Trajectory of Insulating Particles in High Voltage Cyclone Filter

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Abstract **-** The electrostatics cyclone is used for purification of powder and small particles of non conductive materials from air, by using high voltage excitation electrode. The aim of numeric simulation of electrostatics cyclone in2D with finite element method permitted the evaluation of electric field and charge in small insulating particles characteristics of separation. The results show the electric field distribution in cyclone and polyvinyl chloride circular particles with different voltage is presented in this paper. These results help to increase the separation force and the recovery rate of recycling materials with high purity.

Keywords **–** Electrostatics cyclone, high voltage, particules separation, recycling.

I. INTRODUCTION

Recoveries of materials from wastes and purification air from small particles have become a major challenge nowadays. Recycling provides a good source of materials and encourages recovery of valuable materials because reusable nature of metal, legislation and high cost of disposal also encourage recycling [1,2]. All the techniques of separation and purification are based on several physical phenomena like: gravity, flotation or filtration or sedimentation some other technique [1].

Recovery and filtration of powder and small particles from a mixture of waste via least energy source is still a challenge. Eddy current separation is the best technique for separating non-ferrous metallic particles from wastes (such as gold, copper aluminum …. Etc) .

The electrostatic technique is a process able to purify the air from small particle waste of factory industrial and minimize the air pollution of environmentally respectful conditions, at reduced the earth and water pollution. The electrostatic separation technique is based on the electrostatic force generated by electric field on small charged or polarized particles. There are several electrostatic prototype have been developed in this past decades, used to treat the various kinds of particles. This work aims to numerically simulation of electric field in electrostatic cyclone and behavior of very small insulating particles near of high voltage electrode. The numerical simulation model of the electrostatic field is calculated by COMSOL.

II. CYCLONE MODEL

The electrostatic cyclone separator of small particles is composed by : the high voltage electrode supplied by potential of 10KV to 30 KV , the cyclone shape relied to ground , the compressor of polluted air with polyvinyl chloride small insulating particles (Fig. 1).

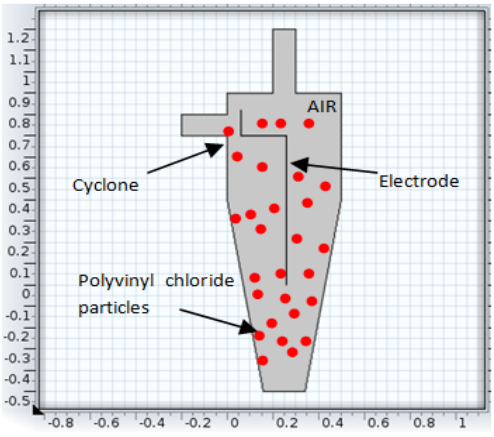


Fig. 1. The electrostatic cyclone.

The particles was feed with initial velocity in electrostatic cyclone, during their movements, the particles will be charged are attracted by an electrostatic force to the ground of cyclone due to the action of the electric field produced by the electrode.

III. FORCES STUDY

The particles suspended in the gas are subjected to different forces, which will allow the migration or cohesion of the dust. The main forces acting on a particle. Coulomb's electrostatic force is responsible for the migration of charged particles to the collection electrode[4]. The flow rate can be broken down into three components. The tangential and axial velocity components are the primary velocity components in comparison to the radial velocity component. This causes centrifugal force for particle separation.
The axial component is responsible for both flow currents (down and up).

This electric field is sufficient to deflect particles to filter through the drifting area of the filter.

Force of gravity : This force is the simplest to calculate, can be expressed by:

$$F_{grav} = m.g \quad (1)$$

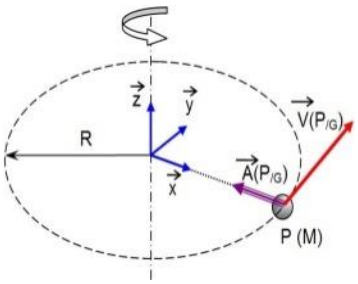
F_{grav} : Force of gravity
m: Mass of particle
g: Acceleration of earth gravity

In the case of very small particles (nano particles), it is possible to ignore the presence of gravity because its order of magnitude is often negligible compared to other forces [7],[9-10].

The Centrifugal Force:

$$F_{cent} = m.w^2.R = m.v^2/R \quad (2)$$

F_{cent} Centrifugal force in newtons (N)
m: Mass of particle
w:Angular velocity in radians per second (rad/s)
R: is the distance from the axis of rotation to the center of gravity of the object, that is the radius of curvature of the trajectory in meters (m).
v: Linear velocity on tangent to trajectory in meters per second (m/s).



Friction Force (Stokes' Law) :

$$F_{drag} = 3\pi\eta d_p v_r \quad (3)$$

F_{drag} : Friction force
v_r: Drop speed limit (m/s)
η: Dynamic viscosity (Pas)
d_p : Particle diameter

Electrical Force (Coulomb Force): The force of Coulomb is expressed by the following relatively simple relation insofar as the electric field is easily calculable in an inter-electrode space [11], [12], [8]:

$$F_{elec} = q_p.E \quad (4)$$

F_{elec} : Electrical force
q_p: Particle charge
E: Electric field.

The expression (4) is the basic equation of the electrostatic force acting on suspended particles in electrostatic precipitators [6].

IV. RESULTS AND DISCUSSION

The electrostatic simulation will be studied numerically using the finite elements method with the COMSOL Multiphysics software is shown in Fig. 2 [6-7].

