculation of capacity of blower

INLET OF BLOWER

Static head (Ps) = -2050Pa= -207mm of H2O

Velocity head (Pv)=ρv2/2g=1.2*402/2*9.81=96mm of H2O

Friction head=f L /m*(v/4.04)2=0.005*35/.25* (40/4.04)2= -68.66 mm of H_2O

Total inlet head (H1) = -207+96-68.66=-197.66 mm of H_2O

OUTLET OF BLOWER

H_2=mm of H_2O of N.D. IN CHIMENEY=176.5H/Ta

=176.5*30/300= 17.65 mm of H_2O

Total head=H=17.65-(-197.66)=197.31mm of H_2O

Discharge=Q=A*V=.7*40=28m3/s

Total power=9.81*Q*H/1000=9.81*28*197.31/1000=54Kw

Considering η_{motor}= 80% and η_{blower} = 50%,

TOTAL POWER= 54/0.5*0.8=136KW

But available capacity of blower in market Q=150m3/h-150000m3/h,

H=100mm-1500mm of H_2O, power=1HP-50HP (37KW)

Total no of blowers=136/37=3.66=**04**

CONCUSION

The smoke flow simulation inside the shed is minimum at outlet duct pressure -2050pascal.

The capacity of each blower is 37 KW.

The no of blowers is recommended to be 04.

All the outlet ducts are located in same line along z axis at a distance of 25m from floor.

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