INFLUENCE OF PARITICLE CHARGING ON THE PERFORMANCE OF FABRIC FILTERS

Allan S. Issangya
Dept. of Chemical Engineering, University of British Columbia,
2216 Main Mall, Vancouver, B.C. V6T 1ZA, Canada

ABSTRACT

The electrical resistance of a dust cake formed on a filter cloth from a pre-charged limestone powder has been measured. the cake samples were filtered off the gaseous suspension in a separate test rig at a number of filtration speeds and levels of particle charging. Charging of the particles prior to filtration was found to lead to the formation of a cake which has a higher electrical resistance compared to the one filtered from unchange particles. This is in agreement with pressure drop measurements reported in the literature which showed a lower aerodynamic resistance for cakes of charged particles. Resistance of cakes of charged particles obtained at different filtration speeds indicated a possible presence of a critical speed below which the resistance remained more or less constant and beyond which it increased continuously.

INTRODUCTION

The principles of particle separation from a gaseous stream are generally classified according to the nature of the forces involved. These forces may be external forces due to fields of acceleration which are external to the gaseous suspension, such as gravity, electrostatic or magnetic forces, or internal forces due to fields or effects which take place within the suspension itself, such as inertial or centrifugal forces, diffusion, coagulation electrostatic effect of charged particles, etc. A gas cleaning equipment often combines two or more of these principles in one unit and the classification of the equipment does not necessarily follow the same pattern. The most common classification falls into the following four groups [1]. first are aero-mechanical dry separators in which gravity or inertial effects prevail, e.g. settling chambers, cyclones, etc... Second are aero-mechanical wet separators which make use of diffusional and inertial effects, e.g. scrubber. Third are electrostatic precipitators which utilize electrostatic and gravity forces. And lastly, are filters which use inertial and diffusional effects, e.g. sand filters, inertial fibrous filters, fabric filters, etc.

In the recent past a lot of attention has been directed at the enhancement of fabric filters by the use of electrostatic forces [2,3,4]. This is due to the need of developing a combination type filter which incorporates the advantageous aspects of conventional electrostatic precipitators and the conventional fabric filters thereby producing a hybrid device with performance characteristics superior to those of either one alone. Successful separation in electrostatic filters occurs only for particles having moderate electrical respectivities [5,6]. For a resistivity of less than about 10^6 Ωm, depending on the particle size, the particles discharge on contact with the ground electrode, acquire a charge of the opposite sign and are repelled from the surface. Though a drawback in this aspect, the effect can be used advantageously in the mining, industry to separate high resistivity rock from the low resistivity one. On the other hand, if the resistivity is greater than typically 10^{11}Ωm a localised electrical breakdown known as back discharge or back corona occurs in the precipitated layer. This acts as a source of ions to the main discharge space of opposite polarity to those normally present, leading to charge neutralisation which degrade collection efficiency and waste electrical power.

The method of electrical enhancement of fabric filtration has been in the form of charging the particles prior to filtration or applying an external electrical field on the particles and fabric or in some instances combining both. Fabric filter s are less sensitive to changes in the type of dust handled and no evidence yet exists of the type of resistivity effect of the sort described for electrostatic precipitators above [2]. They also have an additional advantage in the control of toxic emissions when combined with suitable pre-coatings.

The chief manifestation of the improve performance of a fabric filter attributable to electrical charge deliberately added to the dust by a corona charger is [3,7] a reduced pressure drop across the fabric for a given dust load collected on the fabric. This means, therefore, extended filtering periods before dust clean-off are attained. The reduced therefore, extended filtering periods before dust load collected on the fabric. This means, therefore, extended filtering periods before dust clean-off are attained. The reduced pressure drop is due to at least two mechanisms. First is a dust cake porosity effect in which the charged dust forms a layer of reduced aerodynamic resistance compared to that of an equal mass of an uncharged dust forms a layer of reduced aerodynamic resistance compared to that of an equal mass of an uncharged dust layer. The second is a pre-filter dust removal by the corona charger similar to the action in an actual electrostatic filter that reduced the total mass reaching the fabric filter. Accompanying this pre-filter action is a charged particle size distribution of the dust reaching the fabric because some or all of the bigger particles are removed at the corona charger. This means that only the smaller particles are reaching the fabric. In normal filtration it would be expected that these particles would build a more dense cake on the filter and therefore a higher pressure drop. This is, however, not the case for charged particles. In experiments where the pre-filtering effect was minimised by modifying the charger design [7] a lower pressure drop was also observed. It is most probable, therefore, that the presence of charge on the particles leads to the build-up of a dust layer with altered properties in comparison to neutral particles. The charged dust either forms a more porous layer (a depth effect) or deposits in non-uniform clumps (surface effect). the later was found to be the case in the case in the results of Linoya et al. [8] on the surface appearance of calcium carbonate deposits.

