Use of Nanofilters for the Control of Polution from the Industrial Chimneys

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ABSTRACT

The objective of this study is to elaborate the use of nano filters for controlling the pollution of the industries coming out of the chimneys. The nano filters allow small gaseous molecules to pass trough them. The nano filters are the kind of filters that have the pores of the size 3-20nm.
The main component that is considered most important for the removal from the industrial pollution is NOx, i.e., NO2 or NO. The SCR (Selective Catalytic Reduction) technique can be used for the control of NOx emission from the chimneys of the industries. In SCR technology the mostly used catalyst is Aqueous Urea {in the form of solid particulate form}.The nano filter and the absorber must be used together to control the emission of pollution from industries.

Keywords: Industrial Chimneys[1], NO_X & Soot particles[2], Nano Filters[3], NO_X Adsorbents[4].

1. INTRODUCTION

Our society is now-a days technologically advancing in each and every field. The use of nano technology is increasing very rapidly due to the reduction in size of the technology [ref. 6, 10, 14] along with the increasing speed of work.

Some recent studies have shown that health risks corresponding with the inhalation of NOx are significant. NOx here implies to the oxides of nitrogen, i.e., NO & NO_2. These gases NO & NO_2 are highly toxic and therefore, have to be monitored frequently.

For detecting NO & NO_2 concentrations many approaches have been reported, these include photo ionization and laser included fluorescence, chemiluminescence's method, calorimetric method, semiconductors based gas sensors and many more.

But all these methods are only for the detection of concentration of NO & NO_2 and are also very expensive for their application at industrial level. Out of the methods, the chemiluminescence's method is the most common technique for the determining concentrations of NO & NO_2. This is the method in which NO_2 is converted to NO and then NO reacts with O_3.

This is the most effective method but still the instruments are expensive and unable to control the emission of NO & NO_2.Thus for controlling the emission of NO & NO_2, the concept of nano filters can be introduced. The nano filters can be used for controlling NO & NO_2 along with soot particles (carbon particles).

In an industrial setup the main problem that is arising now-a-days is the pollution level of the place and the pollution check of the industry. The governments of most of the multi cities of the world do not allow the industries with the high pollution rating to install their setup near the residential area due to which the industries have to face a high cost for the manual labor and transport of material. By the help of this project/paper the industries in the major cities of the world such as Delhi, New York, etc. can reduce their level of pollution at a considerable extent. Our findings in this paper may help industries to reduce the level of pollutants such as [NO_X & carbon particles] upto a considerable extent.

The use of nano filters is also seen in few applications of diesel engines to control the emission of soot particles but it can neither be used as such for controlling the emission of NO & NO_2. Thus along with nano filters the adsorbents for NO & NO_2 can also be coupled to prevent the emission of the NO & NO_2 from the chimney of the industry.

The walls of the nano filters shall be coated with the solution of urea at the time of manufacturing so that it can absorb the NO & NO_2 at the time of their emission. This procedure of controlling NO & NO_2 is the method which is cheap and practical in nature and also it is very useful for the mankind. It is thus suggested to be experimented further.

2. PROCEDURE

2.1 Mathematical modeling

A model of particle dynamics equation can be collaborated with air flow model. The organic & inorganic pollutants in the chimney of an industry are expected to be in the gaseous phase. The pollutants are all in the gaseous state and are mixed together to form a gaseous mixture. It is thus very difficult to separate them and treat them to control their emission. Since the walls of the nano filter are coated with the adsorbent which is solution of urea thus the NO & NO_2 gets adsorbed.

In the transportation of pollutants in the multi-stage the temperature do not change abruptly or virtually, thus in the analysis of the flow of polluted air through nano filter the equilibrium is to be considered constant. The mass of the pollutants is described as their concentrations in the air which is flowing through the filter.

