Vibration Performance Evaluation of Collecting plates of Electrostatic Precipitators Using FEA Approach

Pannkaaj More[1], D.H. Burande[2]
[1](Thermax Ltd. Enviro Division, Pune, Maharashtra, India)
[2](Department of Mechanical Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India)

ABSTRACT

Electrostatic Precipitators is the device used for removal of dust from boiler process gases. Various factors affect the effectiveness of this device. One of them is regular cleaning of the collecting electrodes. The dust removal takes place due to vibrations of collecting electrodes.

Further, in time bound project development, it becomes very difficult to test at every stage of design improvements which also affect the project cost. In such cases, more practical approach is to make design improvements through simulations followed by validation through physical measurements.

This paper presents FEA approach for modeling and analysis of collecting electrodes in an electrostatic precipitator using Implicit transient dynamic analysis approach. Experimental testing is done for validation of results. The results of FEA approach and testing are discussed.

***Keywords* -** Collecting electrodes, Electrostatic Precipitator, Experimental testing, FEA, Vibration analysis

I. INTRODUCTION

Dust particles contained in various process gases is one of the major industrial air pollution problem that must be controlled. Electrostatic Precipitator (ESP) is one of the more frequently used device to remove the dust from process gas. The effective work of an electrostatic precipitator depends on the conditions of gas flow, the generated electric field and the geometric parameters of the electrostatic precipitator (ESP).

The efficiency of ESP also depends on the efficiency of the periodic cleaning of the collecting electrodes [1]. The collecting electrodes are provided with a dust removal system, which removes dust that has gathered on the electrodes. Dust is removed by inducing vibrations at accelerations, which will effectively detach dust that has collected on electrode surfaces [2].

The vibrations generated at the assembly plays vital role in improving ESP performance. These vibrations are created by gravity operated rapping system, in which plunger is made to fall on rod. Due to these vibrations dust deposited on collecting electrodes falls in hoppers.

Thus effective working of rapping system plays important role in dust removal process. Different accelerations are developed are at different locations of the system. Accelerations are mainly depends on both energy of the rapper at the moment of impact and the way in which the force is transferred to the collecting electrodes and also Geometrical features of the electrodes (shape, length, thickness) .Impact force generated by the rapper have an essential influence on tangent and normal accelerations at different points of the plates, and thus on the effectiveness of the dust removal process [3].

Various experimental studies were done by researchers to ensure effective removal of dust from collecting electrodes.

This experimental approach has major drawbacks of higher time lines and cost involved in physical testing. Need is felt to develop a quick and reliable method to evaluate the vibration performance of ESP. CAE simulations are often used to for evaluating different designs.

This paper describes simulation procedure of evaluating ESP.

II. DETAILS OF ESP SYSTEM

Typical ESP System consists of rows of collecting electrodes mounted parallaly and hanging between top and bottom hangers. Top hangers are mounted on support channel, which are hanging through roof bolts. Anvil is mounted on top hangers on which rapper rod is placed. Electromagnetically operated plunger is placed on top of rapper rod which lifts and falls on it periodically. Due to this impact collecting electrode gets vibrated. These periodic vibrations are responsible for removal of dust from collecting electrodes.

Fig.1 shows typical assembly of collecting electrodes and rapping system of ESP.

