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# COLLECTING EFFICIENCIES AND MIGRATION VELOCITIES OF DUST PARTICLES FROM A THREE SECTIONS ELECTROSTATIC PRECIPITATOR

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**ABSTRACT:** *In this article were performed simulations of the collecting efficiency and the migration speed of the dust particles from gas, depending on the dust particles' diameter (by classes of diameters between 0.1 and 60 μm) for a 3-field ESP used at the thermo-electric power plants. The 3-field ESP's are often used in this industrial branch. For simulations it was used a performance program (ESPVI 4.0.a) for the study of the industrial ESP's with plates and there were performed simulations in pure DC conditions and classic supplies of the fields, with and without dust layer on the collecting surfaces, with and without fields' rapping. It was found that the dust particles with diameters up to 10 μm (especially the ones below 2 μm) are collected the most difficult.*
**KEYWORDS:** *dust particles, thermo-electric power plants, simulations*

## INTRODUCTION

*A plate-type electrostatic precipitator is a device that removes pollutions, in general from the air, by an electrostatic charging process, than followed by the migration of particles to collecting plates. The particles are removed periodically from the plates through rapping. This type of electrostatic precipitator is used to remove pollutions from large flow gas (hundreds of thousands m$^3$/h) in thermal power station.*

*The plate-type electrostatic precipitators are using because of the following advantages [2]:*

- *pressurize in ESP is loss;*
- *may be used for different size of particles;*
- *have long life;*
- *may be used for any gas flow;*
- *high grade separation;*
- *may be used for different temperature of gases;*
- *reduce maintenance.*

*A well function of electrostatic precipitators depends by the resistivity, the temperature of gas, the pressure, the type of power supply unit, the shapes of discharge wires, the geometry of electrostatic precipitators.*

*In the plate-type precipitators the rows of discharge wires are positioned between parallel collecting electrodes forming ducts (Figure 1). In thermal power stations the gas flow has big value and the total length of collecting electrodes is divided into series and parallel fields, each of them is characterized by an independent power supply unit [4].*

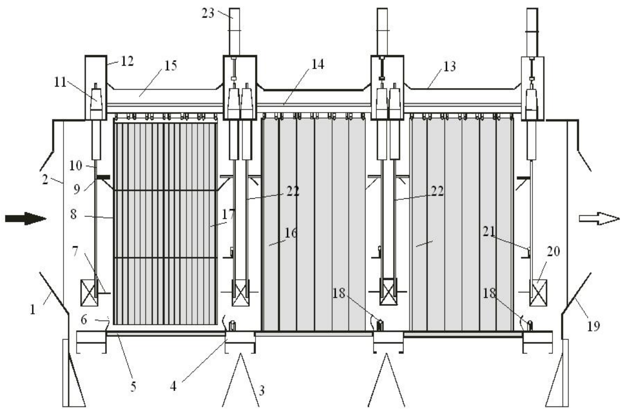



*Figure 1. A plate-type electrostatic precipitator with three sections – construction*
*1 – inlet connector; 2 – drain levelling wall; 3 – dust bunker; 4 - interior platform; 5 – shaking bar; 6 – deflection plate; 7 – spacers; 8 – discharge frame; 9 – rack; 10 – supporting rod; 11 – electric insulator; 12 – roof beam; 13 – roof for rain; 14 – sealing roof; 15 – supporting beam of the collecting plates; 16 – collecting plate; 17 – discharge wires; 18 – shaking device of the collecting plates; 19 – outlet connector; 20 – access door; 21 – shaking device of the discharge wires; 22 – supporting frame; 23 – drive system of the discharge wires' shaking.*

## SIMULATIONS USING ESPVI 4.0.A SOFTWARE

*Today, there are several software to compute the performance of plate-type electrostatic precipitators. One of them is ESPVI 4.0.a software that shows good agreement with experimental measurements taken at plate-type electrostatic precipitators under several operation conditions, including high resistivity ashes, the use of rectified current and pulse energization, different size of dust particle (up to 100μm), detects the onset of back Corona, including peak to average ratios of voltages, different shape of discharge wires, even through the dust layer thickness is a parameter (the dust layer voltage drop effects the electric field in the wire-plate duct).*