The reduction in the pollutant mass in dm filter charge is directly proportional to the amount of pollutants [ref. 22, 23], m, and absorption length, di:

$$-dm = \alpha m di, \qquad (1)$$

where α is the constant known as biodegradation constant. Assuming the pollutant mass before filtration as m_0, and after filtration as m, the following equation can be derived as [Ref. 23]:

$$m = m_0 e^{-at}, \qquad (2)$$

Replacing the mass of the pollutant with the concentrations we get [ref. 23]:

$$C = C_0 e^{-at}, \qquad (3)$$

We see that α, i.e., the pollution degradation constant is a value inverse to the time length during which the pollutant amount in the filter goes down e times.

The equation that describes the pollutant dynamics and the cleaning process occurring in the filter can be derived from the diffusion equation in the biomedium, complementing the equation mentioned above with the member αC, which describes the pollutant biodegradation, assuming that the process are constant, i.e., independent of time span:

$$V\left(\frac{\partial C}{\partial x}\right) + D\Delta C + \alpha C = 0, \qquad (4)$$

where C = C(x,y,z,t) is the pollutant concentration, V is the flow rate of polluted air in the filter, Δ is Laplace Operator. As pollutants move in the filter at a rather high rate in the direction x, the diffusion coefficient D in the equation (4) might be discarded, and now equation (4) becomes:

$$V\left(\frac{\partial}{\partial x} C(x,y,z,t)\right) + \alpha C(x,y,z,t) = 0, \qquad (5)$$

When this type of equation is integrated, we get the following:

$$C(x) = C_0 e^{-\frac{\alpha x}{V}} \qquad (6)$$

If the constant of bio degradation α is known then the equation can be used to determine the efficiency of filtering. The value of the constant α at nano level becomes critical to be derived theoretically and also fails to bring good result, thus the value of the constant should be derived experimentally.

It is necessary to find out the dependence of the cleaning efficiency, i.e., efficiency of the filter to clean the air passing through it, on the filter parameters. Applying the law of conservation of mass the following equation can be obtained [ref. 23]:

$$(1/\in)(VC_{x1} - VC_{x2})\, S\, \Delta t = [(C+\beta)_{t2} - (C+\beta)_{t1}] \in Z\, \Delta x \qquad (7)$$

Here:
C is pollutant concentration,
$\in$ is the filter porosity,
β is the filter absorption capacity, i.e. , the amount of NO & NO_2 absorbed in $1m^3$ of filter,
t_1 is the moment when NO & NO_2 get into the filter,
t_2 is the moment when NO & NO_2 leave the filter,

In equation (7), passing over the margin, when $\Delta x \to 0$ and $\Delta t \to 0$, and taking into consideration the pollutant infusion, we obtain the following:

$$V\frac{\partial C}{\partial x} = -\frac{\partial}{\partial t} \in^2 (C+\beta) + D\frac{\partial^2 C}{\partial x^2}, \qquad (8)$$

where $\in$ is the porosity of the filter.
Let us consider β as a constant since it represents the absorption capacity of the filter and hence can be taken as the fixed numeric value. Thus by the rules of simple

differentiation, the value of $-\frac{\partial \beta}{\partial t} \in^2$ will be zero.

Now the equation (8) becomes:

$$V\frac{\partial C}{\partial x} = -\in^2 \frac{\partial C}{\partial t} + D\frac{\partial^2 C}{\partial x^2} \qquad (9)$$

Hence after re-arrangement we get the following equation:

$$D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} = \in^2 \frac{\partial C}{\partial t} \qquad (10)$$

Now applying the method of separation of variables to solve the differential equation we get the following result:

$$C = A_1 e^{-\frac{p^2}{\in^2}t}\left(A_2 e^{\frac{V+\sqrt{V^2-4Dp^2}}{2D}x} + A_3 e^{\frac{V-\sqrt{V^2-4Dp^2}}{2D}x}\right) \qquad (11)$$

Here, A_1, A_2, A_3 & p are the constants of integration.

