Investigation of Performance Efficiency on the Effect of Wet Scrubber Inlet Dimensions on the Flow Pattern

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ABSTRACT

The main objective of the work is to determine performance efficiency of wet scrubber by changing the inlet width and height while maintaining the optimum ratio from 0.5 to 0.7.The flow pattern has been investigated computationally using Reynolds stress turbulence model. This method is designed to handle static pressure, volume fraction and velocity. Nevertheless, comparison also shows a good argument between theoretical prediction and numerical simulation.

Keywords: Wetscrubber, CFD, Reynolds stress turbulence model aspect ratio.

1. INTRODUCTION

Metal casting is one of the most ancient and primary manufacturing process .It holds its position as the most commonly used manufacturing process in foundries. Along with globalization, the present economic scenario and stiff competition among the foundries at both indigenous and global markets have made the foundries to be competitive. For the achievement of high rate of production and high quality products,pollution controlled and a healthy environment is required in the foundries to overcome the difficulties of working condition of the workers and production process. Due to the increase of indoctrination and urbanization, air pollution is a burning problem in the foundries. The typical problem involved in foundries is high temperature melting and casting of metals into objects of desired shapes which involves an enormous amount of energy usage. The emission of particulate matter during melting and casting treatment of molten metal is of great importance and concern. In this regard a few researchers have concentrated on pollution control devices specifically wetscrubber system(Bhave et al., 2008;Chang et al; 2008; Alonso et al; 2001; ping et al;2011;Xavier et al ;2004). Li et al. (2008) developed an umbrella plate scrubber to prevent sulfur dioxide, dust and harmful gases emitted from coal burning boilers, and also studied using standard k–ε turbulent model and Reynolds stress model (RSM swirl flow is suitable) in computational fluid dynamics (CFD)for gas phase.Pak and Chang (2006) modeled the performance estimation of Pease–Anthony Venturi scrubber (three dimensional numerical approach) using CFD to calculate the pressure drop and collection efficiency. The gas flow was solved using the Eulerian simulation and the momentum of dust and liquid droplets using the Navier stokes equation and the dealing of gas, impact of droplets, and liquid spray formation of droplets.Goncalves et al. (2004) proposed a rectangular Pease-Anthony Venturi scrubber part II positioned horizontally of its throat dimension was 24mm × 35mm and length varied from 63 to 140 mm was impart and examined both experimentally and theoretically before bursting of liquid jet.Meikap and Biswas (2004) experimented in a multi-stage bubble column pilot wet scrubber plant for dust collecting in presence of other gaseous and vapor emission and fly ash were removed with more than 95% efficiency and achieved 99.5% for most of the scrubber (indicates the worth of the contraction–expansion disks collection efficiency) that are within pollution control norms. Gonçalves et al. (2001) predicted the running cost due to pressure drop of venturi scrubbers of different sizes (throat diameter from 1.9 to 16 cm), geometries, operating variables and liquid injection arrangement. The mathematical models paid with caution and much attention to the validity of the assumptions employed. The main aim of this paper is to investigate the effect of wetscrubber inlet dimensions and to compare existing system with theproposed system. The proposed model has been developedusing Reynolds stress turbulence model (RSM) for analysis in numerical simulation.

2. METHODOLOGY

A realistic dust collector model must account for many effects and parameters. The most important are (i) variation in process feed rate (ii) capacity of the system (iii) type of scape fed. In order to solve the problem a proposed model is investigated considering optimum ratio of width to height from 0.5 to 0.7. Velocity magnitude, static pressure, volume fraction is simulated initially pro/e wildfire R 5.0 software package is used for modeling andAnsys fluent software is used for analyzing. In this manner heat flux and temperature distribution is considered treating wall of existing and proposed wet scrubber design as the default boundary condition as shown in fig 1 and fig 2. Simulations were carried out on a numerical grid. The Reynolds stress model(RSM) is used to model the turbulence. The simulation sequence is specified as follows: initially simulation of the gaseous phase (without particles) is carried out. Then discrete phase is considered assuming wet scrubber walls are very smooth subsequently the roughness was increased with different mass flow rate and pressure drop.