*The ESPVI 4.0.a (Electrostatic precipitators U-I curves and Performance model) software has an interface that includes: File Options, Data Entry, Calculate V-I, Performance, View Results, Output Results, Graph Results, Utilities, Exit each of them having other menus. For simulations was used a plate-type electrostatic precipitators with three sections (table 1) [7]. The general factors and gas factors are presented in table 2.*

*Table 1. Plate-type electrostatic precipitators with three sections*

| Section | Collecting area/gas flow [$m^2/(m^3/s)$] | Collecting area [$m^2$] | Distance plates-discharge wires [m] | Length [m] | Height [m] | Width [m] |
|---|---|---|---|---|---|---|
| 1 | 226.15 | 2107 | 0.14 | 2.74 | 9.14 | 11.73 |
| 2 | 226.15 | 2107 | 0.14 | 2.74 | 9.14 | 11.73 |
| 3 | 226.15 | 2107 | 0.14 | 2.74 | 9.14 | 11.73 |

*Table 2. The general factors and gas factors*

| Resistivity [$\Omega\cdot$cm] | Velocity of gas [m/s] | Temperature [$^o$C] | Pressure [atm] | Viscosity [kg/(m·s)] | Reynols number |
|---|---|---|---|---|---|
| $1.7\cdot10^{10}$ | 1.45 | 157 | 1 | 0.00026 | 12700 |

*For simulations was considered an ESP that treats medium gas flows (33540 $m^3$/h). The sections are considered identical as geometrical dimensions (table 1). The dust resulted after burning has an average resistivity ($1.7\cdot10^{10}\,\Omega\cdot$cm) (table 2). From this reason, the fields' supply sources can be considered of classic type (voltage rectified bi-alternative, with „–" on the discharge wires and „+" on the collecting plates). At the inlet of precipitator the gas analysis are presented in table3.*

*Table 3. The inlet of precipitator the gas analysis*

| $N_2$ [%] | $CO_2$ [%] | $SO_2$ [%] | $O_2$ [%] | $H_2O$ [%] | $SO_3$ [%] |
|---|---|---|---|---|---|
| 73,5 | 14,9 | 0,08 | 3,3 | 8,21 | 0,01 |

*The main chemical components from gas were considered the ones from table 3. Approximately, these chemical components are found in the same percentage also in the real gases resulted further the coal's burning.*

*In table 4 are presented the discharge wires positions in a duct for any sections. The discharge wires are round type with 3 mm diameter and Corona onset factor for any element 0.8. Any duct (from any sections) has 12 equidistance discharge wires.*

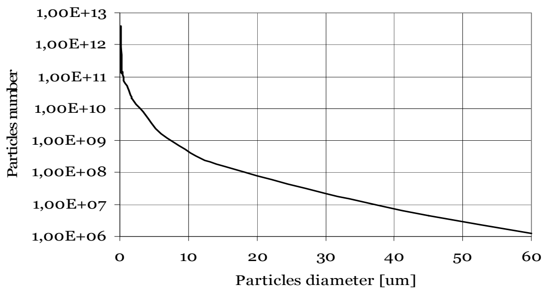



*Figure 2. Particles number distributions at inlet of electrostatic precipitators*

*Table 4. The discharge wires positions*

| Element | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance from inlet [cm] | 13.97 | 36.37 | 58.77 | 81.15 | 103.55 | 126 | 148.36 | 170.76 | 193.17 | 215.54 | 238 | 260.35 |

*In figure 2 the particles number distribution at inlet of precipitator is showing. In figure 2 was considered the number of dust particles, at input in ESP, considered into a $m^3_N$ of gas. As the dust particles have smaller diameters, they are many more. It was considered a distribution of dust particles ranged between 0.1 and 60 $\mu$m. The smallest dust particles, with diameters under 0.1 $\mu$m, are much more by seven magnitude orders, compared with dust particles with the highest diameters, over 60 $\mu$m [4]. It was simulated five cases: when precipitator was supply with pure DC voltage (case a) and classical energization (full wave 1:1, cases b-e). For these cases in table 5 are presented the main electrical parameters.*

