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Electrostatic Bifilar Deduster for Organic Dust Removing

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This paper presents a new solution to unconventional use of bifilar windings. Usually, they are used in metrology because this kind of windings has no inductance. Bifilar windings supplied with DC or AC voltage generates heterogeneous electric field around. This field induces charges in surrounding dielectric particles. The effect of this influence is in the form of mechanical forces attracting particles in the heterogeneous field generated by the winding.

Keywords: Bifilar windings, dust removal, electrostatic precipitators.

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Introduction

Rapid industrial development results in natural environment changes. Industrial waste results in the degradation of many ecosystems. One of key tasks is cleaning of the air from the pollution originated from different industrial processes. The most noxious industry applies electrostatic separators called electrofilters.

Dust removal from gas can be performed by means of dry and wet methods. In the result of dry methods the final product is a solid object of the same physical properties as the primary dust. Wet methods give wet solid particles or suspensions.

In general, dedusters can be divided into mechanical filters and electrostatic separators.

Electrostatic precipitators are very efficient in dust removal and consume little energy. They are also useful in a wide range of temperatures and dust concentration. However, some disadvantages limit their use, i.e.: large dimensions, substantial capital investments, high voltage requirements and the risk of explosion which excludes the use of explosive dusts.

The subject of the research is an electrostatic filter the construction of which is based on bifilar windings. The important problem in agri-food industry is air pollution caused by dielectric dust particles of plant origin generated in mills, feed mixers, etc. Agri-food industry does not find use for electrostatic separators because of corona discharge. This phenomenon is dangerous because plant dusts are explosive anyway. That is why, mostly mechanical bag filters are used in agri-food plants. These fabric filters increase the required fan power because of the frictional drag of the fabric and they make the fan load vary because of the dust residue on the fabric. It is then necessary to clean filters quite frequently, and thus to switch them off [2].

This inconvenience and common applications of electrofilters in other fields of industry direct the research towards new electric methods of dust removal allowable in food industry. The research is focused on bifilar filters operation at voltage below partial discharges (Fig. 1).

The dusts of plant origin are usually dielectric. Their molecules consist of symmetrically distributed charges. They have electrical dipole moment in electric field [3]. The influence of heterogenous electrostatic field of the winding on charges induced in particles causes the forces that attract the dust to the winding surface. The attraction force depends on the intensity of the electric field and on free charge quantity that, in turn, depend on dust electric properties [3].

It follows from the equation (1) that the attraction force and thus the effectiveness of bifilar filters in the system of electrodes in Fig.2 is influenced by the construction of the system of electrodes (diameter, distance between electrodes, dielectric permittivity and insulation conductivity) and dust particle parameters (dimensions, dielectric permittivity and conductivity) [7].

$$F_e = \frac{\varepsilon_0 \varepsilon_1 U^2 S_{ef} \cos\frac{\alpha}{2}}{\left(2\delta + 2l_3\sqrt{\frac{\gamma_1^2+\omega^2\varepsilon_0^2\varepsilon_1^2}{\gamma_3^2+\omega^2\varepsilon_0^2\varepsilon_3^2}} + l_2\sqrt{\frac{\gamma_1^2+\omega^2\varepsilon_0^2\varepsilon_1^2}{\gamma_2^2+\omega^2\varepsilon_0^2\varepsilon_2^2}}\right)^2}, \quad (1)$$

where: F_e – dielectric particle attraction force, N;
ε_0 - permittivity of vacuum ($8.85\cdot10^{-12}$ F·m^{-1});
ε_1 – dielectric permittivity of environment, ε_2 – permittivity of attracted dust particle, ε_3 - permittivity of