The influence of the amount of charge on particles on the pressure drop has indicated that [9] the aerodynamic resistance of a given total dust mass on the fabric is reduced when that dust is deposited with a higher electrical charge. However, this influence becomes negligible when filtration takes place at a high relative humidity. This loss of electrical enhancement at high relative humidity cannot be attributed to the back corona degradation since moisture presence decreases the dust resistivity and thus will correct rather than aggravate back corona problems. The most plausible explanation [9] is that an electric filed must exist at the fabric surface in order for a reduced aerodynamic resistance to be realised. In other words, these charges, once deposited on the fabric surface along with the collected dust, must accumulate in sufficient quantities to influence the properties of subsequently arriving charged particles. The value of the accumulated charge and consequently, the electric field on the fabric depends not only on the dust feed rate and dust charge but also on the electrical resistance of the dust layer. In an effort to obtain more insight into the phenomenon of electrical enhancement of fabric filtration, this work investigates the influence of charging the particles prior to filtration on the electrical resistance of the dust layer formed on the fabric surface. The influence of filtration speed on resistance is also determined.

EXPERIMENTAL

Fig. 1 shows schematically the experimental apparatus which consists of a resistance measurement cell connected to an air conditioning apparatus. the cell consists of two hollow cylindrical aluminium parts and a filter element. the filter medium made of needled polyester material has an effective area of 154 cm^2. Two parallel wire electrodes (1 mm diam, 70 mm long) are fastened 700 mm apart on the filter cloth using a cotton thread. To obtain a dust deposit, the filter element was initially installed in the filtration pilot unit shown schematically in fig. 2 and filtration carried out at pre-set operating conditions. A number of other studies are also conducted on the test rig. These include, among others, influences of gas velocity, filtration time, charging of particles prior to filtration, applying of an external electric field on the particles and fibre, etc. on the cleaning efficiency and pressure drop. The air conditioning apparatus consists of a tube heater (a flexible tube surrounded by an electrical heating coil) and a water flash bottle immersed in a water bath. A stepwise increase in the water bath temperature regulates the relative humidity of the conditioning air. Additionally, the cell is covered with a heating mat. For cases requiring a dry atmosphere a silica gel bed was used in place of the water bath. After forming the dust cake on the filter medium the filter is transferred to the cell which is thereafter connected to the air supply line. the temperature and relative humidity of air were measured simultaneously by a problem inserted in the cell. After the cell had attained thermal equilibria, the electrodes were connected to a high DC voltage source and the resulting current measured with a high sensitivity electrometer (Keithley 610C - measures as low as 10^{-13} A). Resistance is then calculated as the ratio of voltage to current. Most dusts and fumes handled in industrial filter applications originate from smelters, furnaces, dryers, calcines, etc. and are bound to be composed of other chemical components such as oxides, silicates, etc. and not water vapour alone [11,12,13,14]. The apparatus described above is therefore expected to be suitable for measurements which may involve chemical conditioning of the dust. This paper reports the results obtained in a dry atmosphere for limestone powders of mean sizes 2.2. and 4.2 μm, denoted here as F1 and F2, respectively.

