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Comparative study of Various Parameter of ESP by Using CFD

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ABSTRACT- The application of computational fluid dynamic (CFD) Modeling techniques to electrostatic precipitators (ESPs) Discussed CFD plays a vital role for ensuring uniform gas & dust flow distribution within ESP fields. Many times, through ESP design conditions are well evaluated while sizing ESP, inlet/outlet duct routing along with nozzle design & orientation may play a major role in spoiling performance of ESP. Even correctly sized ESP, through uneven gas and dust flow distribution will affect ESP performance. That is where CFD study plays a major role in improving gas distribution in ESP. the modeling methodology is reviewed. A range of ESP fluid flow characteristics that can be evaluated using CFD techniques is explored. The comparison study done between flow, velocity, temperature and scale

Keywords*:* Electrostatic Precipitator (ESP), CFD, GD screen, Guide Vanes;

INTRODUCTION

ESP though helps us to prevent pollutants from entering the atmosphere also actually adds to the operational costs in the industry & hence its very important to have an efficient ESP. An efficient ESP can be one that requires minimum electrical energy to separate out the charged particles of the bulk gaseous waste. Further understanding the physics of the process, one just needs to minimize e the force required to attract & separate out the particulates by reducing their kinetic energy resulting by decreasing the flow velocity. The flow velocity can be reduced by increasing the cross sectional duct area that may further result in change of flow distribution pattern. This then, becomes an important point to study as to how uniformly the flow pattern is? This can be a very good CFD study & let's discuss here a case study to better understand the CFD work.

The gas velocity characteristics, Flow, Temperature within an electrostatic precipitator (ESP) play an important role in overall ESP performance. If the gas velocity is too high, then the aerodynamic forces upon the particles can overwhelm the electrostatic forces generated by the collecting surface and electrode .this leads to degradation in collection efficiency. Similarly if local velocities are too low then collection surface is in not being adequately utilized and the potential of particulate build up in the ESP inlet and outlet ductwork increases. The proper design and study of CFD of ESP is important. This paper examines the case study of various parameter of ESP in CFD and their outcome result.

MODELING METHOD

A fluid dynamic tool uses to examine the three dimensional flow characteristics of ESP through the collection region and associated ductwork. The main reason for using the model is that if offers cost effective controlled environment to evaluate various design element. There are certain assumption and simplification inherent in any modeling process result in deviation between model result and observed performance in the field. Computational modeling is described as below

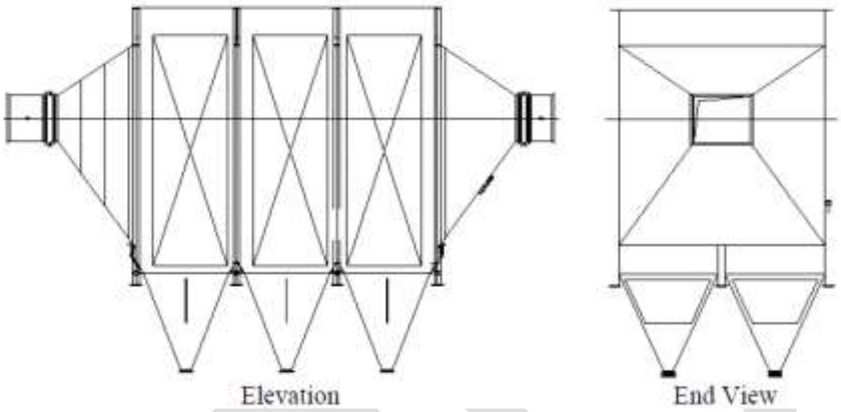
- **Computational fluid modeling**

The basic equations that govern the motion of fluid have been known for over century. These coupled, non linear, differential equation express and relate the laws of conservation of mass. Momentum and energy. Unfortunately, closed form solution of this equation proves impossible to find for most real word configuration. However the advent of high-speed computing and advances in numerical method allow researchers to develop highly accurate approximation to such a solution, even for extremely complex

STEP TO PERFORM CFD ANALYSIS OF ESP

- **Step 1: 3D Geometry modeling using ICEM CFD**

To create the CFD model for ESP, it is important to model all the major obstructions in the flow like collecting plates, baffle plates, girders and perforated sheets to calculate mechanical pressure drop across ESP and to maintain flow distribution. The model has to be generated with exact dimensions to predict accurate results. Guide vanes, gas distribution screens, wall plates, and other flow obstructions are modeled as baffle-computational cells (solid baffles) that are effectively zero thickness, two dimensional cells that otherwise act as solid cells and are placed at a distance equal to the actual dimensions in the filter.