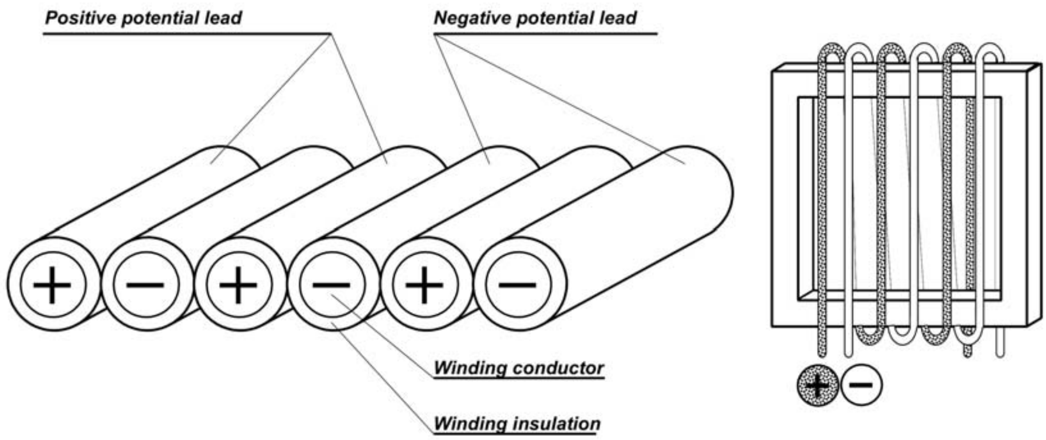

Fig. 1. Configuration of bifilar winding wires and filter frame arrangement.

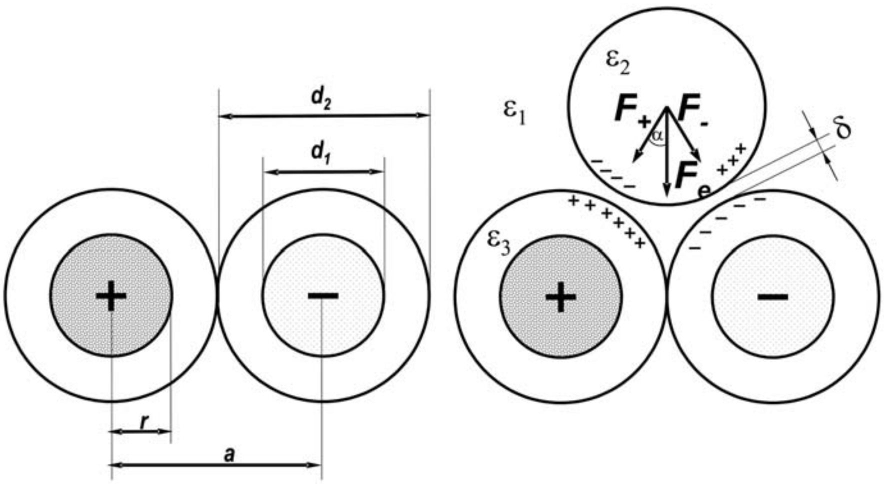

Fig. 2. Electrodes dimensions and distribution of forces acting on a particle in a bifilar winding.

bifilar winding insulation;
γ_1 – electric conductivity of environment, γ_2 - conductivity of attracted dust particle, γ_3 - conductivity of bifilar winding insulation, $S\cdot m^{-1}$;
δ - spacing between the dust particle and the winding, m;
l_2 – distance between the dust particle contact points and the opposite windings, m;
l_3 – bifilar winding insulation thickness, m;

S_{ef} – the mean value of the section area of the electric induction transfer a through dielectric particle, m^2;

ω - pulsation of bifilar winding voltage, s^{-1};

α - half of the angle outlined by the centres of windings and the centre of a dust particle;

U - voltage, V.

The analyzed case shows that the conductivity γ_1, γ_2, γ_3 can be neglected (dielectrics) and have similar values. The spacing δ is small in comparison to winding dimensions. The surrounding environment is the air (ε_1=1). The increase of conductivity and thinning of insulation could lead only to the reduction of electric strength of the system. The critical importance for winding insulation breakage has supply voltage U of the system.

I. Test stand

The filter tests have been performed on the stand presented in Fig. 3. The air flow is forced by an exhaust fan, that takes the air from the filter chamber and thus leads the air – dust mixture into the chamber. The dust in the chamber falls down on the bottom under the influence of forces caused by the induced charges in the dust particles.

The final version of the dust removal chamber has been constructed with steel sheets (Fig. 4). This eliminates dust residue on chamber walls thanks to the earthing and increases the strength to electrode cleaning. The construction incorporates also the set of filter frames in the form of a compact cassette [6].