*At supply with pure DC voltage (ideal), the currents through the fields have higher values compared with cases when the sections are supplied by rectified bi-alternative voltage (classical energization). In all situations, the higher currents are for the output fields (section 3) compared with the input fields (section 1).*

*In cases c and d, from table 5 it was considered that on the collecting plates is a dust with average thickness of 2.5 mm. In table 5, the current's density is calculated for each section in part as ratio between the current absorbed by source (of each section) and the total surface of the field. The highest current density is obtained at supply with pure DC voltage (impossible to be obtained in practice). The voltages applied on fields were considered, same as in practice, to be within 45-60 kV, with higher voltages for the input fields, compared with the voltages of the output fields [6]. In table 6 are the experimental results with rappers on, and in table 7 when rappers off.*

*There are been made simulations in conditions of using rappers (rappers on) and when rappers are not used (rappers off). In tables 6 and 7 was considered that the dust has the same density and same average value of the dust particles (MMD). By PM10 was noted the density of dust particles with diameters under 10 $\mu$m (the particles are harmful to the fauna and flora, and hard to collect) [5].*

*Generally, for all cases, the collecting efficiency is over 99.6 %, smaller results being obtained when the fields are rapped periodically. The dust particles with diameters below 10 μm are the hardest to collect, when the fields are supplied by pure DC. A thin dust layer (i.e. 2.5 mm) doesn't have a notable influence upon the collecting efficiency.*

Table 5. The current's density

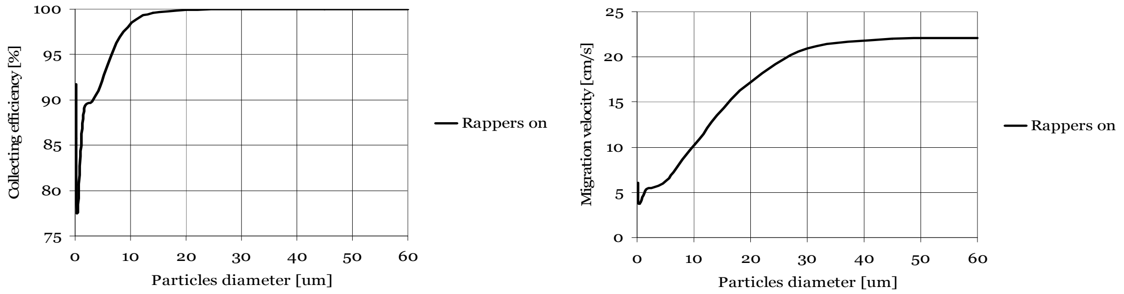
| Case | Section | Voltage [kV] | Current [mA] | Density current [mA/cm²] | Peak/average voltage [-] |
|---|---|---|---|---|---|
| a. | 1 | 59.5 | 735 | 35 | 1.01 |
| | 2 | 56.8 | 903 | 43 | 1.06 |
| | 3 | 56.6 | 1050 | 50 | 1.06 |
| b. | 1 | 56.1 | 354 | 16.81 | 1.17 |
| | 2 | 46.2 | 486 | 23.08 | 1.29 |
| | 3 | 45.2 | 550 | 26.11 | 1.33 |
| c. | 1 | 48.6 | 373 | 17.70 | 1.23 |
| | 2 | 46.1 | 501 | 23.79 | 1.29 |
| | 3 | 45.1 | 557 | 26.44 | 1.32 |
| d. | 1 | 55.5 | 411 | 19.52 | 1.1 |
| | 2 | 54.9 | 444 | 21.06 | 1.11 |
| | 3 | 54.4 | 490 | 23.23 | 1.1 |
| e. | 1 | 55.8 | 389 | 18.48 | 1.09 |
| | 2 | 55.1 | 418 | 19.84 | 1.08 |
| | 3 | 54.6 | 468 | 22.22 | 1.1 |