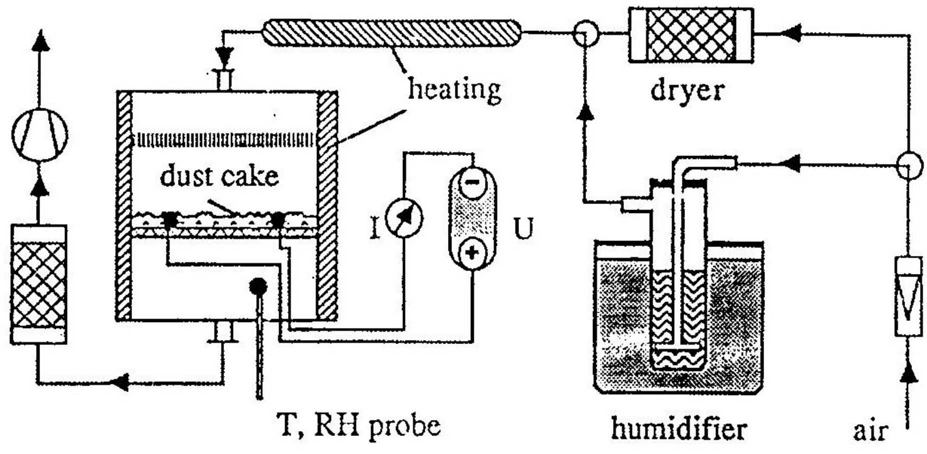

Fig. 1 Schematic diagram of the resistance measurement apparatus

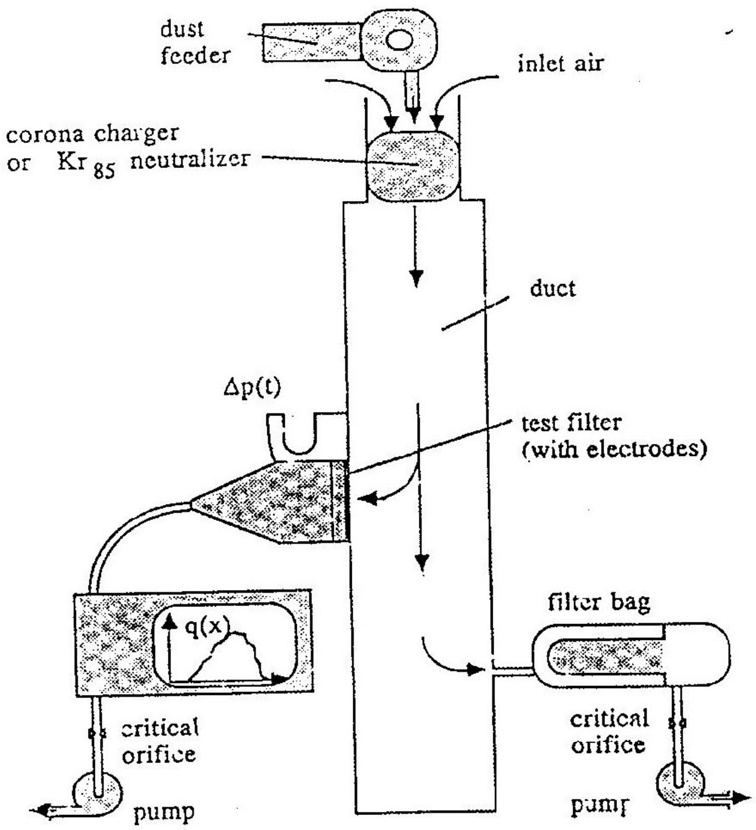

Fig. 2 Schematic diagram of the filtration test rig

The resistance measured here is the combined resistance of the dust cake and filter medium holding it between the two electrodes. The evaluation of the resistivity of the dust cake requires its thickness to be known. direct measurement of the thickness was, however, found to be complicated. Assuming that all the separated dust layer lies only on the surface of the filter medium its thickness h could be obtained as

$$h = \frac{W}{\rho_c(1-\varepsilon)+\rho_a\varepsilon} \approx \frac{W}{\rho_c(1-\varepsilon)} \qquad (1)$$

where W is the areal mass density of dust, ε the priority of the cake ρ_a and ρ_c are the densities of air and the dust particles, respectively. This may not be a bad assumption in fabric filtration because the initial dust layers actually serve as the primary filtration medium for the subsequent filtration, the role of the fabric, being primarily that of initiating a support structure for the build up of the layer [3].

Equation 1 includes porosity as one of the parameters. Porosity is however, not uniform over the cake thickness [3] and typical values range from about 0.79 near the filter medium to about 0.89 in the higher regions of the cake. With these difficulties of specifying the resistance rather than the resistivity itself. One way of isolating the cake resistance would be to look for a suitable calibration procedure of the cell to eliminate the cloth resistance.