2.2 Manufacturing of nano filters

The polyester filter is generally utilized in the experiments. It is usually 4.5 mm thick. Images of a filter cross-section taken on a Scanning Electron Microscope and analyzed .The measured porosity are generally of 0.882 ± 0.003. The filter diameter is generally very uniform, as can be seen in Fig. 2(a). A mean diameter of 16.0 ± 1.0 m was obtained by image analysis. The mean filter diameter was adopted as constant for the whole filter bed.

The particle (urea solution) laden gas can be obtained with the use of the TSI Electro spray Aerosol Generator. This device can be used to generate monodisperse nano metric particles, at a concentration of 107particles/cm^3 and a flow rate of 0.2–2.5 l/min.

The efficiencies of the filters could be obtained by counting the particles before and after the filter, using a TSI Condensation Particle Counter. The tests should be accomplished at gas velocities varying from 0.03 to 0.25 m/s and at an ambient temperature of 25 ◦ C.

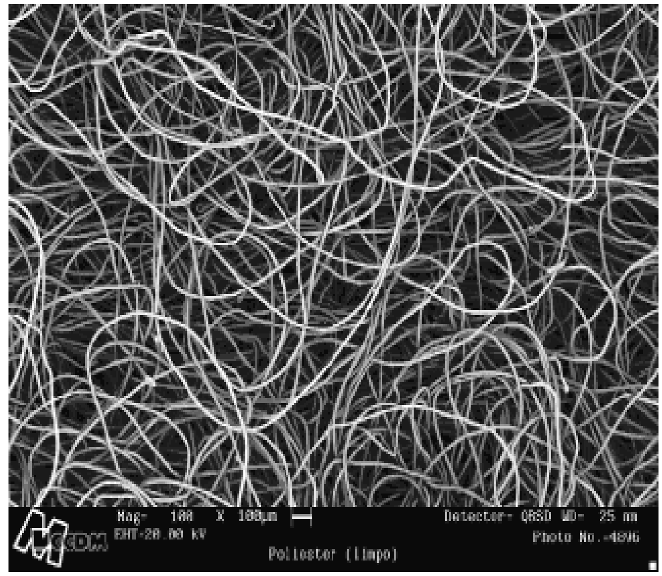

Fig.1 The polyester felt utilized in this work (100×).

This movement happens even in a stationary gas, with constant particle concentration. The physical principle here then differs from the diffusion mechanism that relies on a concentration gradient. This chaotic movement can be associated to the particle as an 'effective' diameter, once the particle is actually occupying a volume which is higher than its own [see Fig. 2(a); (b)]. Therefore, when reaching the vicinity of the fiber surface, the particle will be collected if this 'effective' diameter, rather than the particle actual diameter, is accounted for in the interception parameter. This 'effective' diameter can be estimated by the average dislocation of the particle during the time it spends close to the fiber surface, which is a function of the fiber diameter and of the gas velocity.

These urea particles will form a coating on the surface of the surface of the walls of the nano filter and on cooling at a specific temperature this coating will become ready for the control of the emission of NO & NO_2 for industrial purpose. The brown and blue portion in the figure denotes the sudden decrease in the concentration of the NO_X particles in the polluted air.