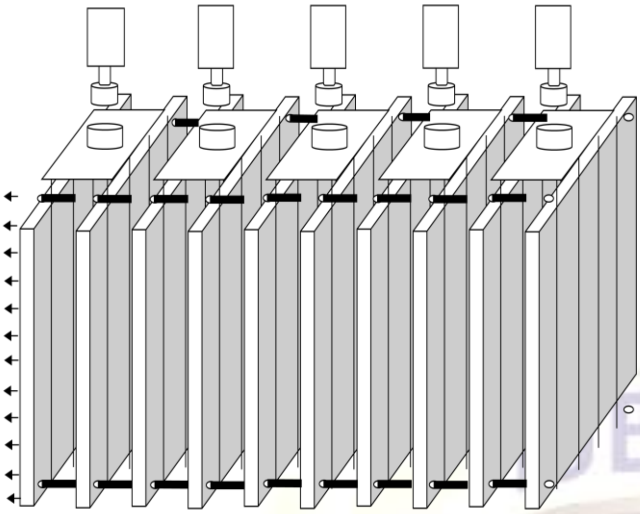

Fig.1 Typ assembly of collecting electrodes of ESP

III. DETAILS OF FE MODEL

Due to complicated geometry and large size of dimensions use of FEA method for modelling and analysis of vibrations of collecting electrodes is much suitable option. For finite element analysis subassembly of two parallel collecting plates is considered as shown in fig.2. The commercial software packages are used for modelling, meshing and analysis of the system. In this collecting plates and top & bottom hangers are modelled using shell63 element. Discretisation of the solid components like rapper rod, anvil & bolt is done using solid45 element. Collecting plate to hanger bolt connection is modelled using rigid element. Connections of top hanger to support channel and rapper rod to anvil plate are considered as fixed connections as shown in fig.3. Analysis is done by using ANSYS package.

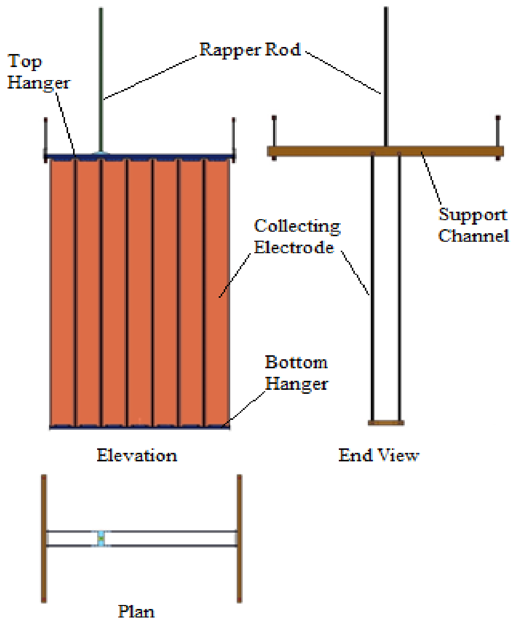

Fig.2 Subassembly of ESP collecting plates

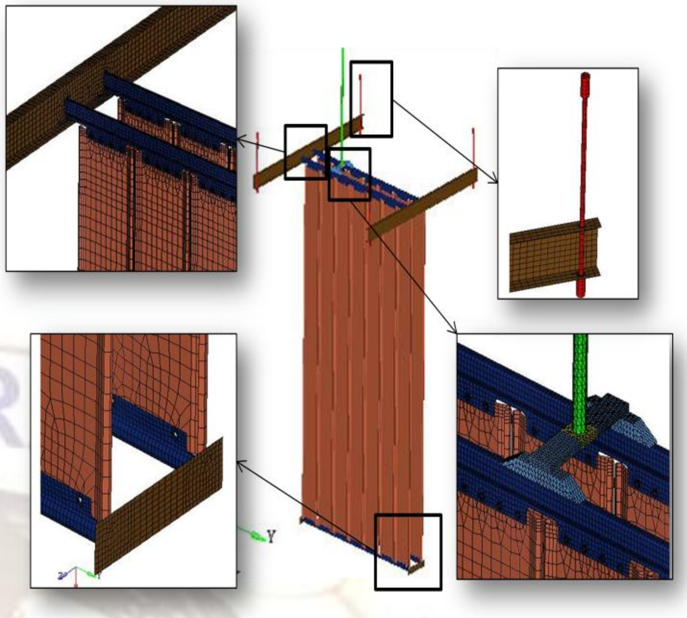

Fig.3 FE Model details of ESP subsystem

IV. ANALYSIS METHODOLOGY

Following analysis are done for evaluation of ESP subsystem.

Modal analysis:

It is done to study of the dynamic character of a system. These characteristics can be defined independently from the loads applied to the system and the response of the system. It is a technique used to determine a structure's vibration characteristics: like, Natural frequencies, Mode shapes, Mode participation factors (how much a given mode participates in a given direction). Refer fig.4 for FE model boundary conditions used for modal analysis.