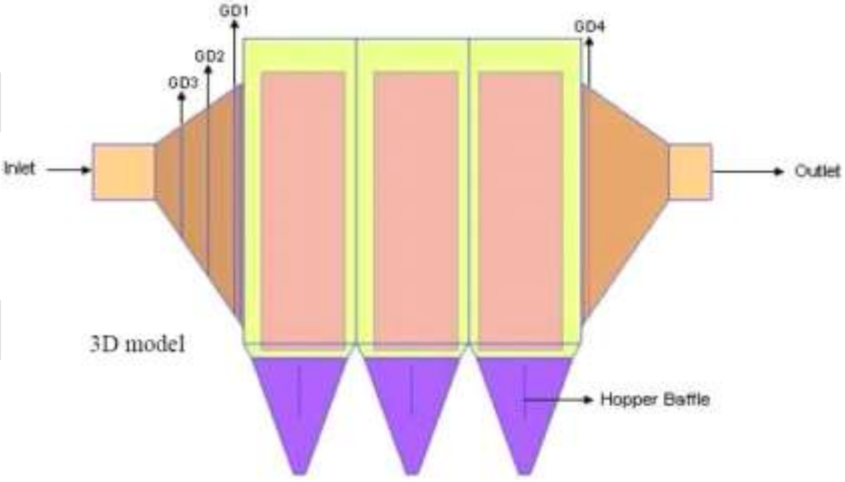


Figure 1:- ESP Model

- **Step 2: Model meshing, which divides the model into millions of small**

Mesh generation is basically the discretization of the computational domain. The 3D CFD model is discretized into small fluid cells called mesh. The accuracy of the results is based on the quality of the mesh. Fine mesh gives more accurate results, which is proportional to computation time and limited to hardware available. Computational cells using ICEM CFD. The mesh quality for ESP should not fall below **0.15** in quality checks in ICEM CFD.

- **Step 3: Model set-up runs and plot in Fluent**

Turbulent model: K-epsilon turbulent model is used. In most cases we use K-epsilon turbulent model, as it is widely used for industrial internal flows.

- **Step 4: reporting, finding and observations**

Boundary Conditions:

Inlet of ESP: velocity inlet

Outlet of ESP: Pressure outlet

Perforated sheet: Porous jump condition (minimum of 23% opening and a

Maximum 60% opening is considered for CFD)

The properties of working fluid (air) are given as per the operating conditions. All other components like baffle plates, girders collecting plates, outer casing and nozzle are given as Wall type boundary condition. Once the physical boundary conditions are applied, iterate the solution till it is converged. Now generate the test points at the end of first field and check the flow pattern to meet ICAC guidelines.

- **Measurement Procedure**

1. To measure the flow distribution across the ESP, points should be created along the cross section at the end of first field.
2. The number of points created is equal to the number of gas passages along the x-axis and at y-axis a maximum of 1 meter distance between each point along the height of collecting plates.
3. Velocities should be measured at those points and then check for ICAC guidelines & RMS value.