The maximal voltage value that has been applied in the research on the filter depends on the electric strength of the filter windings. The strength tests show that the insulation breakage voltage is between 38÷68 kV. Moreover, there has been found that despite no punch-through breakdown, at 15 kV, the discharges between the

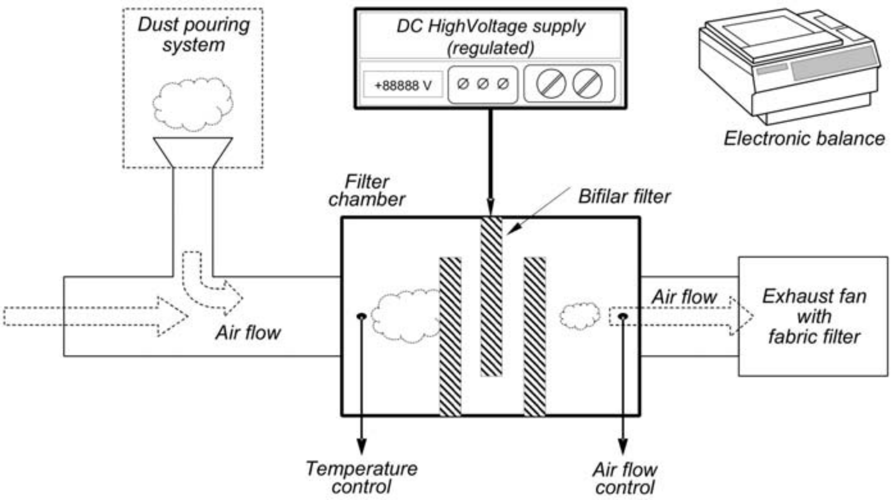

Fig. 3. Block diagram of a test stand.

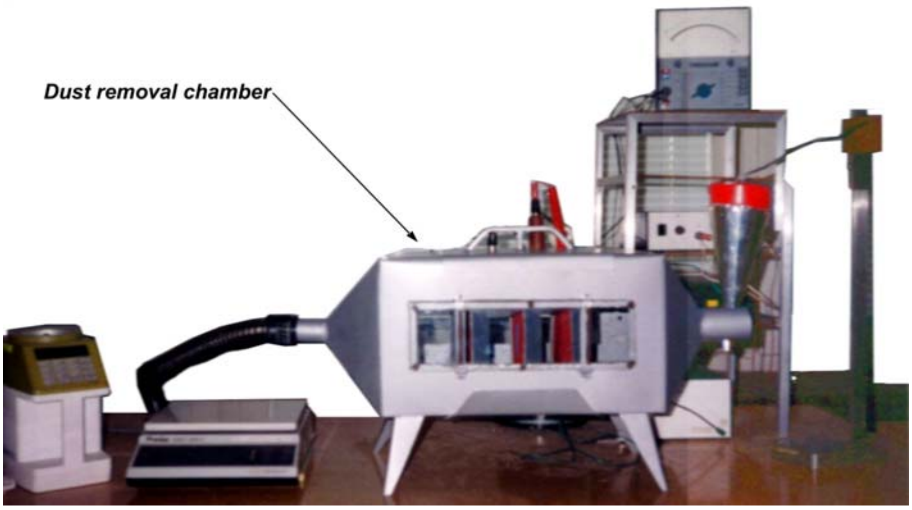

Fig. 4. Bifilar deduster chamber.

Table 1

Tested dust material and the range of measurements [5]

Wheat bran dust fractions (diameters) [μm]:	<150	150÷230	230÷500	>500
Air velocity [$m \cdot s^{-1}$]	0,30	0,50	0,70	
Air flow [$m^3 \cdot s^{-1}$]	0,015	0,024	0,034	
Dust concentration [$g \cdot m^{-3}$]	9,18	5,51	3,94	
Filter voltage [kV]	0	8	10	12
Lead diameter [mm]	0,38	1,38	1,72	2,76
Winding diameter (lead and insulation) [mm]	1,08	2,48	3,34	4,50

lead terminals have occurred [1]. The voltage 12 kV applied in the tests provides maximum effectiveness at simultaneous 3 kV safety margin.

The complete set of data related to the tested material and measurement ranges are collected in Table 1. The removal effectiveness has been determined by a standard method, on the basis of the dust mass that is introduced and captured in the chamber [4].

II. Results

The bifilar filter should combine properties of filters commonly used in agri-food industry and electrofilters. That is why the range of investigated flow velocities has been selected to relevant flow velocities occurring in fabric filters (0.05 $m \cdot s^{-1}$) and dry electrofilters in power industry (1.2 $m \cdot s^{-1}$) tj. 0.3÷0.7 $m \cdot s^{-1}$. The detail set of results of measurements taken on wheat bran dust and

Table 2.