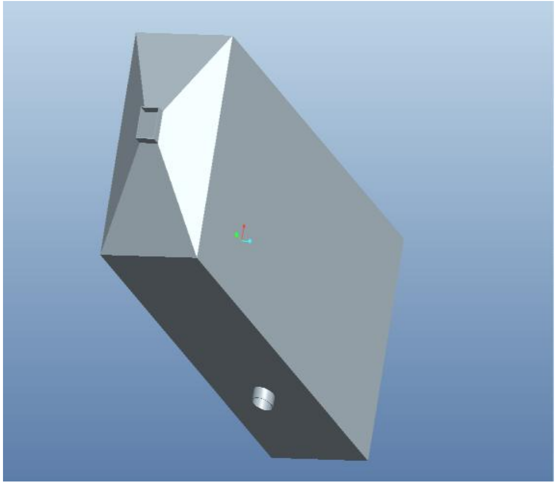

Fig.1 Model of Existing wet scrubber design.

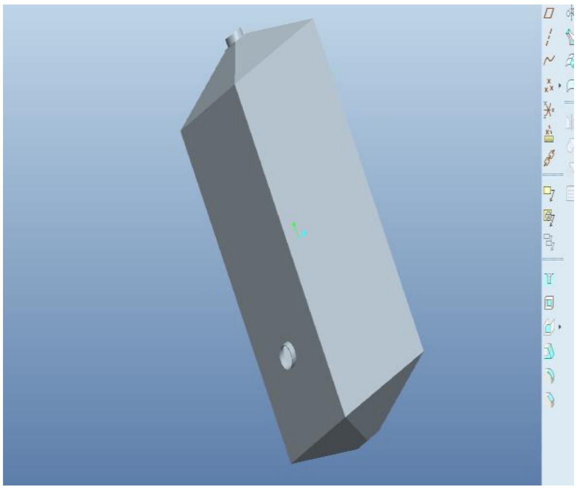

Fig. 2 Model of Proposed wet scrubber design.

3. RESULTS AND DISCUSSIONS

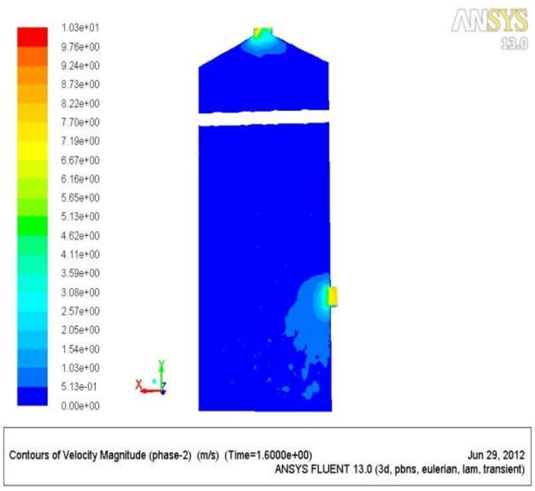

Fig.3. Velocity Magnitude (U_{in}= 8 m/s) of Existing Wet scrubber design

Fig. 3 illustratesthe velocity distribution of flue gas for a velocity of 8 m/s entering into the inlet wet scrubber, and at the outlet it is approximately 2.57 m/s. The value at the bottom of the wet scrubber reached zero velocity.

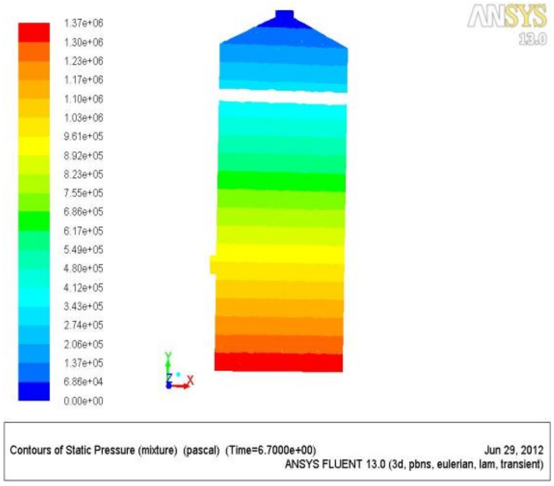

Fig. 4. Static pressure (P) for Existing model of Wet scrubber at 8 m/s

The static pressure along the conventional wet scrubber shown in Fig. 4, at the inlet the pressure is 9.61×10^5 Pa, and the maximum pressure of 1.37×10^6 Pa is at the bottom of the wet scrubber.

