The Distinctive Changes of Particles' Numeric Concentrations, Are Caused by Electrostatic Flue Gases Cleaning.

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THE DISTINCTIVE CHANGES OF PARTICLES´ NUMERIC CONCENTRATIONS, ARE CAUSED BY ELECTROSTATIC FLUE GASES CLEANING

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INTRODUCTION

A burning processes are always accompanied by emissions, and solid fuel combustion is believed to be the main source of dust releases. Solid fuels are predominant for using by boilers under 300 kW, which are mostly use for heating the domestic buildings and small premises in industrial and other use. It is well known, that using such boilers is inevitably involves the pollution releases, among which are emissions of oxides of carbon, nitrogen and sulfur oxides and particulate matters. After 2020 all boilers in European Union are have to be consistent with the list of ecological norms, and norm ECODESIGN is the one of them. This norm, inter alia, means that PM concentration could not exceed 40 mg/m^3_N. Such legislative measures are compelling the producers to make steps to decrease boiler´s pollutions. However, it is hard to achieve the desired results by optimization of burning processes only. That´s why arises a need to equip the boilers with the gas cleaning units. Within this context, precipitation particulate matter with electrostatic method is one of the most perspective. Within studies to optimize the constructional and high voltages parameters of ESP, it was appeared unusual phenomenon, which has describing below.

EXPERIMENTS DESCRIPTION

Researches of electrostatic precipitation efficiency were carried out on boiler with automatic fuel feeding and alone standing ESP. The brown coal and wooden pellets were used in kinds of a fuel. Tests were conducted at 30% and 100% heating power.

Technological scheme of installed equipment is shown on Fig. 1. Thus equipment installation allows the objective assessments the values of dust concentration and corresponds to norm AS/NZS 40T3:2014 and EPA Method 5G.

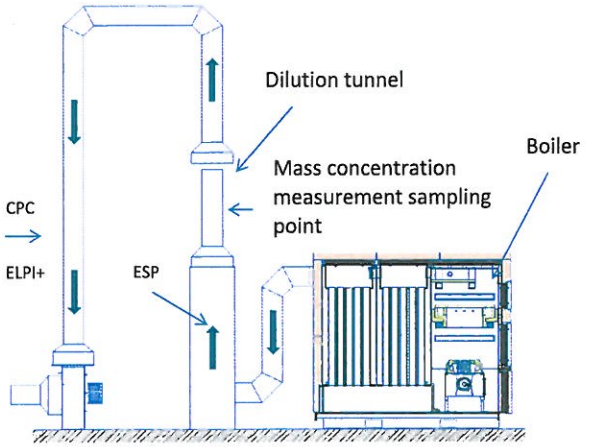

Fig. 1. Equipment installation scheme.

Tested automatic solid fuels boiler was about 107 kW heating power. Flue gases, which of the fuel burning, were tacked out by fun and subsequently sent to ESP for cleaning from ash particles.

ESP is a vertical unit, which collecting honey comb electrodes. Discharge electrodes were presented by stainless wire and were mounted coaxially to each hexagonal cell. High voltage power source provides the ESP feeding with high negative voltage with value about 12 kV. Mass concentrations were measured due gravimetric method, based on the isokinetic flue gases sampling and further filtration by pre and post weighted filters, due norms ISO 9096 and EN 132484-1. Respective sampling point was set consequently behind the ESP and samplings were provided with alternately off and on switching the ESP, thereby avoiding an influence of mechanical inertial component of dust separation. Every sampling procedure takes unless 30 minutes.

At the same time, the samples for defining the numeric dust concentration value were taking by using the ELPI+ and CPC. Because of impactor structure, ELPI®+ enables to get the values of total numeric concentration and, at once, dust particles distribution. This ability to classify particles into fractions will find further using in post-measurement chemical analyses of some particular fractions. Applied condensation particle counter (CPC) is a devise that counts particles upon their previous condensation enlarging. As the result of CPC measuring plays total numeric particles concentration.

Numeric particle concentrations measuring was held concurrently with both methods during the all experiment time.

During the experiment the wooden pellets and brown coal were used as fuels. The chemical composition of both fuels is detailed in Tab. 1.

Tab. 1 The fuels chemical composition.

Element	**Designation**	**Content in pellets, %**	**Content in coal, %**
Carbon	C	47,73	52,72
Hydrogen	H	6,10	4,28
Nitrogen	N	0,04	0,74
Oxygen	O	40,00	13,34
Sulphur	S	0,05	1,01
Water content	H_2O	6,00	22,00
Ash	A	0,39	5,9

THE EXPERIMENTS RESULTS, DISCUSSION AND CONCLUSIONS

The filters in top row with numbers 170,172,174 are belong to samples without ESP acting. The bottom row of filters (with numbers 171, 173, 175) corresponds the concentrations with flue gases were pre-cleaned by ESP. The experiments were provided under the conditions due the All samples expanded data about evaluation of ESP effectivity are given in Tab. 3.

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Tab. 2 The coal combustion experiment conditions

Parameter	**Units**	**Value**
Boiler power	kW	105
Type of fuel	Brown coal	
Flue gases temperature	°C	165
Flue gases quantity	m^3_N/h	122,3

Tab. 3 ESP´ effectivity in coal combustion case.