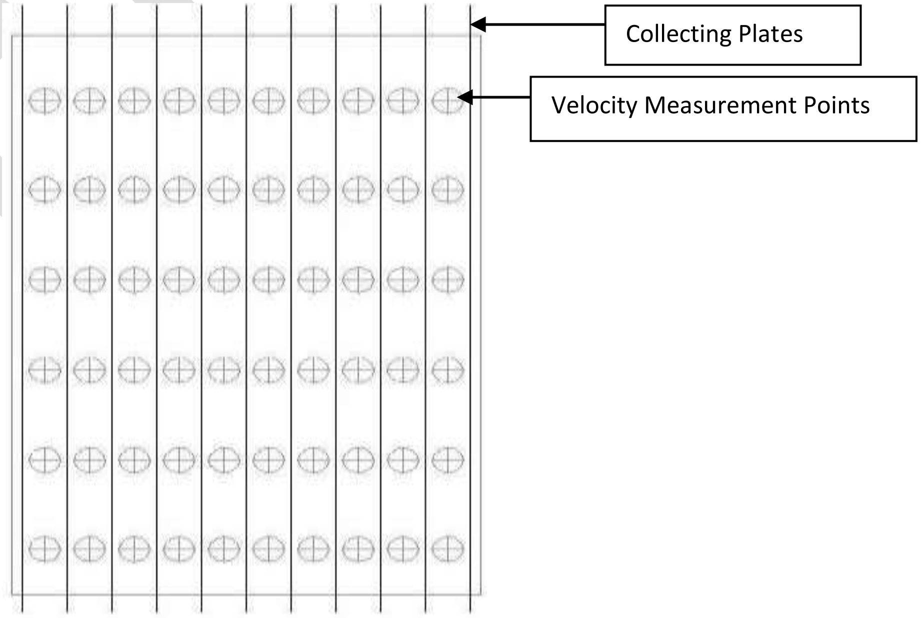


Figure 2:-Velocity measurement points (End view)

ACCEPTANCE CRITERIA

All the ESP's should follow the ICAC guidelines for uniform flow distribution for attaining maximum efficiency.

- The velocity pattern shall have a minimum of 85% of the velocities not more than 1.15 times the average velocity and 99% of the velocities not more than 1.40 times the average velocity. Average velocity refers to the mean of all velocity measurements made at a given face of the precipitator.
- As per ICAC guidelines all this velocities should be measured near the inlet and outlet faces of the precipitator collection chamber, where as we measured at the end of first field.
- The typical goal in industry is to achieve a Percent RMS of less than 15% at the ESP inlet and outlet planes where as we measured RMS value at the end of first field.

CFD OUTPUT RESULT

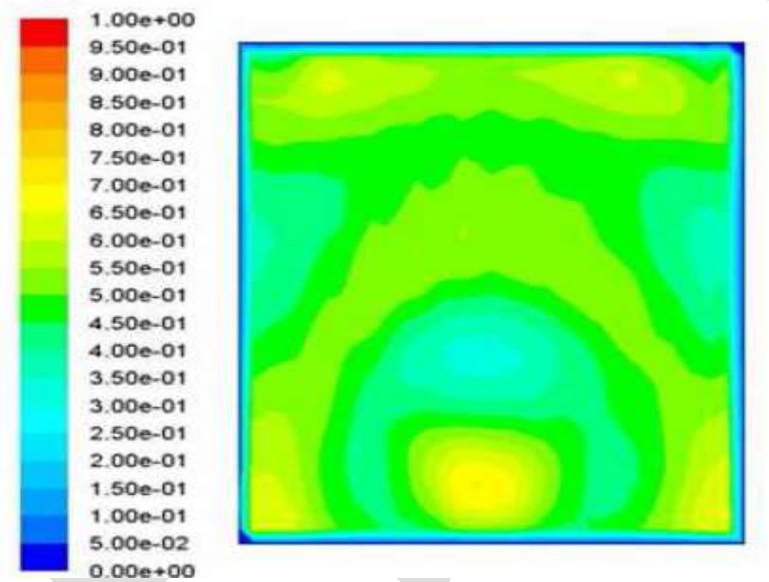


Figure 3:- Velocity Contours at the end of first field

CASE STUDY OF VERIOUS PARAMETRE OF ESP

- **Impact on flow distribution & Pressure drop**

1. **By varying inlet flow rate**

Case		Volume flow rate Am3/hr	Inlet Area (m2)	Velocity (m/sec)	Temperature (Deg C)
1	Actual flow rate	275400	4.35	17.5	40
2	0.5 time of actual flow	137700	4.35	8.5	40