RESULTS AND DISCUSSION

Influence of filtration velocity

Dust cake samples of equal mass areal density (about 525 gm_2) were obtained at three different filtration velocities; 69, 165 and 223 m/h. Their electrical resistance together with that of a clean filter cloth were measured at different temperatures in relatively dry conditions and are plotted in Fig. 3. In all instances resistance decreases with temperature which is typical of all dielectric materials [14,16]. It is also observed that the electrical resistance of a clean filter medium is much higher (of the order of 10^3 higher) that of a loaded filter under similar conditions, which means therefore, that no significant error is expected by neglecting the contribution of the fabric resistance in the total resistance. As regards filtration speed, the resistance of the cake obtained at the highest superficial air velocity is about 50% lower than that of the other two cake types. this indicates a build up of a more compact cake at higher velocities. the similarity in the resistance of the samples filtered at the lower velocities. The similarity in the resistance of the samples filtered at the lower velocities indicates a possible existence of a range of filtration speeds in which the cake porosity remains unaffected by the velocity. More data re required to confirm this occurrence.

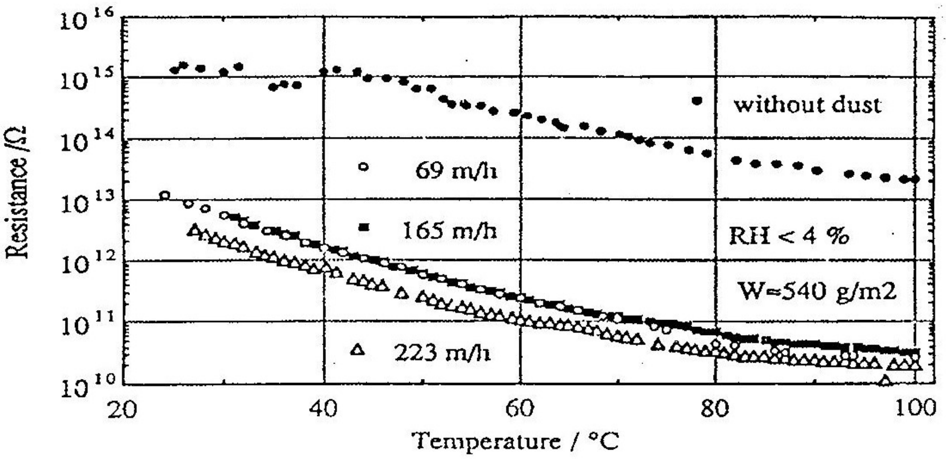

Fig. 3 Resistance of cakes collected at different filtration velocities

Influence of charging the particles prior to filtration

To determine this effect the resistance of cakes from dusts which had been pre-treated as described below were measured.

Notation	Treatment
O0	Normal powder without any pre treatment
Q0	The Natural charge existing normal powder was neutralised by a Kr - 85 radioactive source
K0	The powder was electrically charge by a corona charger (-25 kV)

Filtration was done at a gas velocity of 128 m/h and electrical resistance measurements were made in a dry atmosphere at a number of different temperatures. Results are plotted in Fig. 4 and Fig. 5 where it can be seen that, whereas the electrical resistance of cakes of the neutralised samples (Q0) is lower than that of the normal/untreated particles (O0), that of cakes of charged particles is much higher than that of the other two. In other words, the cake from the least charged dust possesses the least electrical resistance and vice versa. although the mass deposited per until area is not exactly the same for all the samples under comparison the charge influence is vividly observed if resistance is plotted against dust loading for the three charge level scenarios (Fig. 6).

