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Research Article

RESULTS OF OPTIMIZING THE PROCESS OF CLEANING AIR FROM SOLID PARTICLES

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ABSTRACT

The article presents the results of the optimization (optimization) of the mode indicators of the process of cleaning the air from solid particles by the Box-Wilson method of steep ascent. Acceptance was based on three factors, i.e., solid content (solid particles), the hydraulic resistance of the circulation pipe that circulates fine dispersed dust up to 5 μm in the device, and the speed of the dust flow. Based on the computer, studies carried out to determine the optimal opera-tion modes of the dust cleaning process, the following conclusions were drawn: solid content is 75%; hydraulic resistance of the circulation pipe is 51.3 Pa; it was determined that the speed of dusty air flow is 21.7 m/s.

KEYWORDS

Optimization, cyclone, circulation pipe, vertical rise, Box-Wilson, hydraulic re-sistance, fine-dispersed particles, structural dimensions, flow rate.

INTRODUCTION

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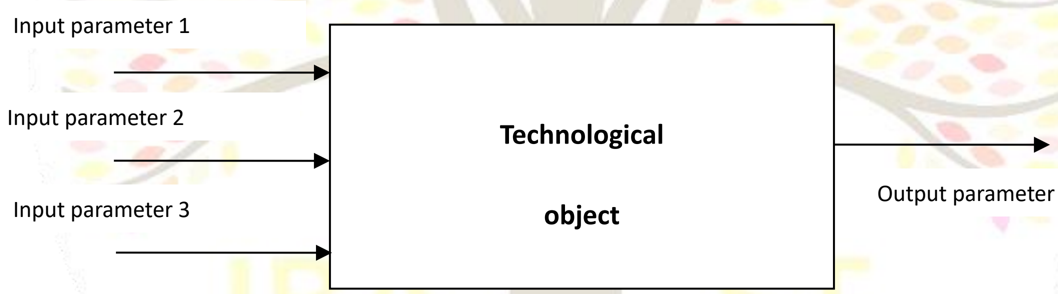
The goal of the work is to find a new direction of the gradient for the order of steep ascent. This is the content of the second cycle of the process [1-5].

Based on the similarities described above, we select the variability intervals for each factor and fill in the table of factor values during the study. Then we make a research plan, implement it and put the results in the research implementation table.

Table 1. The new direction of the gradient for steep ascent order

Name of the factor	Unit of measure	Minimum value	Maximum value	Process departure mode
Solid content	%	70	90	80
Hydraulic resistance of the circulation pipe	Pa	28	80	54
Dust air speed	m/s	19	25	22



The value of the range of changes for each factor is limited from below; first of all, by the errors of the instruments and devices, and with their help of them, the values of the factors are measured and set during the experiment. [6-10]

As for the upper limit, it is impossible to make clear statements.

We get as follows: $0.05 \cdot x_{0j} \leq \Delta_j \leq 0.07 \cdot x_{0j}$

Here Δ_j - x_j factor change interval

x_{jB}-x_j - the maximum allowable value of

x_{jH}-x_jn - the minimum allowable value

From this, we get:

$$\Delta_1 = 0{,}05 \cdot (90 - 70) = 1$$

$$\Delta_2 = 0{,}05 \cdot (80 - 28) = 2{,}6$$

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$\Delta_3 = 0{,}05 \cdot (25 - 19) = 0{,}3$

Table 2. Table of values of factors as a result of experimentation

Name of the factor	Unit of measure	Minimum value	Maximum value
Solid content	%	69	81
Hydraulic resistance of the circulation pipe	Pa	25.4	82.6
Dust air speed	m/s	18.7	25.3

After designing a fully factorial experiment 23, we have the following experimental results:

Table 3. Results of experiments

No	Experimental design						Result			
	Solid content		Hydraulic resistance of the circulation pipe, Pa		Dust air speed		Concentration			
	code	Value	code	value	code	value	Por. No	value	Por. No	value
1	-1	69	-1	25.4	-1	18.7	7	41.53	1	40,61
2	+1	81	-1	25.4	-1	18.7	5	42,43	3	42,14
3	-1	69	+1	82.6	-1	18.7	9	45.00	13	42.40
4	+1	81	+1	82.6	-1	18.7	6	46.81	16	46,41
5	-1	69	-1	25.4	+1	25.3	4	45,27	11	43.50
6	+1	81	-1	25.4	+1	25.3	2	46.00	12	45.30
7	-1	69	+1	82.6	+1	25.3	14	48,41	15	48.02
8	+1	81	+1	82.6	+1	25.3	8	49.10	10	50.03

The result of the estimation values of the regression coefficients:

Table 4. Table of estimation of coefficients of the model

Rate estimation	Appraisal value	Statistical value	t_{kr}	Hypothesis test result
$\bar{b}_0$	45,1850	204.5625345	2.31	1
$\bar{b}_1$	-0.8425	3.814184692	2.31	1

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$\bar{b}_2$	-1.8375	8.318770768	2.31	1
$\bar{b}_3$	1.7688	8.007524243	2.31	1
$\bar{b}_{12}$	0.2225	1.007306937	2.31	0
$\bar{b}_{13}$	-0.1888	0.854513188	2.31	0
$\bar{b}_{23}$	0.0987	0.447063191	2.31	0
Mean squared deviation of regression coefficients				0.220886
The number of remaining coefficients				4

Thus, the model will look like this in the normalized variables:

$$y = 45 - 0{,}84 \cdot x_1 - 1{,}83 \cdot x_2 + 1{,}77 \cdot x_3$$

Table 5. Checking the adequacy of the model

Average	According to the model	Dispersion	
41.07	40.74	0.222778125	
42.29	42,42	0.037128125	
43.70	44,41	1.011753125	
46.61	46.10	0.527878125	
44.39	44.27	0.024753125	
45.65	45.96	0.190653125	
48,22	47.95	0.141778125	
49.57	49.63	0.009453125	
Adequacy variance		0.541544	
Repetition Dispersion		0.78065	
F statistics		1.441527	

Fisher's criterion

F=Sad2/Se²

(1)

F=2.79, $\nu_1=4$, $\nu_2=8$,

From the Fisher distribution table, we determine $F_{kr}=3.84$.

It can be seen that the obtained model is adequate. The model will look like this in natural variables:

$$y = 45 + 0{,}84 \cdot (x_1 - 80)/1 + 1{,}83 \cdot (x_2 - 54)/2{,}8 - 1{,}77 \cdot (x_3 - 22)/0{,}3$$

from this:

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$$y = 72{,}31 + 0{,}84 \cdot x_1 + 0{,}65 \cdot x_2 - 5{,}9 \cdot x_3$$

Here x1— Solid content, %;

x_2 — Hydraulic resistance of the circulation pipe, Pa;

x_3 — Speed of dusty air, m/s;

y — output parameter concentration, %.

To obtain the coordinates of the first point using the Box-Wilson method, the following multiplication should be obtained: [10,11]

$$\delta_j = b_j \cdot \Delta_j \qquad (2)$$

here,

$\delta_j - j$ - factor coefficient estimation value;

$b_j - j$м - factor evaluation coefficient;

$\Delta_j - j$ - change interval for the factor;

For this option

$$\delta_1 = 0{,}84 \cdot 1 = 0{,}84 \qquad (3)$$

$$\delta_2 = 1{,}83 \cdot 2{,}6 = 4{,}76 \qquad (4)$$

$$\delta_3 = 1{,}77 \cdot 0{,}3 = 0{,}53 \qquad (5)$$

Then, according to the procedure, the maximum of all δ_j was selected and δ_0 was taken as the base value.

In this case, for a variable (factor) δ_j is called the maximum baseline and the baseline step λ is chosen for this variable. The sign and size of the steps for each factor are determined by a general formula.

$$\lambda_j = \lambda_б \cdot \delta_j / |\delta_0| \qquad (6)$$

here,

λ_j - *j*- step movement by the j-factor;

δ_j - *j*- calculation value;

δ_0 – basic value;

λ_b is the base step.

In our case, we consider when choosing a basic step equal to half of the change interval for the second factor $\lambda_б = 3{,}5 \cdot \Delta_1 = 3{,}5 \cdot 1 = 3{,}5$:

$$\lambda_1 = \lambda_б \cdot \delta_1 / |\delta_0| = 0{,}5 \cdot 0{,}84 / 8{,}72 = 0{,}05$$

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$\lambda_2 = \lambda_б \cdot \delta_2 / |\delta_0| = 0{,}5 \cdot 4{,}76 / 8{,}72 = 0{,}27$ $\lambda_3 = \lambda_б \cdot \delta_3 / |\delta_0| = 0{,}5 \cdot 0{,}53 / 8{,}72 = 0{,}03$