- **Case -1:- With Actual flow rate**

Points	Ht	GP	1	2	3	4	5	6	7	8	9	10
1	10		1.2	1.09	1.34	1.5	1.45	1.38	1.32	1.28	1.25	1.08
2	9		1.28	1.14	1.09	1.15	1.17	1.13	1.09	1.07	1.05	1.05
3	8		0.93	0.83	0.74	0.93	1.01	1.02	1.03	1.04	1.05	1.06
4	7		0.78	0.61	0.71	0.95	1.06	1.09	1.1	1.1	1.09	1.02
5	6		0.86	0.69	0.87	0.95	1.14	1.12	1.08	1.05	1.03	1.03
6	5		1.05	0.88	0.99	1.16	1.2	1.17	1.14	1.11	1.09	1.1
7	4		1.16	1	1.13	1.27	1.25	1.18	1.12	0.99	1.07	1.04
8	3		1.15	1.2	1.14	1.03	0.98	0.97	0.98	0.99	1.01	1.04
9	2		1.52	1.27	1.13	1.12	1.1	1.07	1.05	1.03	1.03	1.06
		100	300	700	1100	1500	1900	2300	2700	3100	3500	3900

AVERAGE VELOCITY (V avg)	**1.08**	**m/Sec**	
1.15 times V avg	**1.24**	**m/Sec**	
1.40 times V avg	**1.51**	**m/Sec**	
Total Velocity Readings	**90**	**Nos.**	
No. of readings within 1.15 times V avg	**87**	**In %**	**97%**
No. of readings within 1.40 times V avg	**90**	**In %**	**100%**
Standard Deviation	**0.2**		
RMS in %	14%	**In %**	

- **Case-2 :- 0.5 time of actual flow**

Points	Ht	GP	1	2	3	4	5	6	7	8	9	10
1	10		0.65	0.57	0.65	0.71	0.7	0.68	0.65	0.63	0.62	0.61
2	9		0.59	0.54	0.52	0.54	0.55	0.55	0.54	0.54	0.53	0.53
3	8		0.47	0.39	0.38	0.43	0.46	0.47	0.47	0.47	0.46	0.46
4	7		0.44	0.34	0.36	0.43	0.47	0.48	0.48	0.47	0.47	0.47
5	6		0.49	0.39	0.42	0.48	0.51	0.5	0.52	0.48	0.48	0.46
6	5		0.54	0.45	0.47	0.53	0.55	0.54	0.54	0.51	0.51	0.49
7	4		0.58	0.51	0.54	0.59	0.59	0.56	0.52	0.53	0.53	0.52
8	3		0.66	0.6	0.58	0.55	0.53	0.52	0.52	0.52	0.52	0.53
9	2		0.72	0.62	0.58	0.57	0.56	0.55	0.54	0.54	0.54	0.55
		100	300	700	1100	1500	1900	2300	2700	3100	3500	3900

AVERAGE VELOCITY (V avg)	**0.53**	**m/Sec**	
1.15 times V avg	**0.61**	**m/Sec**	
1.40 times V avg	**0.74**	**m/Sec**	
Total Velocity Readings	**90**	**Nos.**	
No. of readings within 1.15 times V avg	**90**	**In %**	**100%**
No. of readings within 1.40 times V avg	**90**	**In %**	**100%**
Standard Deviation	**0.1**		
RMS in %	14%	**In %**	

- **Result Comparison by varying inlet flow rate:-**

Case	Volume flow rate Am3/hr	Velocity (m/sec)	Average velocity (m/sec) V avg	ICAC Criteria		RMS %	Pressure drop mm WC
				1.15 times V avg (85%)	1.40 times V avg (99%)		
1	275400	17.5	1.09	97%	100%	14%	38
2	137700	8.5	0.53	100%	100%	14%	10.5

2. By varying inlet Temperature

Case		Volume flow rate Am3/hr	Inlet Area (m2)	Velocity (m/sec)	Temperature (Deg C)
1	Actual flow rate	275400	4.35	17.5	40
2	0.5 time of actual flow	137700	4.35	17.5	140