Table 6

| Case | Density [g/cm³] | MMD [μm] | PM10 [g/m³] | Wave form | Efficiency [%] | Emissions [g/m³] |
|---|---|---|---|---|---|---|
| a. | 2.40 | 12.2 | 0.13 | Pure DC | 99.87 | 0.18 |
| b. | 2.40 | 12.2 | 1.5E-02 | Full wave | 99.72 | 1.6E-02 |
| c. | 2.40 | 12.2 | 1.4E-02 | Full wave | 99.73 | 1.5E-02 |
| d. | 2.40 | 12.2 | 1.9E-02 | Full wave | 99.64 | 2.1E-02 |
| e. | 2.40 | 12.2 | 2E-02 | Full wave | 99.61 | 2.2E-02 |

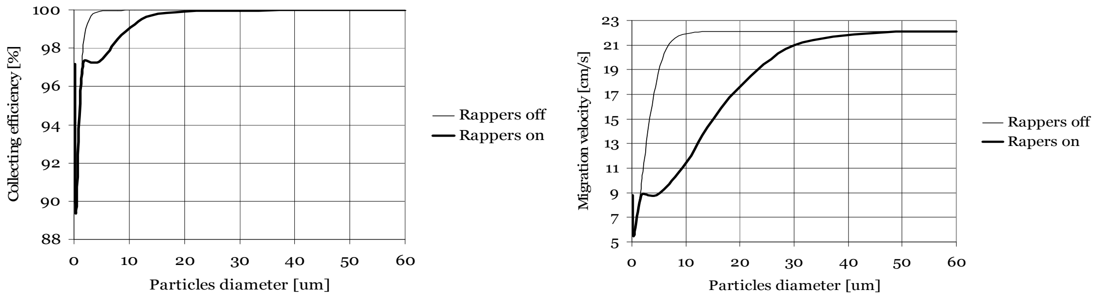
Table 7

| Case | Density [g/cm³] | MMD [μm] | PM10 [g/m³] | Wave form | Efficiency [%] | Emissions [g/m³] |
|---|---|---|---|---|---|---|
| a. | 2.40 | 12.2 | 5.8E-02 | Pure DC | 99.87 | 7.7E-03 |
| b. | 2.40 | 12.2 | 4.1E-02 | Full wave | 98.90 | 6.3E-02 |
| c. | 2.40 | 12.2 | 4E-02 | Full wave | 98.92 | 6.2E-02 |
| d. | 2.40 | 12.2 | 4.9E-02 | Full wave | 98.73 | 7.2E-02 |
| e. | 2.40 | 12.2 | 5.2E-02 | Full wave | 98.68 | 7.6E-02 |



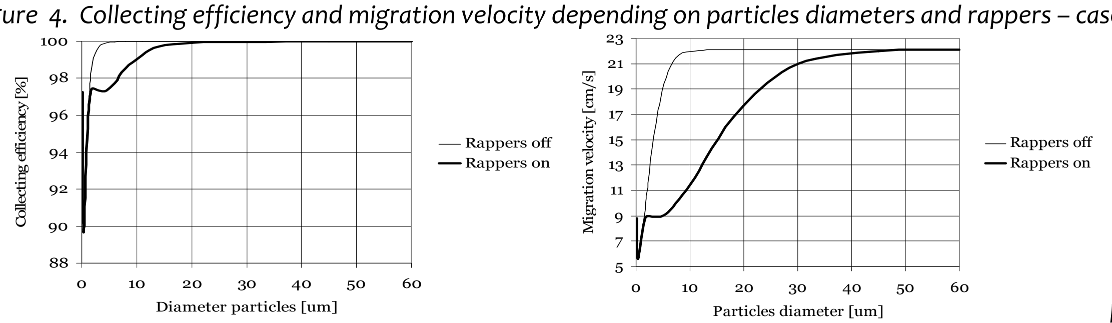

a. b.