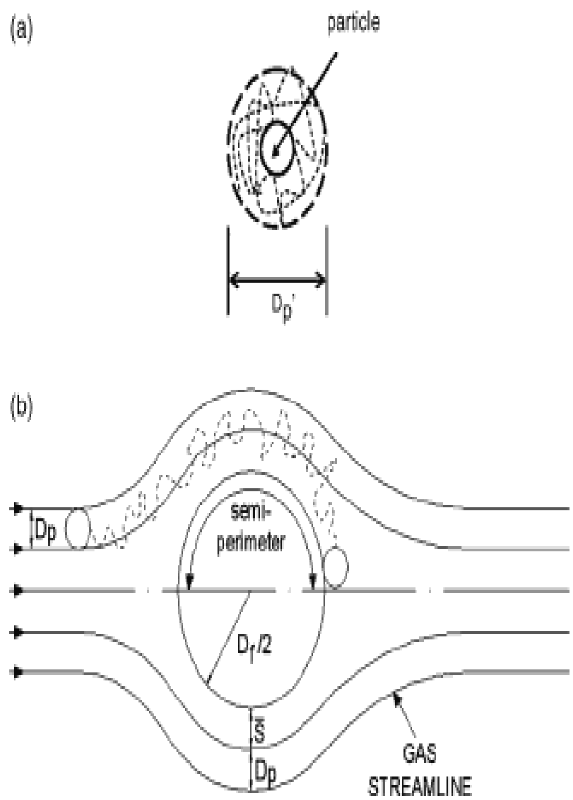

Fig.2 (a) The 'effective diameter' (b) Schematic view of the particle path close to the fiber surface.

3. RESULTS AND DISCUSSION

Referring to equation(7) it can be noticed that the efficiency of the nano filter decreases strongly with increasing particle size. Also, the efficiency decreases with increasing gas superficial flow rate. Both trends indicate the predominance of the diffusion collection mechanism in the studied range. The theoretical prediction of the filter efficiency can easily be calculated utilizing Equations (1)–(8). The equations (9)-(11) can be easily used to calculate the concentration of the oxides of Nitrogen in the air. Observing the equation and considering the values of diffusion coefficient and flow rate of oxides of nitrogen as researched and obtained previously, then we can get the graph between time, distance traveled by the air and concentration [Fig.3]. The theoretical predictions should be compared to the experimental data obtained in this work. It can be noticed that the prediction may tend to overestimate or underestimate the results, especially for the smaller efficiencies. However, the molecules of NO_x are suspended in the carrier gas, and are subjected to random displacements due to molecular collisions with the gas, resulting in the well known Brownian motion. It is widely known that this phenomenon is in the deep of the diffusion mechanism and is accounted for. The physical concept from which equations are derived is based on the classical diffusion transport mechanism. It is assumed that a concentration difference within a fluid creates a driving force from the high to the low concentration region. As the fiber surface collects the particles, their concentration in the vicinity of the fiber surface approaches zero and therefore a concentration gradient between the bulk of the fluid and the fiber surface is established.

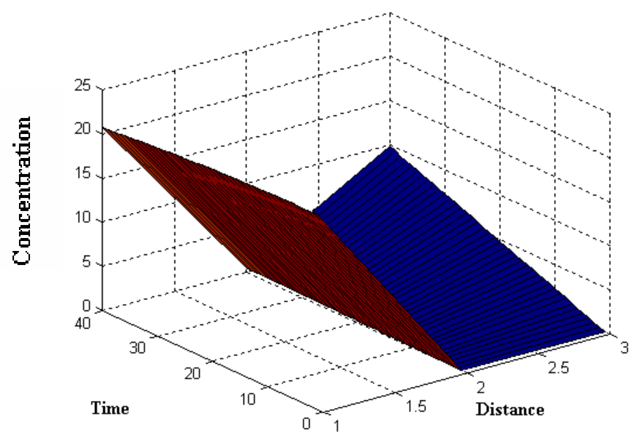

Fig.3 Graph showing relation between Concentration, Distance and time

4. CONCLUSION

The nano filters are not yet used for the control of the emission of the NO & NO_2 at the industrial level, but these nano filters must be used for this industrial application because they have the capability of removing the main components of the polluted air emitted from the industrial chimney. The nano filters have a high efficiency for removing the pollutants from the polluted air. Thus they can be effectively used for the control of pollutants in the industrial chimney. Not only this but the nano filters can also be utilized for the control of the main components of the polluted air, i.e., NO & NO_2. These components of the polluted air are very harmful to the living creatures and add up a lot to the destruction by the pollution. But these filters can not be as such utilized in the control of emission of NO & NO_2. This is because the nano filters have pores of the size of the order of 10^{-9} m which is larger than the size of the molecules of NO & NO_2. Therefore the walls of the filters must be coated with the solution of absorbent which can absorb or adsorb the molecules of NO & NO_2. This concept of using nano filter technology for the control of NO & NO_2 must be further experimented.

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