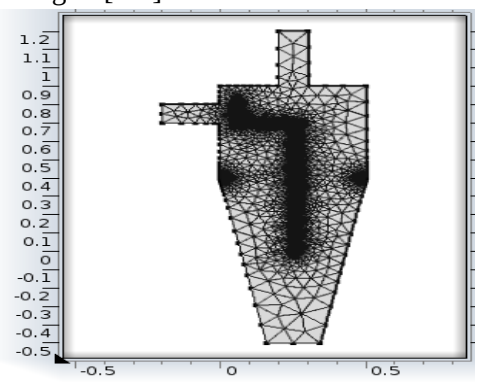


Fig. 2. Meshing of cyclone filer of polluter air in 2D.

Electric Characteristic of the device : the simulation results show strong electric field concentration at the center and near of the electrode (Fig. 3).

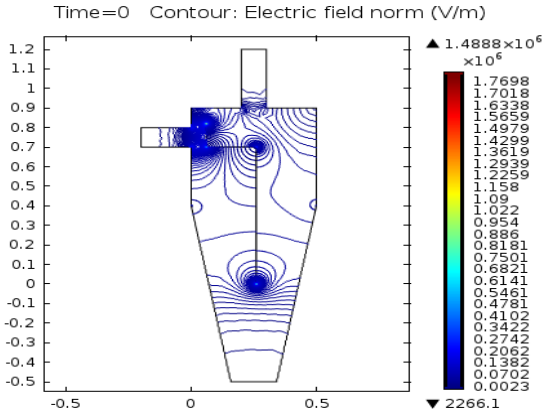


Fig. 3. Electric field in cyclone.

The voltage across the copper electrode is 10KV with frequency of 50 Hz see in the Figure (4). Model results in 2D show simulation the electric potential is concentrate inside the vacuum of cyclone.

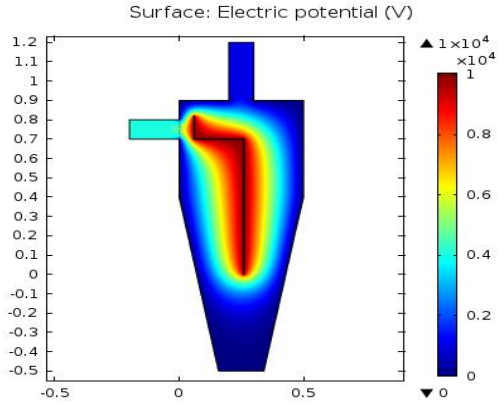


Fig. 4. The representation of electrical potential.

The result of the air flow in the cyclone is shown in figure (3,4), we have chosen the following conditions:

1) The air speed is set at a constant value of 10 m/s.

2) The pressure at the outlet of the cyclone zone is fixed at a constant value equal to the ambient atmospheric pressure 1 atm.

Simulation and processing of results : in order to improve the performance of our cyclone, several simulations were made on different geometries to increase the filtration efficiency and thus avoid disturbances due to the influence of the distribution of the electric field on the trajectory of the particles in the filter.

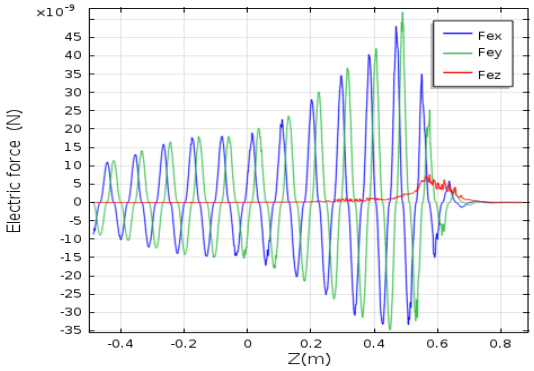


Fig. 5. Calculation result of the electric Force obtained by COMSOL.

The results of the simulation (COMSOL) are obtained. The result of distribution of the electric field for a single configuration is represented in Fig. 6 :

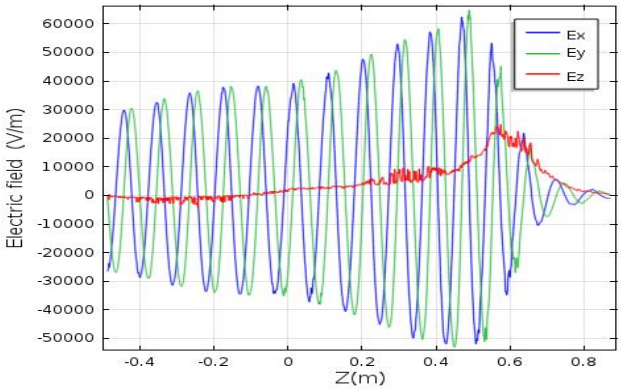


Fig. 6. Calculation result of the electric field obtained by COMSOL

V. CONCLUSIONS

The Finite Element method is more accurate for computation the electrostatic behavior of particles and the performance of cyclone filter. The simulation results show the electric field distribution in the cyclone filter and around the circular small size polyvinyl chloride particles, and the charge of particles. The simulation will promise a new design of other prototype by varying the parameters of device in the future (geometry characteristics, material properties, the force magnitude at the several frequencies as

function of variable size of particle with different velocity, etc…). These results help to increase the filtration force of purification air with important rate at high purity.

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