Number of filter		**170**	**171**	**172**	**173**	**174**	**175**
Sampling start	h:min	10:00	10:45	11:30	12:07	12:45	13:22
Sampling end	h:min	10:30	11:15	12:00	12:37	13:15	13:52
Remark		ESP off	ESP on	ESP off	ESP on	ESP off	ESP on
Ach concentration	mg/m^3_N	37	8	35	8	34	8
ESP effectivity	%	78,4		77,1		76,5	

In the background of expected mass concentration declining, the numerical particles concentrations' growing was detected. Detected by CPC total numerical particle concentration growing has its reflection in Fig. 3.

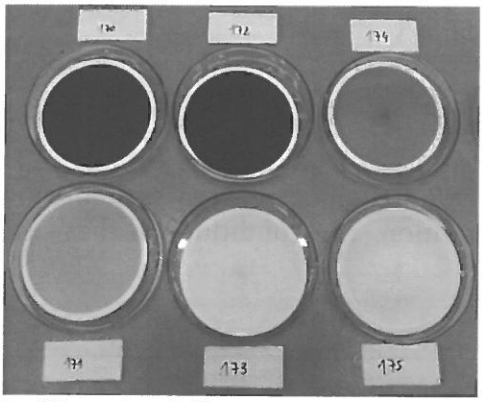

Fig. 2 Coal burning full power case samples filters.

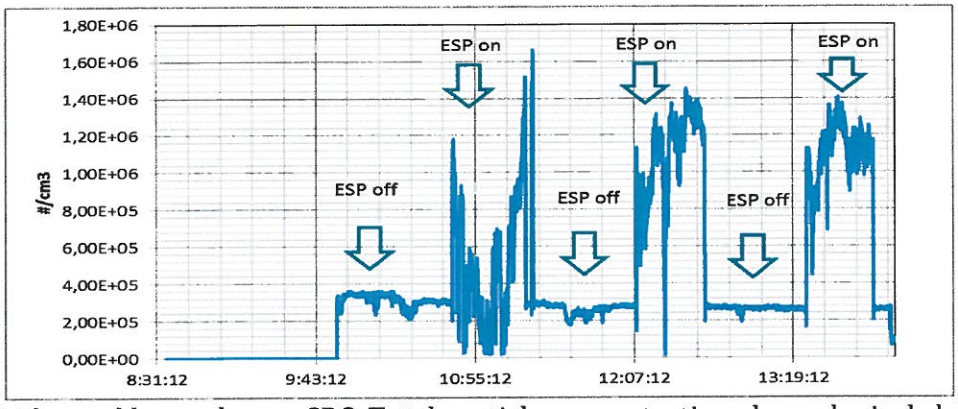

Fig. 3 The coal burned case. CPC. Total particle concentration chronological change.

Meanwhile, with the help of ELPI+ sampling, was confirmed the similar changing of particle concentration. Moreover, has been defined that total numeric concentration rising was achieved because of rising concentration of particles with diameter about 17 nm only. That effect can be viewed on the further Fig. 4. It should also de noted, that all samples were made in similar (with deviation less 5%) experiment condition, such as boiler power output, flue gases temperature, quantity and their under pressure in chimney.

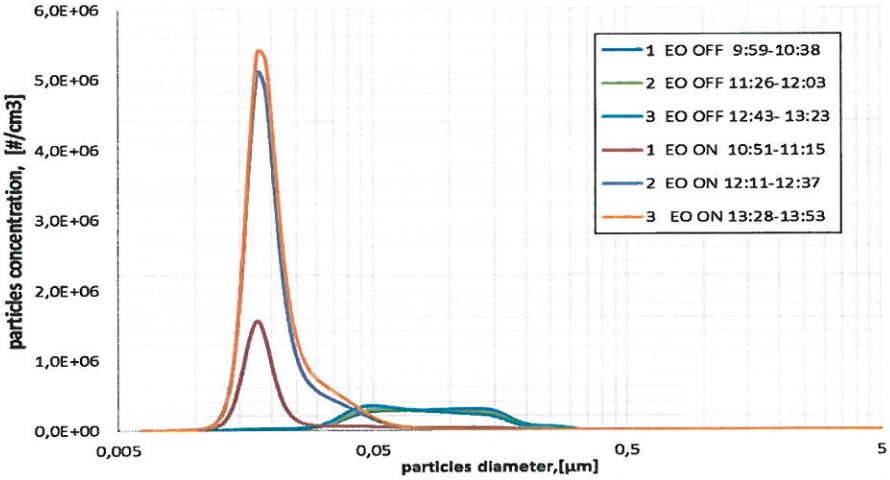

Fig. 4 The coal burned case. ELPI+. Numerical particles distributions with ESP on/off.

In case of the wooden pellets combustion, there were taken several alternately samples with off and on ESP switching. Only two samples were selected out due the stability of experiment condition. The conditions of that's case experiments are get in Tab. 4.

