Modeling and Investigating the Characteristics Performance of Wet and Dry Scrubbers

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ABSTRACT

The present work details the pressure drop measurements from a large-scale dust collector with flow rates varied with the velocity of 40m/s. The results show that the pressure drop depends on both the gas and liquid phases flow rates. Water with a mass flow rate of 0.01kg/s is injected through water inlet.Both the outlets (water outlet and hot air outlet)are modeled as pressure outlet with ambient conditions. Hot air is considered to be continuum; Water and Dust are modeled as discrete phases and are solved by DPM(discrete phase modeling). The fluid is assumed to be three dimensional, turbulent and incompressible in nature. Steady state solver is used and simple algorithm is activated. Segregated solver algorithm is used for pressure–velocity coupling. The pressure drop in the diverging section is well predicted by K-E realizable turbulence model.

Keywords*:* Wet scrubber; Pressure drop; Dry scrubber; Multiphase flow; DPM (discrete phase modeling).

1.INTRODUCTION

Emission control is an integrated part of any manufacturing industry,needed to enhance the performance of emission control units (Krishnaraj et al., 2012). Wet and dry scrubbers are the most used systems for the emission control flow physics in these systems are highly complicated as it is three dimensional, turbulent and secondary in nature. Separation of particles is induced by the low suction area available at the centre region of these units. Although theoretical calculations are developed for this system, the insight of the flow is yet to be studied.The flue gas/dust particles are collected through a receiving hood and duct is fed into the cooling system, and then passed to cyclone separators. The flue gas/dust particles are controlled by using equipment like Gravitational settling or Cyclone separators or Fabric filters or Electrostatic precipitators(Vijayananda et al., 2008).Either gravitational force or Centrifugal force separates the particulate matter from the polluted gas. Centrifugal force is better than Gravitational force, as it generates a spinning gas stream and this makes cyclone separators more effective in removing the micron level particles. (Barysheva et al., 2003) determined the motion of particles through the fixed bed for a gas-solid-solid down flow reactor. They found that the increase in solids flow rate decrease solids velocity due to appearing essential reciprocal particles interactions. The solid velocity slightly depends onparticles size, while the dependence is more remarkable at higher solid flow rate, the reason being, the motion of a large particle unlike the motion of fine particles through the inter granule void in the fixed bed is impeded by another moving particles. I et al., (2008) developed umbrella plate scrubber toprevent sulphur dioxidedust,harmful gases emitted from coal (Bhave et al.,2008, Biswas et al., 2009)burning boilers using Reynolds stress model(RSM swirl flow is suitable) in computational fluid dynamics (CFD) for gas phase. Molgaand Westerterp, (1997) found that Gas-liquid interfacial areas have been determined by means of chemically enhanced absorption of Co_2 into packed bed bubble column reactor with an inner diameter of 156 mm. The influence of gas velocity and particle diameter on the interfacial areas, pressure drops and liquid holds up hadbeen investigated. For both packing, the limiting values of the gas velocities had determined in the interfacial areas and liquid one stabilized. In particular, gas channeling has been found which is less pronounced in the bed of larger particles. Kuo et al.,(1998) investigated the prevalence and factors related to pneumoconiosis in foundry workers. Seven hundred and eighteen workers from 50 Foundries in central Taiwan were interviewed using a constructed questionnaire. Pneumoconiosis was found in 7.5% of the workers. The highest prevalence was found among furnace workers (15.9%) and molding worker (8.40%), In conclusion, the prevalence of pneumoconiosis was significantly related to high concentrations of dust, especially with a high proportion of free silica.However, smoking and length of exposure were also contributing factors.Vijayanandaet al.,(2008) states Industrialization and urbanization are the two major causes of deteriorating air quality, The concentrations of seven heavy metals (Zn, Fe, Cu, Pb, Ni, Cr and Cd) were estimated. The level of SPM was found to be either at permissible or non-permissible limit depending upon the category of the sampling station. At majority of sampling stations, concentrations of Zn were found to be maximum than other heavy metals. Croteau et al., (2002) studied the effect of local exhaust ventilation controls on dust exposures during concrete cutting and grinding activities. The effectiveness of local exhaust ventilation system for capturing dust is dependent on the proximity of the contaminant source to the shroud, face velocity and the magnitude and direction of competing air current. Tsung-Wen Chien andHsin Chu, (2000) investigated the equipment and its calibration cost, where the concerned parties deny performing the regular examining of emission test. For better follow-up of the system monitoring, the test data should be arrived month wise. Piekoszewski et al., (2001) stated Titanium foil is employed for electron transparent windows in the electron beam, where dry scrubber process adhesion coating was reduced by the flue gas deposition and plasma source ion assisted deposition coating provided the best performance in the emission rate.Malin et al., (2007) investigated that disposal of municipal solid waste incineration dry scrubber residue with cellulose-laden waste should be prevented due to the risk of an increased leaching of critical metals; in particular Cu, Pb and Zn.A dry Scrubbing system unlike the wet scrubber does not saturate the flue gas stream that is being treated with moisture. In some cases, no moisture is added; while in others only the amount of moisture that can be evaporated in the flue gas without condensing is added. Therefore, dry scrubbers generally do not have wastewater handling/disposal requirements. Dry scrubbing systems are used to remove acid gases (such as SO_2 and HCl) primarily from combustion source.The aim of the paper is to execute CFD analysis in order to obtainan insight of wet and dry scrubber units. The air flow with dust is analyzed in the dry scrubber and water is added for the analysis in the wet scrubber unit.

