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FLUE GAS DEDUSTING IN COCURRENT SPRAY SCRUBBER

Selected results of air dedusting process carried out in a large-laboratory horizontal cocurrent spray scrubber are presented. An experimental equation describing the influence of sprayed liquid volume stream to gas volume stream ratio and the efficiency of inertial separation of dust particles of a given size of single droplet on flue gas dedusting interval efficiency was derived. The influence of gaseous phase velocity and spraying rate on total dedusting efficiency was also determined.

1. INTRODUCTION

Spray scrubbers practically used in flue gases dedusting processes may occur in horizontal or vertical configurations, and the liquid can be sprayed inside cocurrently or countercurrently to the flow direction of gases being cleaned. The way in which gases come into contact with droplets affects the efficiency of their dedusting. Horizontal spray scrubbers are used most commonly in the installation for waste gases dedusting.

As yet the gas dedusting in horizontal spray scrubbers had not been examined thoroughly. The results of paper [1] indicates that flue gases in horizontal countercurrent spray scrubbers with the kinetic parameters (gas velocity, spraying rate, liquid spraying degree) appropriately established can be dedusted with an efficiency exceeding even 95%. The aim of this paper was to evaluate, in a technical scale, the usefulness of horizontal cocurrent spray scrubbers for a waste gas dedusting.

2. AIR DEDUSTING IN SPRAY SCRUBBER

The experimental installation [2], [3] contained three main elements:

- A unit of dusty air preparation of a given concentration.
- A horizontal spray scrubber, 300 mm in diameter and of 3 m in effective length,

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with installation for liquid dosing and air supply, in which water was sprayed by stream-rotational atomizers RSW 5-90 [3] (liquid outlet diameter of 5 mm, angle of liquid spray cone of 90°).

• A unit of dusty and cleaned air sampling for dust concentration measurements.

In order to examine the influence of gaseous phase velocity and spraying rate on the interval efficiency of air dedusting in horizontal cocurrent spray scrubber, 90 experiments were conducted (at 6 gaseous phase velocities and at 5 spraying rates).

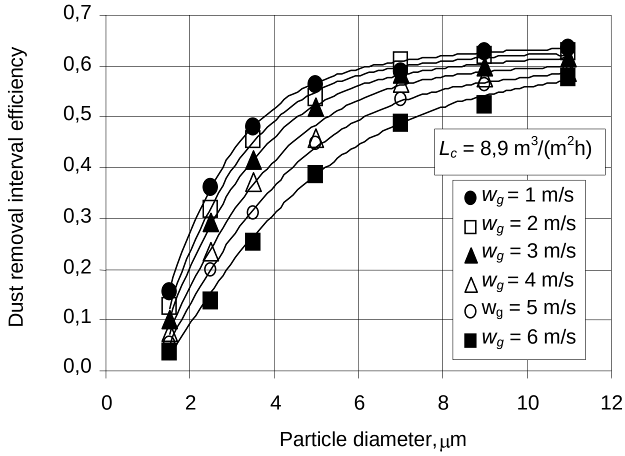

Fig. 1. The influence of dust particle diameter on dust removal interval efficiency, (w_g range of 1–6 m/s, L_c = 8.9 m^3/(m^{2}h))

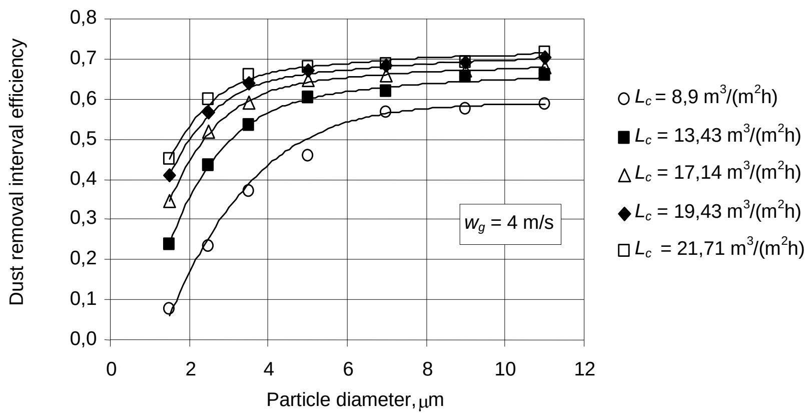

Fig. 2. The influence of dust particle diameter on dust removal interval efficiency, (w_g = 4 m/s, L_c range of 8.9–21.71 m^3/(m^{2}h))

The dust examined was separated from the air used for ventilating a hall in aluminum oxide electrolysis unit. Dust samples taken from the air before its entrance to a dust separator and after its flowing through the separator were divided into 7 grain fractions.

The influence of an average diameter of dust particles on the interval efficiency of dust removal at a gaseous phase velocity ranging from 1 to 6 m/s and a constant rate of spraying of 8.9 $m^3/(m^2h)$ is presented in figure 1, and at constant velocity of gaseous phase of 4 m/s and spraying rate ranging from 8.9 to 21.71 $m^3/(m^2h)$ – in figure 2.

Based on experimental results (210 observations) and a multiple regression analysis it was possible to derive an experimental equation representing the influence of the ratio of the volume stream of sprayed liquid to the volume stream of air being dedusted and the separation efficiency of dust particles on single droplet on the interval efficiency of dust removal from gas. The equation has the form:

$$\eta_i = 1 - \exp\left[-1.99\left(\frac{\dot{V}_c}{\dot{V}_g}\right)^{0.083} \eta_k^{1.088}\right], \quad (1)$$

where:

$\dot{V}_c$ – the volume stream of sprayed liquid, m^3/h,

$\dot{V}_g$ – the volume stream of gas, m^3/h,

η_k – the efficiency of inertial separation of dust particles on single droplet.