Tab. 4. The pellets combustion experiment conditions

Parameter	Units	Value
Boiler power	kW	100
Type of fuel	Wooden pellets	
Flue gases temperature	°C	170
Flue gases quantity	m^3_N/h	108,3

That´s case expanded ESP effectivity data in expressed with decreasing of mass concentration is summarized for those samples in Tab. 5.

Tab. 5. ESP´ effectivity in pellets combustion case.

Filter´s number		**190**	**191**	**193**	**194**
Sampling start	h:min	11:09	11:44	13:10	13:48
Sampling end	h:min	11:39	12:15	13:41	14:18
Remark		ESP off	ESP on	ESP off	ESP on
Ach concentration	mg/m^3_N	21	5	19	6
ESP effectivity	%	76,2		68,4	

The accepted filters´ photo is presented in Fig. 5. Filters 190 and 193 are corresponds to the ash concentration without flue gases precipitation. Filters 191 and 194 are matching to combustion gases, were precleared by ESP. The decreasing of numeric concentration distributed by fractions is presented on

Fig. 6.

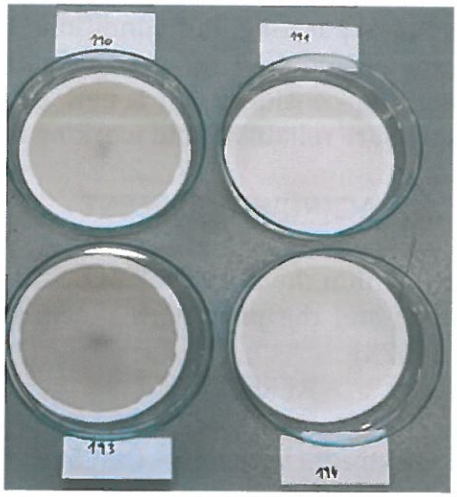

Fig. 5 Pellets combustion full power case samples filters.

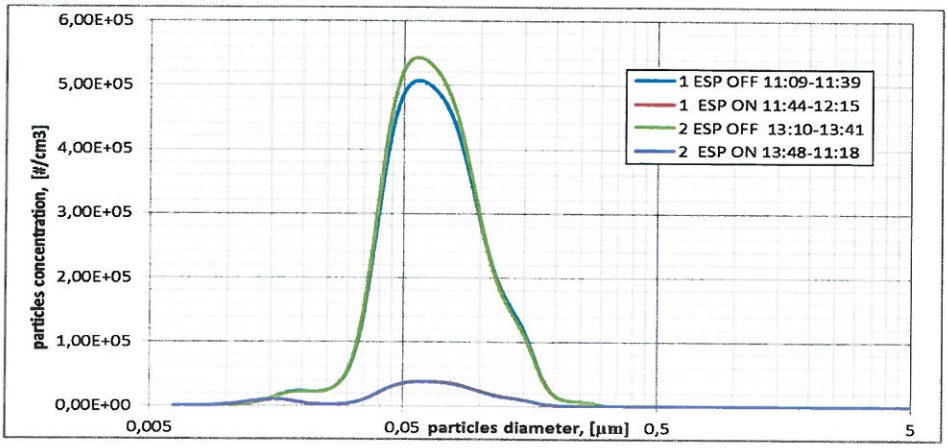

Fig. 6 The pellets combustion case. ELPI+. Numerical particles distributions with ESP on/off.

Affecting of the ESP employing on the particle numeric concentration has been carried out with two independent ways, which were based on different principles.

During the experiment has been determinate the expected numeric concentrations reduction, except uncommon behavior of fractions of 17 nm. That changing has been noticed only in cases of coal burning, and has not been accrued whilst the pellets were combusting. Meanwhile, content of ash in flue gases was has been supposedly reduced by ESP for 70-80 % in mass concentration meaning.

As a reason of that digression the nucleation of sulfur acid´ particles has been suggested. The nucleation process might run under further way. As one of the secondary processes of corona discharging, the ozone formation plays. Because of its high oxidation ability, ozone quite efficiently provides an oxidation of SO_2 up to SO_3. The existence of this oxide, coupled with flue gases humidity, accuse the nucleation of H_2SO_4 drops. During the ordinary conditions of the flue gases – when the ESP is switching off – this acid drops find a condensation on a surface of suspended ash particle evenly. Thus runs the heterogenic nucleation with the ash particles as condensation nuclei. By ESP switching on, all the ash particles are precipitating with certain effectivity. The absence of sufficient particles´ array leads to nucleation is becomes a homogenous. In other words, in the ESP particles are separating, but conditions in flue gases are such, that mount of particles with diameter about 17 nm are nucleating. This possibility of new acid particles nucleating mast be considered in a new cleaning apparatus design, in meaning of its efficiency and ensure reliability and working life.

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Nařízení komise (EU) 2015/1189 ze dne 28. dubna 2015, kterým se provádí směrnice Evropského parlamentu a Rady 2009/125/ES, pokud jde o požadavky na ekodesign kotlů na tuhá paliva. Dostupné na: http://eur-lex.europa.eu/legal-content/CS/TXT/PDF/?uri=CELEX:32015R1189&from=CS

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