2.METHODOLOGY/MODEL DESCRIPTION

2.1 Domain extraction

In the encapsulated tank as shown in fig 1 and fig 2, the model is generated as different parts such as dish, pipe, flange and sockets, etc. The required surface for the model is extracted using the domain extraction tools such as ANSA. When the model is assembled with several parts, there will be discontinuities in the surface during the analysis. This needs to be merged together to consider it as the closed volume.

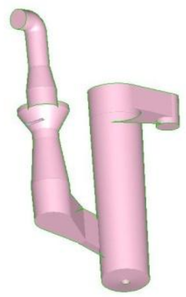


Figure 1: wet scrubber model

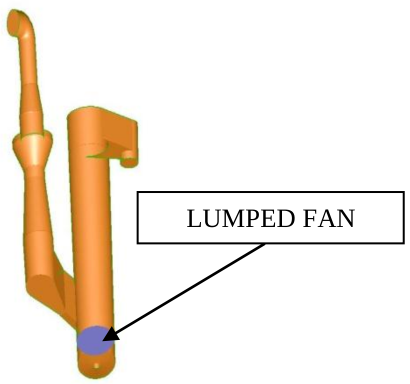


Figure 2 :Dry Scrubber model

2.2 Surface meshing

As shown in fig 3, the cleaned up model is used for surface meshing. The surface mesh is created using the ANSA software. The mesh element type considered for this analysis is tri surface element. Totally about 1,45,589 elements were generated and the maximum skewness of the element is at 0.6 which is clearly indicated in table 1. The term skewness of the element defines the maximum distortion of the element. It can be given as the difference between the angle of the normal element and the distorted element to that of normal element.The skewness of the element should be within the range of 0 to 1. The former is the best form of the element and the latter is the worst element.

Table 1: Building of Mesh

Type	Quantity	Max-Quality
Surface-mesh	1,45,589	0.6
Volume-mesh	6,32,881	0.845

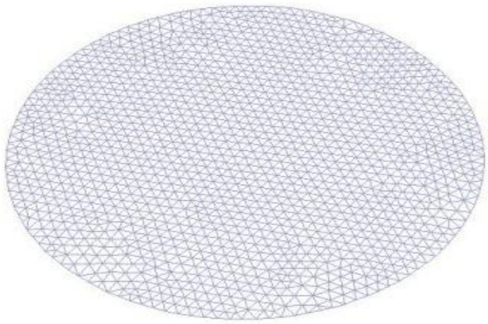


Figure3:Surfacemeshing cut

2.3 Volume meshing

As shown in fig 4, the surface meshed model is used for creation of the volume mesh. Before creation of the volume mesh, the inlet and the outlet boundary conditions are extended from the actual surface for better clarity in setting the boundary parameters. The above model is considered for the volume mesh and it is generated using the ANSA software. The tetrahedrons mesh elements are used here since this is the complex geometry and this element can produce high quality solutions. After creation of the volume mesh, the mesh is corrected in the contoured surfaces so as to avoid overriding of the mesh elements which affects the quality of the solution.