- **Case 1 :- Actual flow rate**

Points	Ht	GP	1	2	3	4	5	6	7	8	9	10
1	10		1.32	1.09	1.34	1.5	1.45	1.38	1.32	1.28	1.25	1.22
2	9		1.28	1.14	1.09	1.15	1.17	1.13	1.09	1.07	1.05	1.05
3	8		0.93	0.83	0.74	0.93	1.01	1.02	1.03	1.04	1.05	1.06
4	7		0.78	0.61	0.71	0.95	1.06	1.09	1.1	1.1	1.09	1.09
5	6		0.86	0.69	0.87	1.08	1.14	1.12	1.08	1.05	1.03	1.03
6	5		1.05	0.88	0.99	1.16	1.2	1.17	1.14	1.11	1.09	1.1
7	4		1.16	1	1.13	1.27	1.25	1.18	1.12	1.08	1.07	1.08
8	3		1.31	1.2	1.14	1.03	0.98	0.97	0.98	0.99	1.01	1.04
9	2		1.52	1.27	1.13	1.12	1.1	1.07	1.05	1.03	1.03	1.06
		100	300	700	1100	1500	1900	2300	2700	3100	3500	3900

AVERAGE VELOCITY (V avg)	**1.09**	**m/Sec**	
1.15 times V avg	**1.25**	**m/Sec**	
1.40 times V avg	**1.52**	**m/Sec**	
Total Velocity Readings	**90**	**Nos.**	
No. of readings within 1.15 times V avg	**87**	**In %**	**97%**
No. of readings within 1.40 times V avg	**90**	**In %**	**100%**
Standard Deviation	**0.16**		
RMS in %	15%	**In %**	

- **Case 2:- 0.5 time of actual flow**

Points	Ht	GP	1	2	3	4	5	6	7	8	9	10
1	10		1.33	1.09	1.34	1.5	1.45	1.38	1.32	1.28	1.25	1.23
2	9		1.28	1.14	1.09	1.15	1.17	1.13	1.09	1.07	1.05	1.05
3	8		0.93	0.83	0.74	0.93	1.01	1.02	1.03	1.04	1.05	1.06
4	7		0.78	0.61	0.71	0.95	1.06	1.09	1.1	1.1	1.09	1.09
5	6		0.86	0.69	0.87	1.08	1.14	1.12	1.08	1.05	1.03	1.03
6	5		1.05	0.88	0.99	1.16	1.2	1.17	1.14	1.11	1.09	1.1
7	4		1.16	1	1.13	1.27	1.25	1.18	1.12	1.08	1.07	1.08
8	3		1.31	1.2	1.14	1.03	0.98	0.97	0.98	0.99	1.01	1.04
9	2		1.52	1.27	1.13	1.12	1.1	1.07	1.05	1.03	1.03	1.06
		100	300	700	1100	1500	1900	2300	2700	3100	3500	3900

AVERAGE VELOCITY (V avg)	**1.09**	**m/Sec**	
1.15 times V avg	**1.25**	**m/Sec**	
1.40 times V avg	**1.52**	**m/Sec**	
Total Velocity Readings	**90**	**Nos.**	
No. of readings within 1.15 times V avg	**87**	**In %**	**97%**
No. of readings within 1.40 times V avg	**90**	**In %**	**100%**
Standard Deviation	**0.2**		
RMS in %	15%	**In %**	

- **Result Comparison by varying inlet temperature:-**

Case	Volume flow rate Am3/hr	Temp (deg C)	Average velocity (m/sec) V avg	ICAC Criteria		RMS %	Pressure drop mm WC
				1.15 times V avg (85%)	1.40 times V avg (99%)		
1	275400	40	1.09	97%	100%	14%	38
2	275400	140	1.09	97%	100%	14%	25

3. By Varying scale of CFD mode

Case	Volume flow rate Am3/hr	Inlet Area (m2)	Velocity (m/sec)	Temperature (Deg C)	Scale
1	275400	4.35	17.5	40	Actual scale
2	2741	0.0435	17.5	40	Scale down 1:10