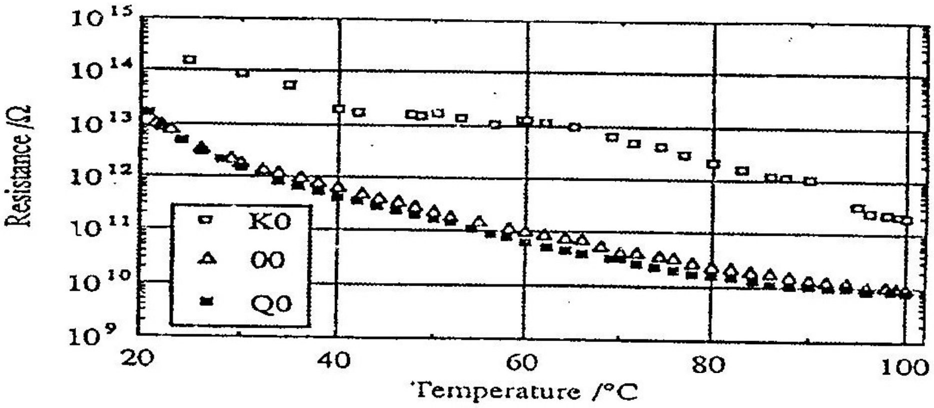

Fig 4. Influence of charging particles prior to filtration on cake resistance (Limestone F1 loading; 290(Q0), 372(O0) and 340 (K0) g/m2)

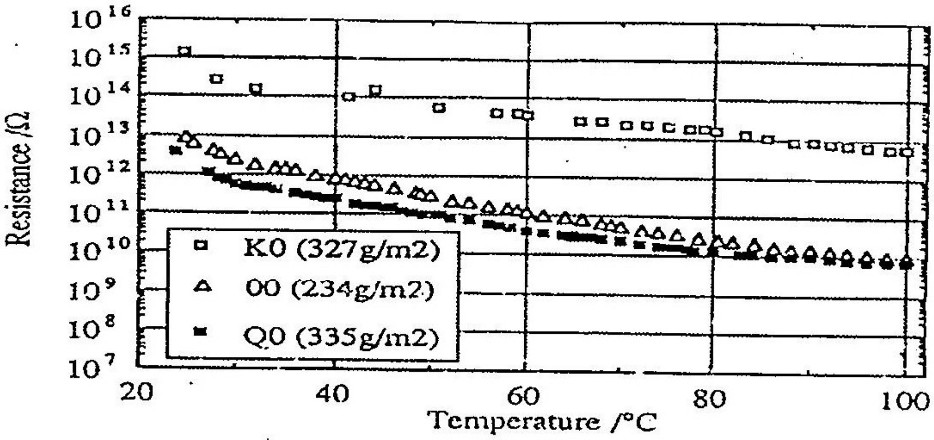

Fig. 5 Influence of charging particles prior to filtration on cake resistance (Limestone F2)

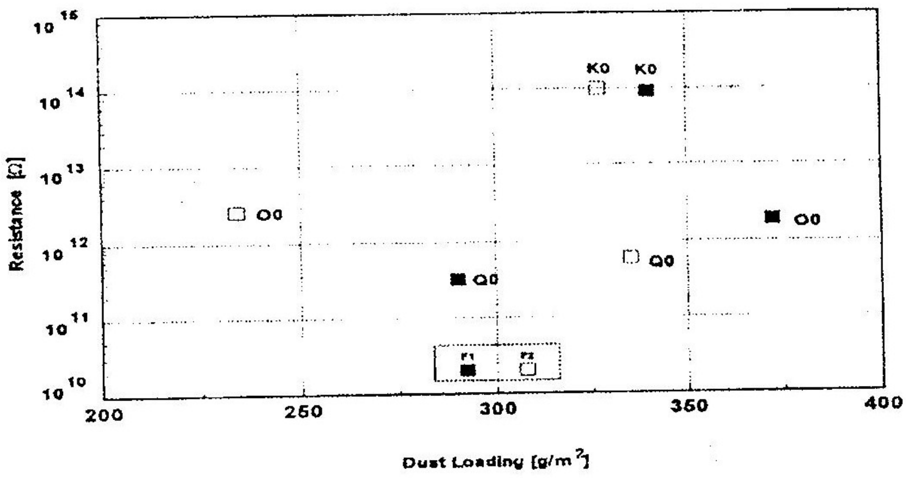

Fig. 6 Influence on cake resistance of charge levels present on particles prior to filtration at 30 oC

The higher electrical resistance of the cakes filtered from charged particles indicates that they are less compact compared to those from uncharged or less charged dusts and consequently will have a lower aerodynamic resistance. this observation is in agreement with the results quoted above which indicated that the presence of charge on the particles leads to the formation of a dust cake of altered properties compared to neutral dusts. Since the physical structure of the cake was not studied in this work it is not readily evident that the lower electrical resistance was a result of the build up of a uniform, more porous cake or the particles agglomerated to form isolated l non - uniform clumps.