The wheat bran dust removal results (dust concentration 3.94 g·m^{-3})

Dust fraction [μm]	0 kV	8 kV	10 kV	12 kV
	Air flow 0.3 m s^{-1}			
< 150	88.08	94.08	94.92	97.58
150-230	87.83	94.17	94.75	96.92
230-500	87.83	92.58	94.50	96.67
>500	86.92	92.00	94.17	96.25
	Air flow 0.5 m s^{-1}			
< 150	88.00	93.08	94.67	96.33
150-230	87.58	92.42	92.83	96.33
230-500	87.25	92.08	93.92	95.67
>500	86.25	92.00	93.58	94.42
	Air flow 0.7 m s^{-1}			
< 150	87.67	91.92	92.83	95.92
150-230	87.08	91.58	92.83	95.42
230-500	87.00	91.42	92.58	94.58
>500	86.00	90.92	92.67	93.58

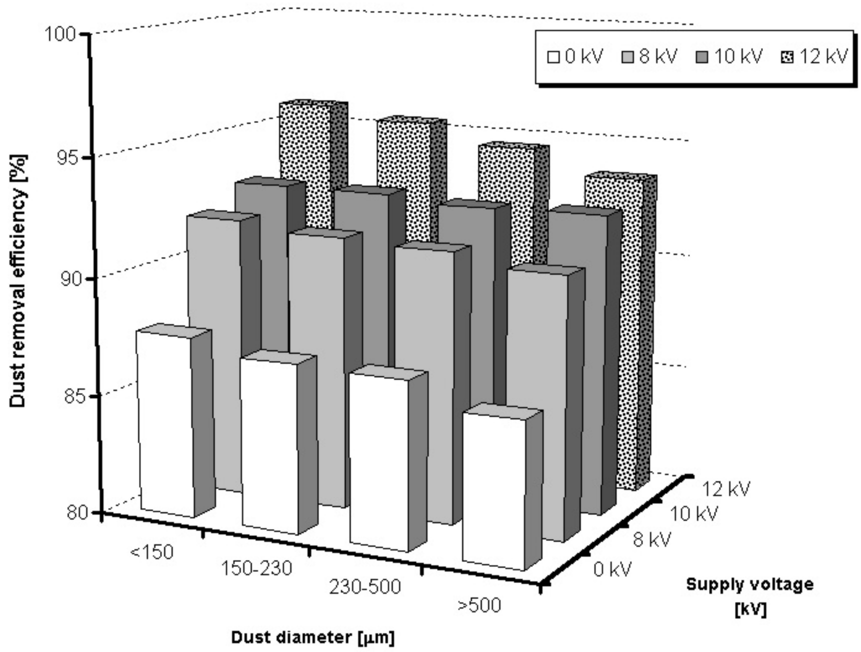

Fig. 5. The wheat bran dust removal efficiency for tested combination of fractions and supply voltage at velocity of 0.7 m·s^{-1} (dust concentration 3.94 g·m^{-3}).

applied voltages are presented in Table 2.

The filter chamber without voltage captures 86.0÷88.1% of pollutants. The dust falls down on the bottom of the chamber under the influence of gravity forces.

The applicatiion of 8÷12 kV increases removal effectiveness to 90.9÷97.6%. The effectiveness increases together with the voltage increase. The most effective removal has occurred for the smallest particles (<150 μm) (Tab. 2, Fig. 5). The same effect occurs in the other scope of the measuring range.

Conclusions

The bifilar filter should combine properties of filters commonly used in agri-food industry and electrofilters. That is why the range of investigated flow velocities has been selected to relevant flow velocities occurring in fabric filters (0.05 m·s^{-1}) and dry electrofilters in power industry (1.2 m·s^{-1}) tj. 0.3÷0.7 m·s^{-1}. The detail set of results of measurements taken on wheat bran dust and applied voltages are presented in Table 2.

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Динаміка змін температури в лініях передачі енергії провідників різних перехресно-секційних областей

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Обчислення сили струму провідника як правило виконуються в припущенні його нескінченної довжини. У цьому випадку емісія тепла відбувається через конвекцією або випромінювання. Ситуація є різною, коли короткі секції провідника нагрівають, коли може виникнути потік тепла, який вплине на результат на температурних кривих.

Дана стаття подає аналіз зміни температури над 5-и метровою секцією мідного дроту 16 мм^2 перехресно-секційної області з використанням провідника 70 мм^2 при проходженні безперервних потоків різних значень. Експериментально одержаний потік температури у провіднику і форми нагрівання кривих вказують на важливий ефект осьового потоку тепла в провіднику.