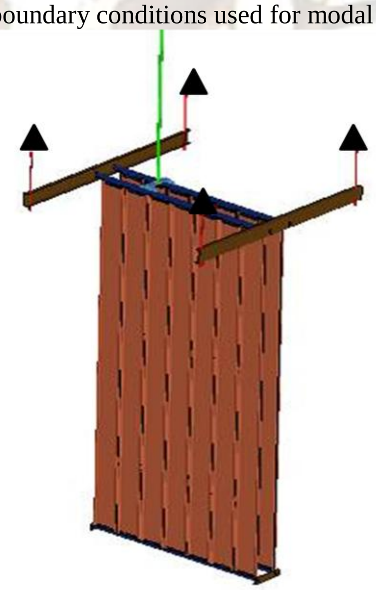

Fig.4 FE model for modal analysis

This also helps to predict resonant frequencies. Refer fig.5 for first 10 modes of ESP subsystem. Significance of modal analysis also helps to set plunger hitting frequency outside the range of natural frequencies of subsystem.

SET	FREQ (Hz)
1	0.15397
2	1.0328
3	1.0855
4	1.1381
5	1.2978
6	1.2984
7	1.4502
8	1.7436
9	1.7495
10	1.7519

Fig.5 Natural frequencies calculated from modal analysis

Transient analysis:

Plunger hitting operation is the transient event which depends on the time taken to complete one hitting cycle. This type of event cannot be simulated using conventional static analysis approach. Transient analysis is the most appropriate approach in order to simulate such events.

Transient analysis approach helps to study response of a system for particular time intervals. Output such as amplitude w.r.t time can be captured accurately at various locations.

In present exercise, transient analysis is carried out to measure plate displacement when plunger hits rapper rod. System response is measured for 3.5sec from the moment of impact. To determine the expected impact force, pulse width of expected time force curve is required to be estimated. Impact acceleration is calculated from the change in velocity during the pulse width time. The highest peak impact forces occur when there is a steel-on-steel impact. The initial and final velocities of impact are depends on structure stiffness. The resulting peak acceleration is calculated from below equation [9],

$$a = \frac{dv}{dt} = \frac{dv}{t_{pulse}} = \frac{V_{Initial} - V_{Final}}{t_{pulse}} = 2\text{x}\frac{\sqrt{2gh}}{t_{pulse}} \quad (1)$$

The impact force is then calculated from Newton's 2nd law equation,

F = ma ... (2)

Calculated impact force is applied at top of rapper rod. Refer fig.6 for boundary conditions of the transient analysis of ESP system. From Transient analysis, displacements at various locations of plates are measured. Higher the displacements better the cleaning efficiency. The displacements targets are decided based on design space constraint and electrical components clearances available.

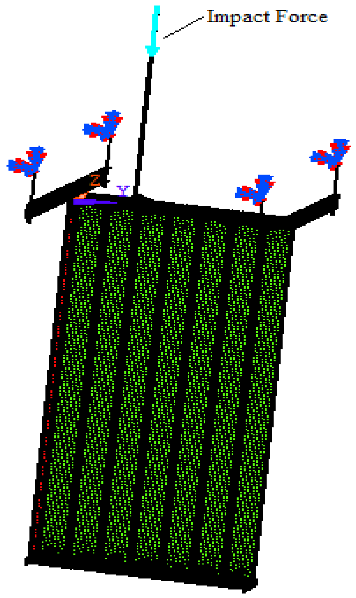

Fig.6 Model for Transient Analysis

V. ANALYSIS RESULTS

Refer fig.7 for details of locations where displacements are measured in analysis.