The efficiency of an inertial dust separation on single droplet for its single flow can be described by the Langmuir–Blodgett equation [4]:

$$\eta_k = \left(\frac{Stk}{Stk + 0.25}\right)^2, \quad (2)$$

where *Stk* is the Stokes number given by the equation:

$$Stk = \frac{d_a^2 w_g \rho_a C'}{18 \eta_g d_k}, \quad (3)$$

where:

C' – Cunningham's correction coefficient [5],

d_a – the diameter of aerosol particle, m,

d_k – an average volume–surface diameter of droplet, m,

w_g – the velocity of a gaseous phase in scrubber, m,

η_g – the coefficient of dynamic viscosity of gas, Pa·s,

ρ_a – the density of aerosol particle, kg/m^3.

The efficiency of dust particles separation on single droplet greatly influences the interval efficiency of dust removal. The influence of the ratio of the volume stream of sprayed liquid to the gas volume stream in scrubber is very slight. In the case of the correlation found at the significance level of 0.95, we arrive at: a multiple correlation coefficient R^2 = 0.987 adjusted to the degrees of freedom, a standard error of evaluation equal to 0.0275 and the maximal relative errors of +12.5% and –8.33%. Equation (1) is valid for the following ranges of variables:

$$0.0004 \le \dot{V}_c / \dot{V}_g \le 0.006 \text{ m}^3/\text{m}^3; \quad 0.0128 \le \eta_k \le 0.9873.$$

The influence of a gaseous phase velocity on the total efficiency at dust removal, being the sum of the interval efficiencies of dust removal for each grain fraction and mass distribution of dust in these fractions, in the range of 1–6 m/s and at different spraying rates, is presented in figure 3, and the influence of the spraying rates in the range of 8.9–21.71 $m^3/(m^2h)$ and at different velocities of gaseous phase on this efficiency is shown in figure 4.

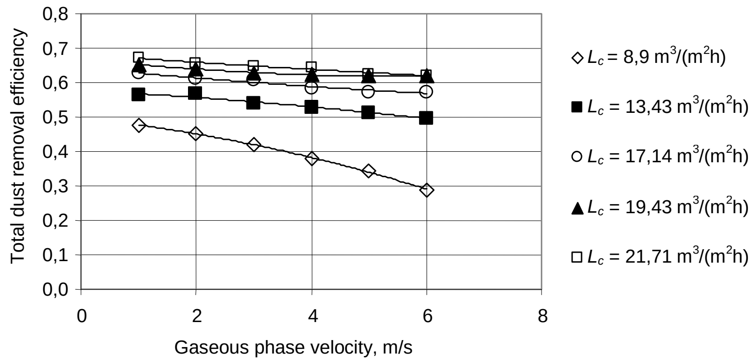

Fig. 3. The influence of gaseous phase velocity on a total efficiency of dust removal at different spraying rates

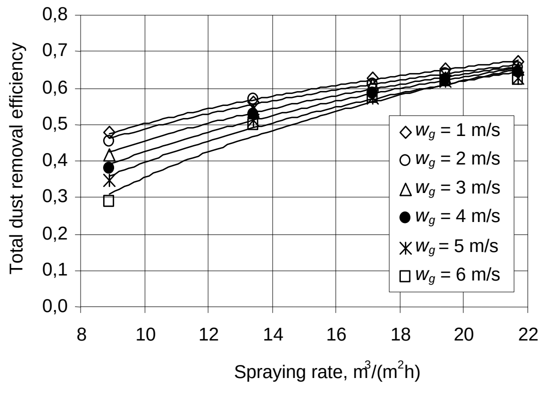

Fig. 4. The influence of spraying rate on a total efficiency

of dust removal at different gaseous phase velocities

The results obtained indicate that an increase of gaseous phase velocity in scrubber results in a lower efficiency of dust removal (figure 3). This efficiency decreases with an increase in spraying rate (figure 4).

3. CONCLUSIONS

The gas dedusting in a horizontal cocurrent spray scrubber at the values of independent variables used is not efficient enough, as the interval efficiencies of dust removal do not exceed 0.73. The interval and also a total efficiency of dust removal can be increased, mainly by using a multistage liquid spraying system in the scrubber or by an increase in the ratio of the volume stream of spraying liquid to gas volume stream in a scrubber; however, the second solution, as resulted from equation (1), is not very efficient. An improvement in the efficiency of dust removal can also be achieved by changing a pressure of liquid spraying or a type of construction and size of outlet hole of spray nozzle.

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ODPYLANIE GAZÓW ODLOTOWYCH WE WSPÓŁPRĄDOWYM SKRUBERZE NATRYSKOWYM

Podano wybrane wyniki badania procesu odpylania powietrza w wielkolaboratoryjnym poziomym współprądowym skruberze natryskowym oraz równanie doświadczalne, określające zależność przedziałowej skuteczności odpylania gazów w tym aparacie od stosunku strumienia objętości rozpylanej cieczy do strumienia objętości odpylanego powietrza i sprawności inercyjnego wydzielania cząstek pyłu określonego rozmiaru na pojedynczej kropli. Określono również wpływ prędkości fazy gazowej i gęstości

zraszania na całkowitą skuteczność odpylania.