Figure 3. Collecting efficiency (a) and migration velocity (b) depending on particles diameters – case a



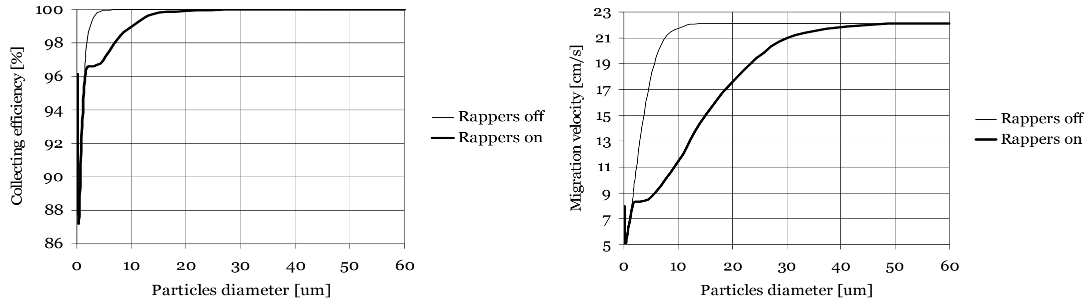

a. b.

Figure 4. Collecting efficiency and migration velocity depending on particles diameters and rappers – case b



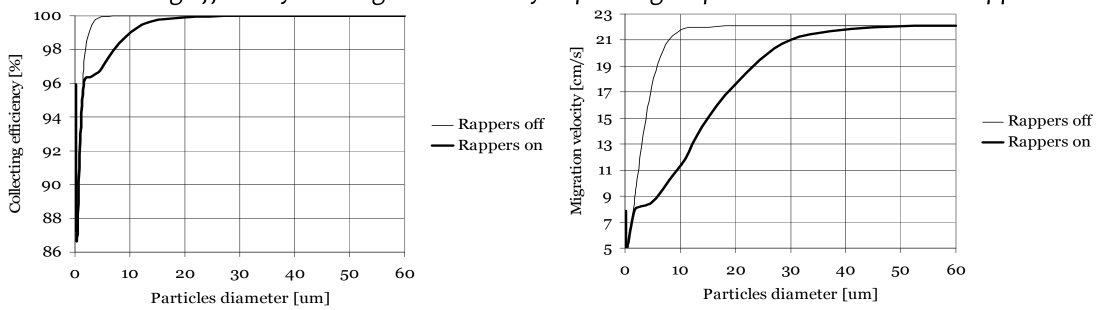

a. b.

Figure 5. Collecting efficiency and migration velocity depending on particles diameters and rappers – case c




a. b.

*Figure 6. Collecting efficiency and migration velocity depending on particles diameters and rappers – case d*




a. b.

*Figure 7. Collecting efficiency and migration velocity depending on particles diameters and rappers – case d*

In Figure 3-7 were achieved simulations of the collecting efficiency and migration speed, with rappers on and off, depending the dust particles' diameters. Generally, the dust particles with diameters below 10 $\mu$m (especially the ones with diameters below 2 $\mu$m) are the hardest to be collected, even in conditions when the fields are not rapped. The dust particles with diameters up to 2 $\mu$m are collected below 90 % (sometimes 75 % for the case of pure DC). The migration speeds of particles up to 2 $\mu$m are four times smaller than the speeds of dust particles with bigger diameters. When the fields' rappers are stopped, the dust particles are collected the best [3]. The fields have to be periodically rapped (not permanently) in order not to accumulate a consistent dust layer that determines important voltage drops on layers, with harmful role upon charging of dust particles. When the fields are rapped (not all together, but one at a time), even the dust particles with diameters under 20 $\mu$m are harder collected.

## CONCLUSIONS

The 3-field plate ESP's are often used in industry (and at the thermo-electrical power plants). From simulations was found that operation of pure DC voltages (impossible to achieved in practice) is nod profitable, especially for collecting of dusty particles with diameters under 2 $\mu$m (which are in the largest number). A better collection of dust particles with small diameters is obtained by using classic sources (rectified bi-alternative voltage) by means of which the collecting efficiency of these particles increases by 10-14 %. To better collect these dust particles, should be used other types of field supply sources (intermittent supply, supply by high-voltage pulses) [1].

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