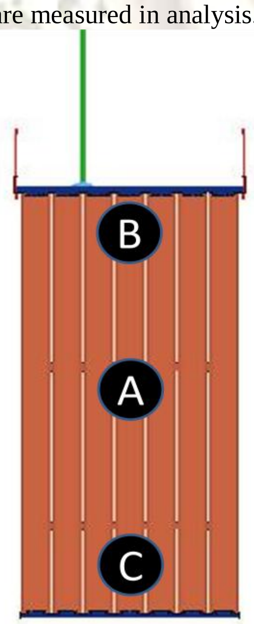

Fig.7 Measurement locations (A,B,C)

The result of FEA method performed using ANSYS package founds good agreement with testing data. Result data is mainly governed by model geometry and accurate estimation of impact force. Fig.8 shows displacement vs time plot. Maximum displacement is occurring within first 0.5 sec time after impact. And within next 1 to 1.5 sec it is almost getting damped.

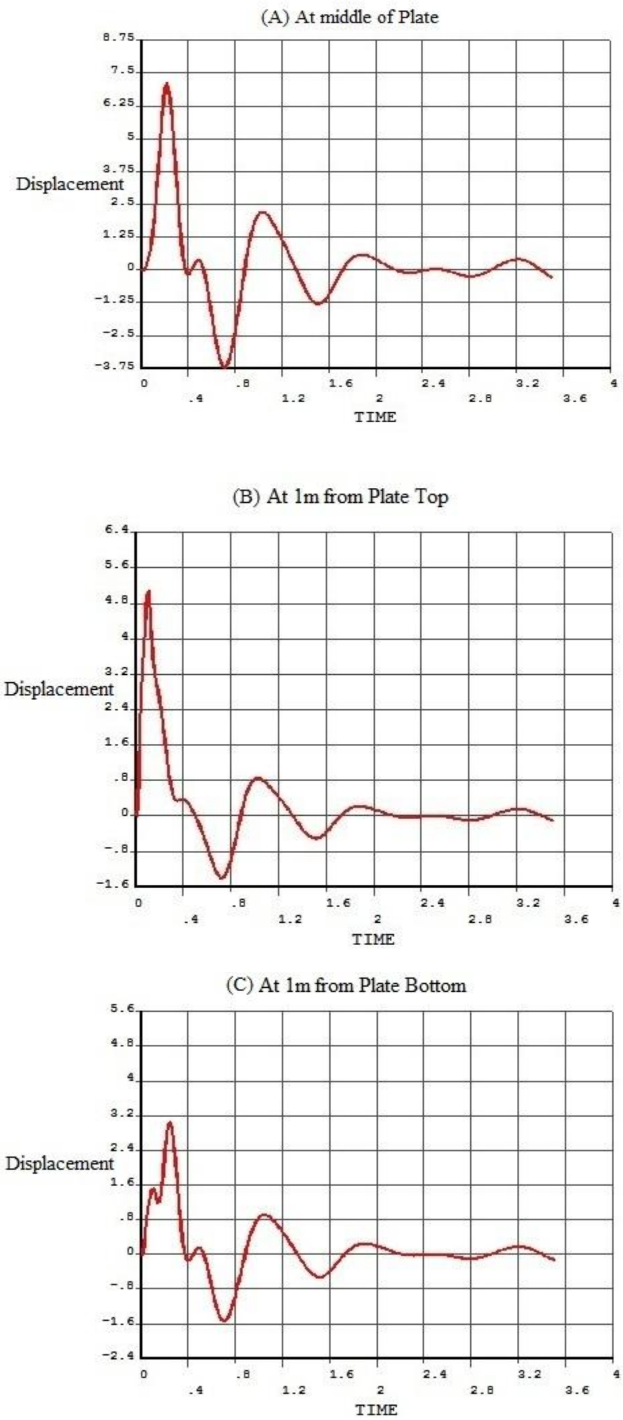

Fig.8 Displacement vs time plots measured at, (A) At Middle of plate, (B) At 1m from top, (C) At 1m from plate bottom

VI. VALIDATION OF RESULTS

Validation is done by comparing the results of FEA method with measurements performed on physical model. Testing is done on actual onsite equipment of Electrostatic Precipitator as shown in Fig.10,11.