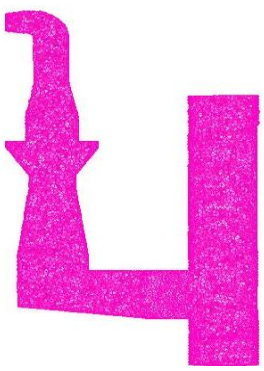


Figure 4: Volumemesh-cut planes

2.4 Solverset up

The fluid is assumed to be three dimensional, turbulent and in- compressible in nature. Steady state solver is used simple algorithm is activated. Segregated solver algorithm is used for pressure–velocity coupling.

2.4.1 Boundary conditions:

- Hot air is assumed to enter the domain with dust, both travelling at a velocity of 40m/s.
- Water is injected through water inlet with a mass flow rate of 0.01kg/s.
- Both the outlets (water outlet and hot air outlet)are modeled as pressure outlet with ambient conditions.
- Turbulent is modeled by K-E realizable turbulence model.
- Hot air is considered to be continuum
- Water and Dust are modeled as discrete phases and solved by DPM(discrete phase modeling)

3.Results and Discussion:

The suction is very low at the center cone which is the mandatory condition for any separator. This is the reason for the separation. Here the lowest pressure expectedat this region is 1.92e3 Paas as shown in figure 5. The pressure drop increaseswith the gas velocity, but the expected relation between the wet and dry scrubber is not apparent for low liquid flow rates. Allen and Van Santen reported that the total pressure drop in the venturi scrubber ismore sensitive to variations in gas velocity than those in liquid low rate. Further, sensitivity increases with the throat length. The present data also shows similar behavior. For low gas flow rates, the effect of liquid flow is very small, but as the gas velocity increases the momentum exchangebetween phase's increases and the liquid influence becomes moreevident. But figure 9 indicates that in the dry scrubber, due to suction generated by the fanthe static pressure pattern differs a little from the wet and less comparatively by around400 Pa. This will enhance the separation of dust. The differences in the dust collector pressure may be due to a higher percentage ofliquid transported asdroplets for a longer period of time. As they contribute to the total pressure drop, this may accountfor the difference between the static conditions. Therefore the trends observed in the pressure drop, may be related with the droplet formation mechanisms.

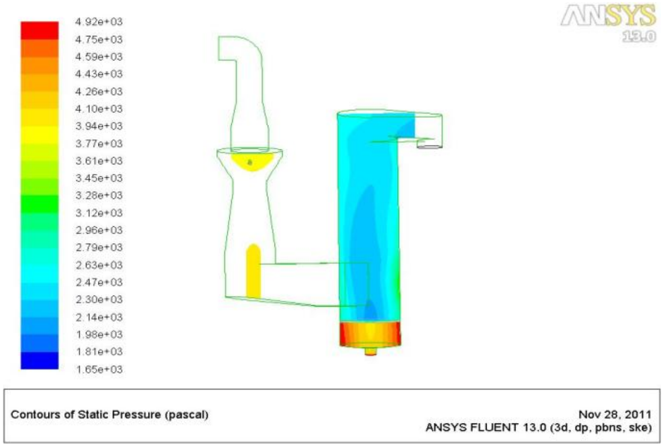


Figure 5Static pressure in wetscrubber

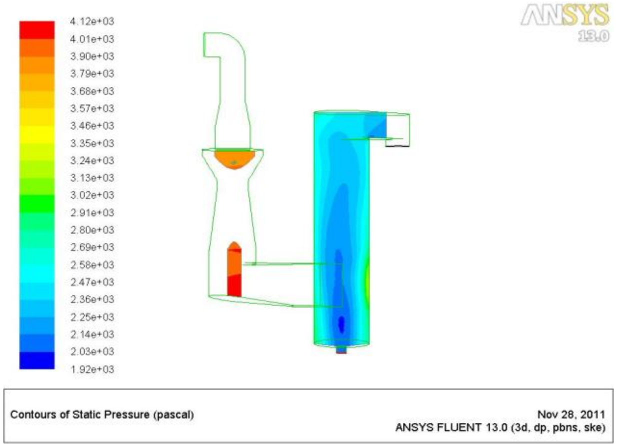


Figure6Static pressure in dryscrubber

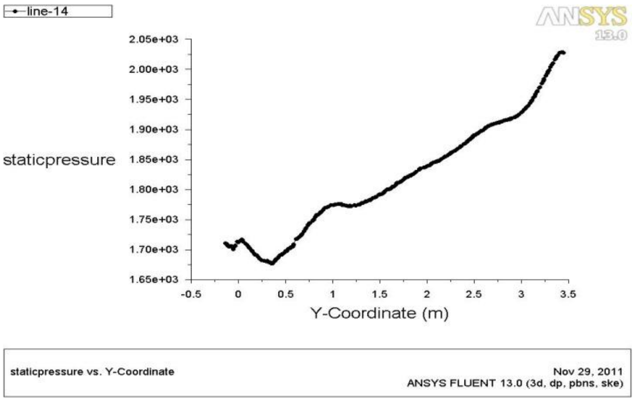


Figure 7Variation of the static pressure in wetscrubber along with its flow rate.