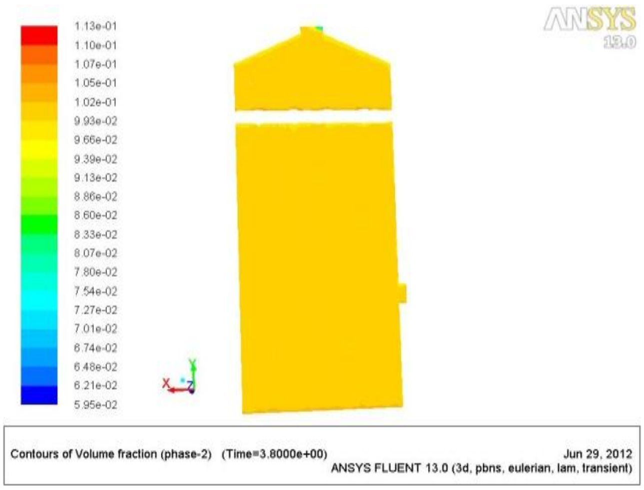

Fig. 5.Volume Fraction of dust concentration of Wet scrubber.

The dust particles with flue gas at the entry is 9.93×10^{-2} microns as shown in the Fig.5, the micron levels indicate that the particles are not filtered, and almost below 5 microns are at the same color along the wet scrubber.

3.1 RELATION BETWEEN STATIC PRESSURE Vs POSITION (8 M/S)

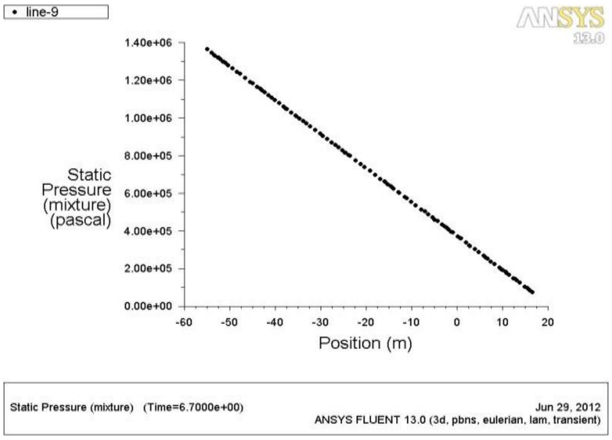

Fig.6. Effect of gas particles flow pressure for Existing model of Wet scrubber.

The increase in position Vs static pressure relationship in Fig.6, as shown with an increase in position along wet scrubber the pressure drop decreases gradually.

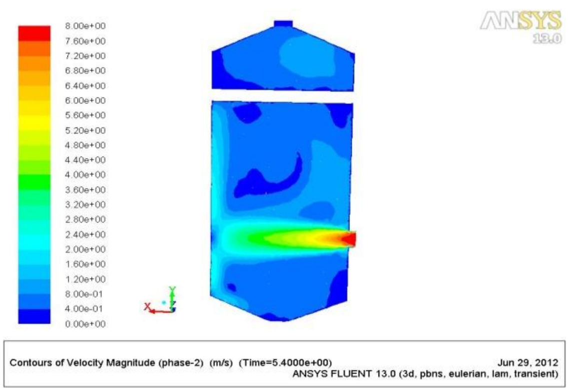

Fig.7. Velocity Magnitude U_{in}= 8 m/s for Proposed model of Wet scrubber.

The image in Fig. 7, shows its Velocity distribution of flue gas dust particles at the inlet is 8 m/s, and at the outlet the velocity is zero. The velocity in between the demister and the tray pad is 0 to 0.8 (8.00×10^{-1}) m/s, at the bottom of the wet scrubber dark blue color explicit zero velocity.

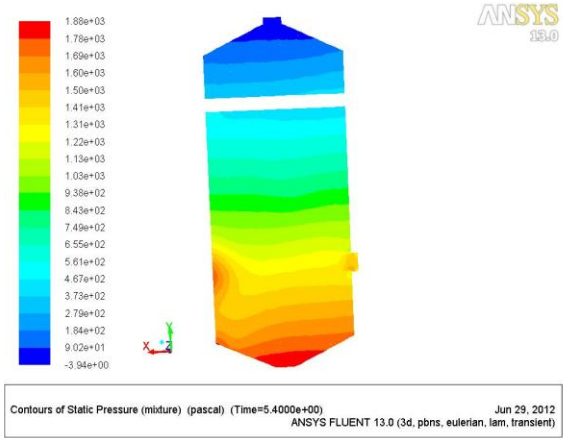

Fig.8. Static pressure distribution for Proposed model of Wet scrubber.