The instrument Vibration Analyzer is used for the measurement of vibrations. As electrode vibrations occurred by rapping system is random process and due to critical geometry and parameters occurring errors in measurement various set of trials are required to be taken during measurement. Fig.10 shows actual picture of collecting plate assembly. The analysis output i.e. displacements are compared with the physical testing measurements, refer Fig.9.

Measurement Locations		A	B	C
Displacement (mm)	FEA method	7.1	5.1	3
	Testing data	6.5	4.6	2.8

Fig.9 Table of displacement values measured

Fig.10 Onsite Equipment of ESP

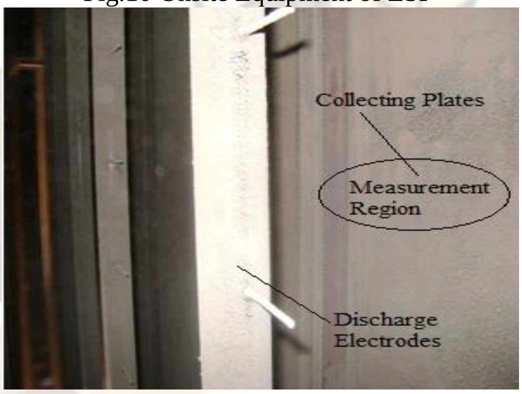

Fig.11 Collecting plate subassembly of Testing Equipment

VII. CONCLUSION

The vibration excitation of collecting electrodes mainly depends upon impact force and system geometry. Maximum displacement is occurring at middle of the collecting electrode and minimum at the bottom. The result of validation gives good agreement between FEA method and testing data. With this respect FEA method presented in this paper can be useful for predicting the vibration behavior of the system during its design stage. It enables us to assess the effect of different geometrical parameters such as collecting plate profile, plate thickness and rapping location of the system on its vibrations. This method is much simpler, cost effective and time saving as compared to actual physical testing of the system.

VIII. ACKNOWLEDGEMENTS

We would like to thank Mr. P.G.Soman (Design-Head) and Mr. Pradeep Deore (Design-Manager) for giving the opportunity to work on this challenging project and to present this paper.

Also we would like to thank Mr.Prashant Chavan and AMCON Consultech for providing guidance in CAE simulation. And Mr.Sandeep Kadam, Mr.Ganesh Chavan, Mr.Nandkishor Yadav and Dr.S.V. Deshpande involved in the physical testing and measurement.

REFERENCES

[1] Andrzej Nowak, *Vibration of collecting electrodes in electrostatic precipitators - Modelling, measurements and simulation tests, Journal of Electrostatics 70 (2012) 327e332*

[2] Nowak Andrzej, Wojciech Stanisław, *Optimisation and experimental verification of a dust-removal beater for the electrodes of electrostatic precipitators, Computers and Structures 82 (2004) 1785–1792.*

[3] Iwona Adamiec-Wojcik, Nowak Andrzej, Wojciech Stanisław , *Comparison of methods for vibration analysis of electrostatic precipitators,Acta Mech Sin DOI 10.1007/s10409-011-0415-2*

[4] Michael Neundorfer, *Electrode cleaning system : Optimizing rapping energy and rapping control, Environment International, Vol.6.pp.279-287,1981*

[5] HU Manyin, LIU Yujing, YIN Qi, LIU Zhong, GAO Xianglin, *Research on Vibration Period Optimization of Electrostatic Precipitator, 11th International Conference on Electrostatic Precipitation.*

[6] S.H. Kim, K.W. Lee, *Experimental study of electrostatic precipitator performance and comparison with existing theoretical prediction models, Journal of Electrostatics 48 (1999) 3}25*

[7] A.P. Nowak, *Measurement verification of the hybrid finite element method, ECCM2010*

[8] Iwona Adamiec-Wójcik, *Modelling of systems of collecting electrodes of electrostatic precipitators by means of the rigid finite element method, The archive of mechanical engineering2010, 10.2478/v10180-011-0002-x*

[9] Robert Metz, PCB Piezotronics, *Impact and Drop Testing with ICP Force Sensors, SOUND AND VIBRATION/FEBRUARY*