As shown in fig 6,7 and 8 , the converging section of dry scrubber is due to flue gas acceleration. In the throat,only the gas friction contributes to the pressure drop.Most of the pressure drop is recovered in the diverging section.The unaccounted energy is lost by friction.Small differences in the pressure drops are observed between the wet and dry scrubber. The combination of the high gas liquid flow rates favors the dry scrubber system. For the wet scrubber system having low gas flow rates, the effect of liquid flow is very small. But the gas velocity increases the momentum exchange between phases to increase and the liquid influences becomes more evident.

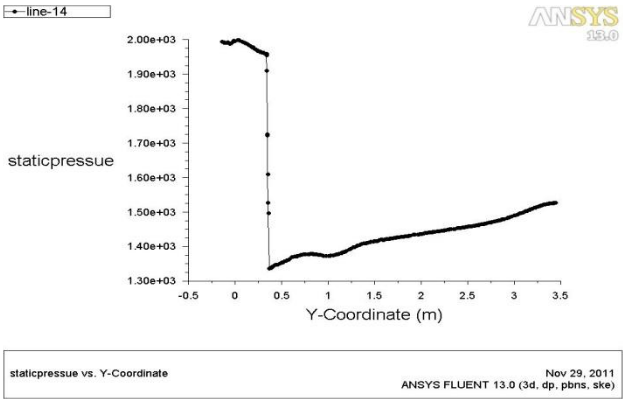


Figure 8: Variation of the static pressure in dryscrubber along with its flow rate.

The main geometrical dimensions of the wetscrubber and dry scrubber together with the flue gas emissions and slurry data of its velocity magnitude are summarized below. Velocity is also very low at the center cone which is the one more mandatory condition for any separator.Here the lowest pressure at this region is 1.88m/s. Moreover the red regions whichare subjected to high velocity will have high erosion. The velocity magnitude is evaluated at every point in the domine.The droplet viscosity has been assumed to vary with the pressure. By comparing Figures9 and 10, one observes that the influence of liquid flow rate upon the pressure drop in the converging sectionis negligible if the liquid is injected as a spray. This is due tothe fact that in this layout the liquid inlet point is further upstream in the venturi. Therefore, a significant fraction of droplet accelerationoccurs upstream of the venturi. The dominediscretization has been simulated. The number of discrete elements has been gradually increasedin order to achieve the independent solution. As shown in fig 11and fig 12 the velocity profile of the gas phase flowing alone across the wetscrubber is strongly modified by the pressure of slurry but in case of dry scrubber, it is quite simple where the flue gas flowing inside the dry scrubber cools down by means ofID fan .It is very economical where the dispersed liquid phase volume fraction reaches a maximum value of 4% increase of efficiency over wetscrubber.The simulation pressure and velocity magnitude agree with this observation.