The contours of Static Pressure are shown in Fig. 8.The maximum inlet pressure is 1.41×10^3 Pa and the minimum pressure is -3.94 $\times 10^0$ Pa. When compared to the conventional wet scrubber, the pressure drop is zero at the outlet. Generally wet scrubber pressure drop is proportional to the inlet velocity. From both cases (conventional wet scrubber and proposed wet scrubber) it is observed that the pressure drop in the proposed wet scrubber is greater than comparable conventional ones.

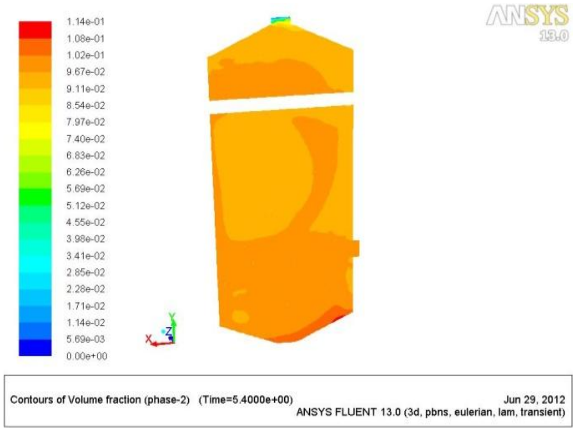

Fig.9. Volume Fraction of dust concentration of Proposed Wet scrubber 8m/s

The Volume fraction of Proposed wet scrubber as shown in Fig.9 represents a maximum value of dust Particle concentration with flue gas at the inner port of 9.11×10^{-2}microns, the micron level particles are not filtered for the range below 5 microns at the outlet of conventional wet scrubber, and the particles are at the same color throughout the conventional wet scrubber as compared to proposed wet scrubber.

3.2. Relation between Static pressure Vs Position at 8 m/s of Proposed Wet Scrubber

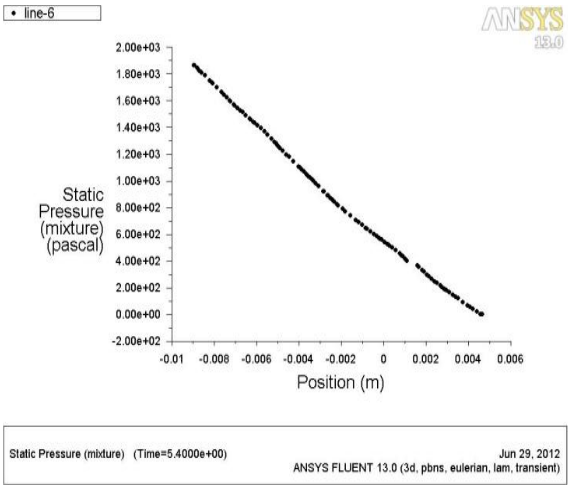

Fig. 10 Effect of gas particles flow pressure difference for proposed model of Wet scrubber at 8 m/s.

The proportionality of the static pressure with respect to dust movement along the wet scrubber relationship is as shown in Fig.10.With an increase in the movement of dust along wet scrubber, the pressure drop decreases gradually at an average level deviation of value with respect to height.

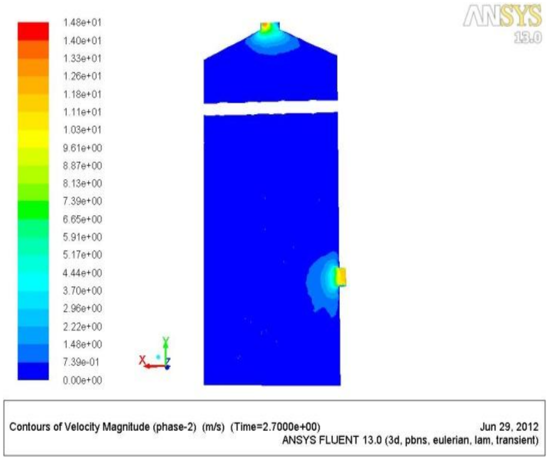

Fig.11. Velocity Magnitude U_{in}= 12 m/s for Existing model of Wet scrubber.

Fig. 11, illustrates the velocity distribution of flue gas for a velocity of 12 m/s entering into the inlet wet scrubber, and approximately 2.22 m/s at the outlet. The value at the bottom of the wet scrubber reached zero velocity.