- **Case 1:- For volume 275400 Am3/hr**

Points	Ht	GP	1	2	3	4	5	6	7	8	9	10
1	10		1.32	1.09	1.34	1.5	1.45	1.38	1.32	1.28	1.25	1.22
2	9		1.28	1.14	1.09	1.15	1.17	1.13	1.09	1.07	1.05	1.05
3	8		0.93	0.83	0.74	0.93	1.01	1.02	1.03	1.04	1.05	1.06
4	7		0.78	0.61	0.71	0.95	1.06	1.09	1.1	1.1	1.09	1.09
5	6		0.86	0.69	0.87	1.08	1.14	1.12	1.08	1.05	1.03	1.03
6	5		1.05	0.88	0.99	1.16	1.2	1.17	1.14	1.11	1.09	1.1
7	4		1.16	1	1.13	1.27	1.25	1.18	1.12	1.08	1.07	1.08
8	3		1.31	1.2	1.14	1.03	0.98	0.97	0.98	0.99	1.01	1.04
9	2		1.52	1.27	1.13	1.12	1.1	1.07	1.05	1.03	1.03	1.06
		100	300	700	1100	1500	1900	2300	2700	3100	3500	3900

AVERAGE VELOCITY (V avg)	**1.09**	**m/Sec**	
1.15 times V avg	**1.25**	**m/Sec**	
1.40 times V avg	**1.52**	**m/Sec**	
Total Velocity Readings	**90**	**Nos.**	
No. of readings within 1.15 times V avg	**87**	**In %**	**97%**
No. of readings within 1.40 times V avg	**90**	**In %**	**100%**
Standard Deviation	**0.16**		
RMS in %	15%	**In %**	

- **Case 2:- For volume 2741 Am3/hr**

Points	Ht	GP	1	2	3	4	5	6	7	8	9	10
1	10		1.32	1.05	0.91	0.91	1.02	1.22	1.28	1.23	1.18	1.15
2	9		1.23	1.04	0.98	0.98	1.05	1.09	1.09	1.06	1.05	1.05
3	8		0.95	0.86	0.89	1.07	1.13	1.11	1.1	1.1	1.11	1.12
4	7		0.84	0.7	0.86	1.07	1.15	1.16	1.16	1.15	1.14	1.14
5	6		0.92	0.74	0.92	1.13	1.18	1.13	1.07	1.03	1	1
6	5		1.09	0.9	0.99	1.09	1.03	0.91	0.82	0.79	0.8	0.83
7	4		1.18	0.98	0.96	0.92	0.86	0.85	0.89	0.95	1.02	1.1
8	3		1.33	1.19	1.16	1.15	1.18	1.24	1.23	1.35	1.2	1.24
9	2		1.55	1.51	1.54	1.54	1.54	1.49	1.45	1.42	1.43	1.49
		100	300	700	1100	1500	1900	2300	2700	3100	3500	3900

AVERAGE VELOCITY (V avg)	**1.10**	**m/Sec**	
1.15 times V avg	**1.27**	**m/Sec**	
1.40 times V avg	**1.54**	**m/Sec**	
Total Velocity Readings	**90**	**Nos.**	
No. of readings within 1.15 times V avg	**80**	**In %**	**89%**
No. of readings within 1.40 times V avg	**90**	**In %**	**100%**
Standard Deviation	**0.2**		
RMS in %	18%	**In %**	

- **Result Comparison by Varying scale of CFD mode:-**

Case	Volume flow rate Am3/hr	Scale	Average velocity (m/sec) V avg	ICAC Criteria		RMS %	Pressure drop mm WC
				1.15 times V avg (85%)	1.40 times V avg (99%)		
1	275400	actual	1.09	97%	100%	14%	38
2	275400	1:10	1.1	89%	99%	17%	38

CONCLUSIONS

From the case study of various parameter of ESP we got the conclusions as follows

1. By changing the inlet flow rate, it is observed that there is 1-2 % change in flow distribution but pressure drop is reduced with respect to velocity. Hence it is concluded that flow distribution does not depends on inlet flow rate and pressure drop is directly proportional to velocity.
2. By changing the inlet flow temperature, it is observed that there is hardly change in flow distribution but pressure drop is reduced with increase in temperature. Hence it is concluded that flow distribution is not depends on inlet flow temperature where as pressure drop is inversely proportional to velocity.
3. By varying the scale of CFD model It is observed that 7-8 % variation in flow distribution and the pressure drop remains same in full scale model and scaled down model.

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