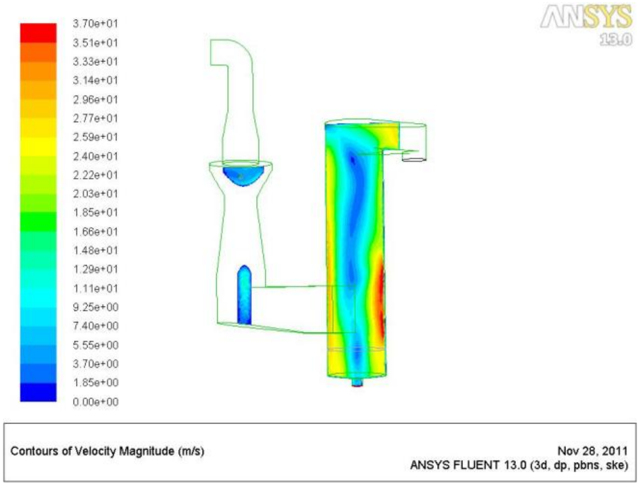


Figure 9 Velocity magnitude of dryscrubber

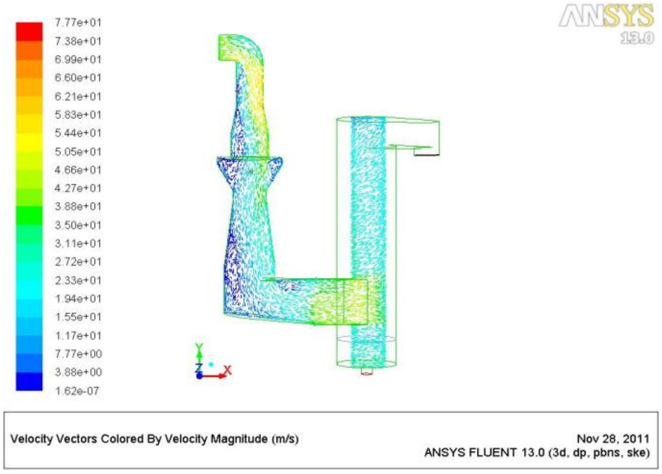


Figure 10 Velocity vector in magnitude.

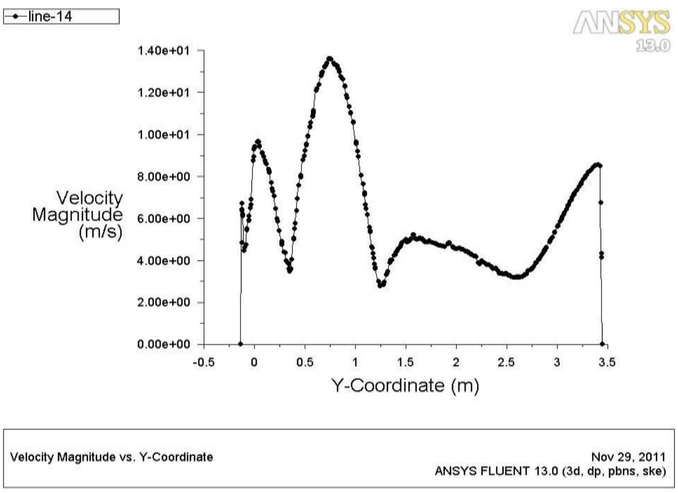


Figure 11 Effect of flow rate velocity magnitude along with wetscrubber

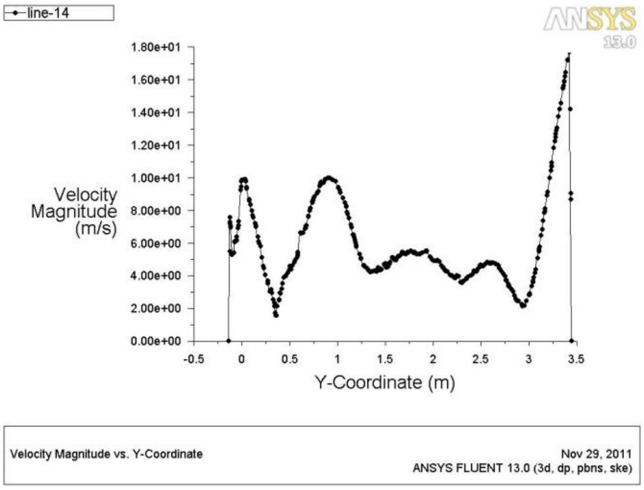


Figure 12 Effect of flow rate velocity magnitude along with dry scrubber

As shown in fig 13 & 14 Path lines are in the form of cyclone which is mainly due to the secondary flow owing to the tangential inlet.The tangential velocity is the dominant component of the gas flow in cyclones, which results in the centrifugal force forparticle separation. Also the development of axial velocity profile in axial direction will be analyzed.The radial profiles of the time-averaged staticpressure, tangential and axial velocity.The tangential velocity distribution in the inner region israther similar at different sections.