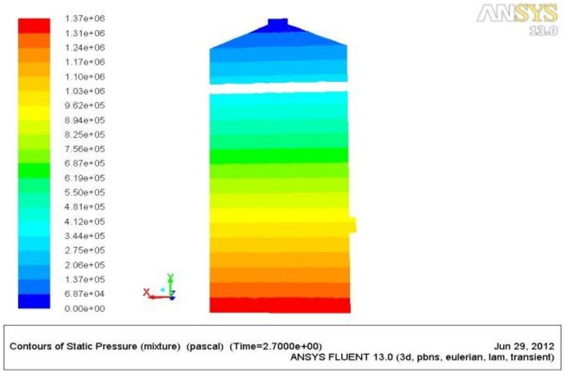

Fig.12. Static pressure variation for Existing model of Wet scrubber at 12 m/s

The static pressure along the conventional wet scrubber is as shown in Fig. 12. At the inlet, the pressure is 9.62×10^5Pa,a maximum pressure of 1.37×10^6 Pa is at the bottom of the wet scrubber. It gradually decreases the pressure taking more residence time.

3.3. Volume fraction of Existing Wet scrubber at 12 m/s

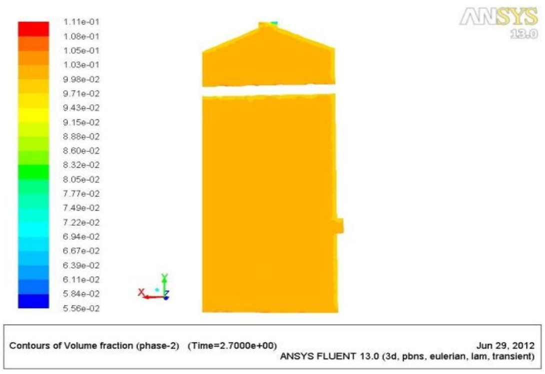

Fig.13.Volume Fraction of Dust Concentration for Existing model of Wet scrubber.

The dust particles concentration along the wet scrubber is 9.71×10^{-2} microns as shown in the Fig. 13, the micron level particles are still presented inside the wet scrubber and almost all the particles are in the same color along the wet scrubber.

3.4. Relation between Static pressure VsMotion of the Particle at 12 m/s

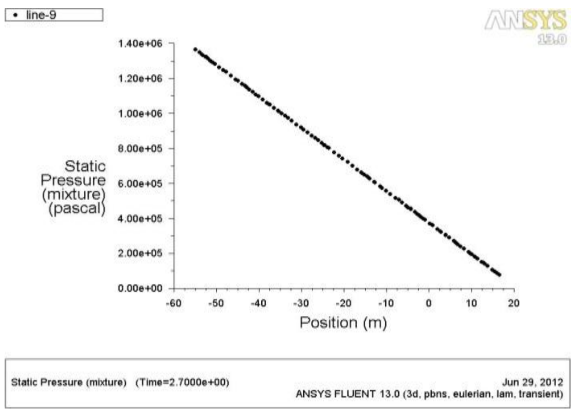

Fig.14. Effect of gas particles flow pressure for Existing model of Wet scrubber

As shown in Fig. 14, with an increase in position along wet scrubber, the pressure drop decreases gradually. From this illustration, the residence time of dust would take longer duration.

3.5. Velocity Magnitude of Proposed Model of Wet scrubber12 m/s

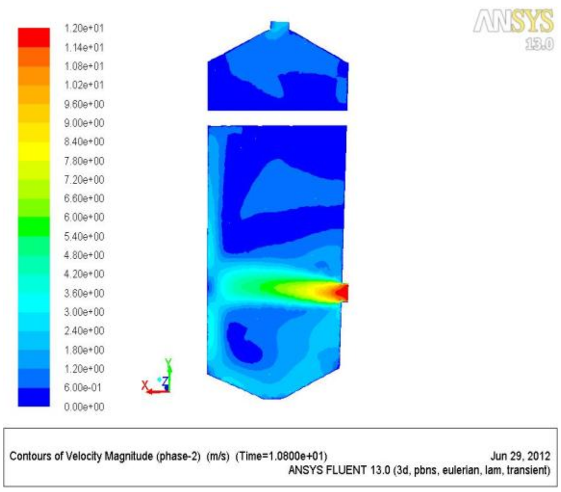

Fig.15. Difference of Velocity Magnitude U_{in}= 12 m/s for Proposed model of Wet scrubber.