CONCLUSION

Resistance measurement for dust cakes formed at a number of filtration velocities indicate a possible existence of a critical speed below which the cake resistance remains unaffected by the filtration speed.

Both the resistance of the filter medium and the limestone powder decrease continuously with temperature, a characteristic property of dielectric materials.

Charging of particles prior to filtration leads to the formation of a cake with a higher electrical resistance compared to that from uncharged particles, a fact which supports other observations of reduced pressure drop across cakes filtered from l charged particles.

Father work to characterise the structure of the cake is recommended so that a more fundamental understanding, prediction and control of electrically enhanced fabric filters can be achieved.

ACKNOWLEDGEMENT

This is part of the work I performed at the *Institut für Mechanische Verfahrenstechnik und Mechanik,* University of Karlsruhe, Germany. I sincerely thank DDAD for assisting me financially and Dr. E Schmidt for the useful discussions we had during the course of my work at the institute.

NOMENCLATURE

q	charge	Coulomb
t	time	s
h	cake thickness	m
W	dust loading	kg/m^2
p	density	lg/m^3
	porosity	[-]
Δp	pressure drop	N/m^2

Subscripts

a	air
c	dust cake

REFERENCES

1. L. Svarovsky, Solid - Gas Separation - Handbook of Powder Technology, Vol.3, Elsevier, Amsterdam, 1981.
2. R.P. Donovan, Fabric Filtration for Combustion Sources, Marcel Dekker Inch.,New York, (1985), 307 - 308.
3. E. Schimidt, and F. Loffler, Forsch. Ber. 01VQ871/3, Un. Kalsruhe, (1989)

4. Particulate emission and operating characterization of electrostatically enhanced fabric filter pilot plant, CS - 5196 Res. Proj. 725 - 12 (1987).
5. H.J. White, Resistivity Problems in Electrostatic Precipitation, *J. Air Poll control Assoc*, **24** (4), (1974).
6. J. Benitez, Chapt. 9 in Process Engineering and Design for Air Pollution Control, Prentice Hall, New Jersey, (1993).
7. See [2] p. 298.
8. Y. Mori, Effects of Corona Precharger on Performance of Fabric Filter, *J. Chem. Eng. of Japan*, **15**(3), 211 - 216, (1982).
9. See [2] p. 324.
10. R.E. Bickelhaupt, surface Resistivity and the Chemical Composition of Fly Ash, *J. Air Poll. Control Assoc.*, 25(2), (1975).
11. S.D.P. Kincar - Djurdvevic, Untersuchungen zur Änderung des elektrischen Widerstandes von Flugasche bei Sorption von Gasen und Dämpfen - Möglichkeiten zue Verbesserug der Entsaubungsgrade von Elektrofiltern. Teil 1 - Neue Mebzelee zur Änderugnsmessug des elektrischen Widerstands bei der Reinhalt, Luft 37 (1977) Nr 6.
12. See 15 - Teil 2 - Einflub der wasserdampfsorption auf die Änderung des elektrischen Widerstandes einiger Flugaschebestandteile, Staub - Reinhalt, Luft 37 (1977) Nr 8.
13. B. Hoffmann, Einflub der Mahlbendingungen auf den elektrostatischen Widerstand von Stauben der Zementindustrie, Staub-Reinhalt, Luft 39 (1979)Nr 6.
14. M.E. Fayed, and L. Ottne, Handbook of Powder Science and Technology, Van Nostrand Reinhold, New York, NY, (1984).
15. W. Simm, Untersuchungen über das Rücksprühen bei der elektrischen Staubabscheidung, *Chemie-Ing. - Tech.*, 31 (1959) Nr 1.
16. Genormte Widerstandsmessungen an hochohmigen, antistatischen und leitfahigen nicht-metallenen Werkstoffe, Fetronic GmbH, Langenfeld.

The manuscript was received on 6th January 1994 and accepted for publication on 5th December 1994.