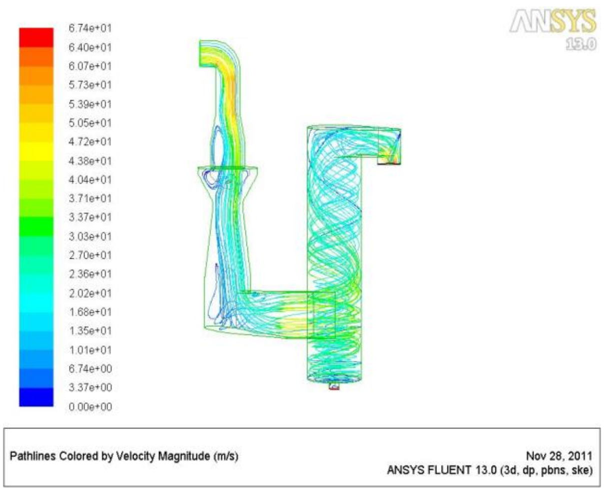


Figure 13The counter pathlines of the velocity magnitude in wetscrubber

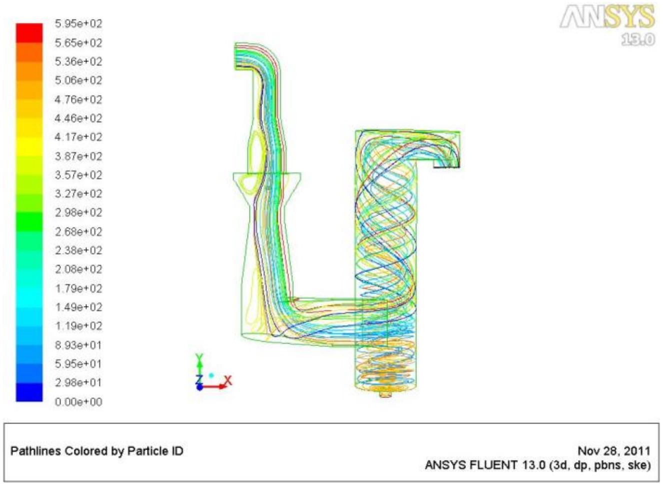
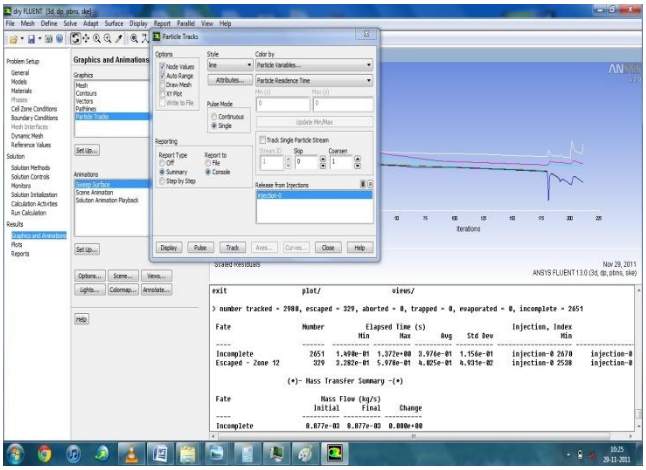
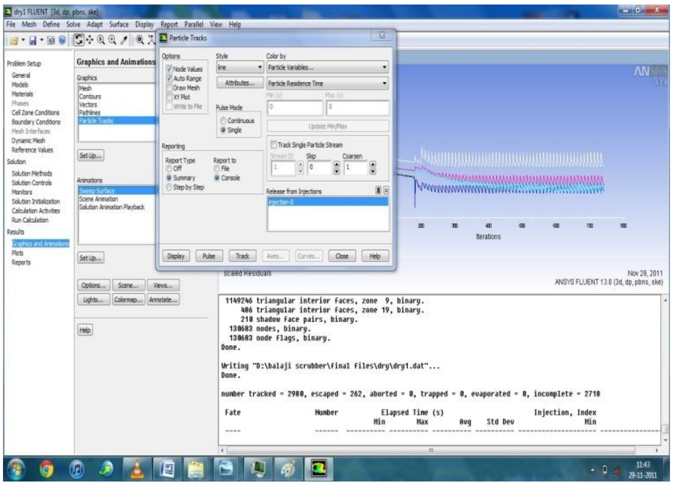


Figure 14The counter pathlines of the velocity magnitude in dry scrubber.





4. CONCLUSION

The analysis for wet and dry scrubber is done for the same boundary condition and fluid conditions. The results are taken and there is considerable variation in both the cases. The suction pressure for dry scrubber is lowered by 300 Pa because of the suction generated which is vivid from the static pressure contour. The velocity is also very much lowered in the centre region for dry scrubber comparing to the wet scrubber. Thus the separation will be enhanced due to this lowered suction pressure. For the wet scrubber case the collection efficiency is about 88.95% where as it is 91.20% for the dry scrubber case for the given boundary condition.Thus itproved the design worth of dry scrubber compared to the wet scrubber.

5. ACKNOWLEDGEMENT

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