Fig. 15 shows the Velocity distribution of flue gas dust particles. At the inlet, the velocity is 12 m/s, and at the outlet 1.8 m/s. The velocity in between the demister and the tray pad is from 0 to 8.00 m/s, and at the bottom of the wet scrubber explicitly at zero velocity. The velocity when compared to the conventional type, proposed type device shows an increase in value of 23%,which is achieved because of porous media (0.000001 μm) introduced in the proposed device.

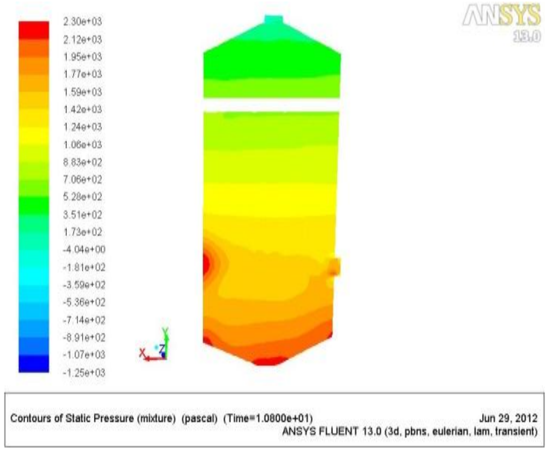

Fig.16. Variation of Static pressure for Proposed model of wet scrubber at 12 m/s.

The contour of Static Pressure is shown in Fig. 16, with the maximum inlet pressure of 2.30× 10^3 Pa, the minimum pressure of -4.04× 10^0 Pa.Both the cases (conventional wet scrubber and proposed wet scrubber) shows that the pressure drop in the proposed wet scrubber is less than comparable conventional ones.

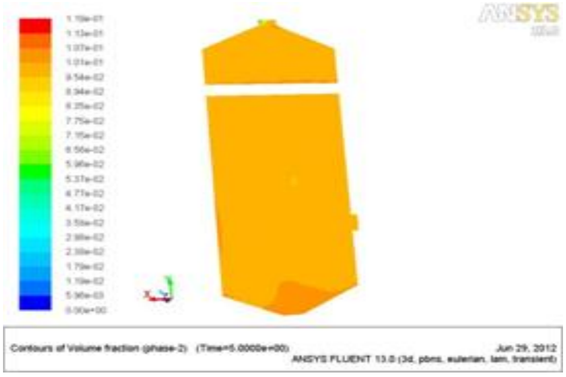

Fig. 17.Significance of Dust concentration for proposed model of Wet scrubber.

The Volume fraction of proposed wet scrubberis shown in Fig. 17. It represents a maximum value of dust concentration at the bottom of the device as 9.54× 10^{-2}microns; the micron level particles are not filtered for the range of below 5 microns at the outlet of conventional wet scrubber, as compared to proposed device.

3.6. Relation between Position Vs Static pressure at 12 m/s

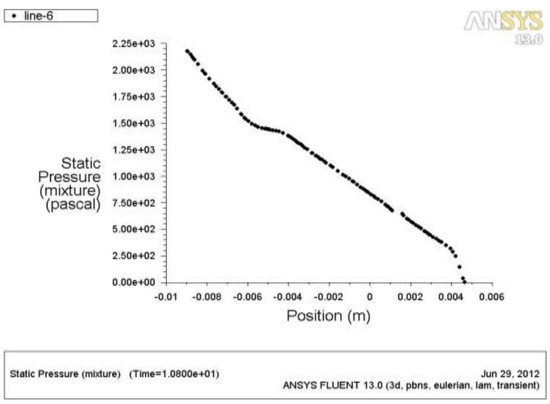

Fig.18. Effect of gas particles flow pressure for proposed model of Wet scrubber.

The proportionality of the static pressure with respect to dust movement along the wet scrubber relationship is as shown in Fig. 18and the pressure drop decreases more than that of existing device.

4. CONCLUSION

The inlet dimensions on the flow pattern were investigated by means of numerical simulation. Besides the inlet particle diameter ranging from 0.01µm to 0.5µm, different particle materials with varying particle densities had also been considered. This method is not designed to handle liquid flow rates and pressure drops. To the end static pressure, volume fraction, velocity magnitude had shown good comparative results with the proposed model. Both numerical simulation and theoretical predictions have strength and weakness. The efficiency is improved by changing the optimum ratios. The results are critically studied and useful for future enhancement.

5. ACKNOWLEDGEMENT

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