Table 6. The main parameters of the model

Model: $y = 72{,}31 + 0{,}84 \cdot x_1 + 0{,}65 \cdot x_2 - 5{,}9 \cdot x_3$								
		Factors			Results			
Naming		Solid content	Tsir-ya pipe hydration resist.	Solid content	Output parameter			
The starting point		80	54	22				
Working step		0.05	0.27	0.03				
Step number	Type of experiment				According to the model	Experiments		Average
					$\bar{y}$	y_2	y_1	Y
1	M	79.50	53.73	21.97	41.67			
2	M	79.00	53.46	21.94	44.87			
3	M	78.50	53.19	21.91	48.08			
4	P	78.00	52.92	21.88	51.28	50.37	50.39	50.38
5	M	77.50	52.65	21.85				
6	P	77.00	52.38	21.82		52.06	52,51	52.78
7	M	76.50	52.11	21.79				
8	P	76.00	51.84	21.76		55.37	55.21	55.79
9	R	75.50	51,57	21.73				
10	R	75.00	51.30	21.70		60.20	60.74	60.97
11	R	74.50	51.03	21.67		54.75	55,46	54.60
12	R	74.00	50.76	21.64		55.49	56,66	55,58
13	R	73.50	50.49	21.61		56,38	56.00	57.69
14	R	73.00	50.22	21.58		57.82	55.35	56.08
15	R	72.50	49.95	21.55		58.03	59.82	57.92
16	R	72.00	49.68	21.52		57.89	57.35	58.01
17	R	71.50	49,41	21.49		59.75	60.15	58.50
18	R	71.00	49.14	21.46		59.85	59.15	60.50
19	R	70.50	48.87	21.43		56.49	58,66	56,58
20	R	70.00	48.60	21.40		57,38	57.00	58,69
21	R	69.50	48.33	21.37		58.82	56.35	59.08
22	R	69.00	48.06	21.34		56.03	58.82	58.92
23	R	68.50	47.79	21,31		58,49	55,66	58,58
24	M	68.00	47.52	21,28		56,38	57.00	55.69
25	M	67.50	47.25	21.25		55.82	54,35	56.08

The purpose of the experiment is to determine the new direction of the gradient for the Box-Wilson procedure, which constitutes the second cyclic content of this procedure [3,5].
Similar to the above, we select ranges of variation for each of the factors and record the values of the factors in a table during the experiment. Then, we plan the experiment, execute it, and put the results in the experiment execution table.

Table 7. Process execution mode

Name of the factor	Unit of measure	Minimum allowed value	Maximum allowed value	Process execution mode
Solid content	%	70	90	72
Hydraulic resistance of the circulation pipe	Pa	28	80	49.68
Dust air speed	m/s	19	25	21.52

Table 8. Table of factor values as a result of experimentation

Name of the factor	Unit of measure	Minimum value	Maximum value
Solid content	%	68	76
Hydraulic resistance of the circulation pipe	Pa	48.2	51.16
Dust air speed	m/s	18.7	24,34

After designing a fully factorial experiment 23, we have the following experimental results:

Table 9. Schedule of the experiment

No	Experimental design						Result			
	Solid content		Hydraulic resistance of the circulation pipe		Dust air speed					
	code	value	code	value	code	value	Por. No	value.	Por. No	value
1	-1	68	-1	48.2	-1	18.7	2	56,38	14	59.15
2	+1	76	-1	48.2	-1	18.7	8	57.82	9	58,66
3	-1	68	+1	51.16	— 1	18.7	3	58.03	1	57.00
4	+1	76	+1	51.16	-1	18.7	6	60.20	11	56.35

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5	-1	68	-1	48.2	+1	24,34	4	59.85	12	58.82
6	+1	76	-1	48.2	+1	24,34	10	59.85	16	55,66
7	-1	68	+1	51.16	+1	24,34	5	56.49	15	57.00
8	+1	76	+1	51.16	+1	24,34	7	57,38	13	54,35

The results of calculating the estimation of regression coefficients and testing their significance are summarized in the table:

Table 10. Table of estimation of coefficients of the model

Coeff. evaluation	Appraisal value	Statistic value	$t_{кр}$	Hypothesis test result
$\bar{b}_0$	57,6869	127,60378	2.31	1
$\bar{b}_1$	-0,1531	0,3387136	2.31	0
$\bar{b}_2$	-0,5869	1,2981717	2.31	0
$\bar{b}_3$	-0,2619	0,5792694	2.31	0
$\bar{b}_{12}$	0,1231	0,2723534	2.31	0
$\bar{b}_{13}$	-0,4619	1,0216708	2.31	0
$\bar{b}_{23}$	-0,5331	1,1792763	2.31	0

Thus, the model will look like this in normalized variables: y=57.69

Fisher criterion F=1,765 $\nu_1=7$, $\nu_2=8$, $F_{кр}=3{,}50$

The results of the experiment showed that the corresponding coordinates of the special extreme in the central area showed that only the coefficient b0 is significant.

Its evaluation value is 57.69. As a result, the optimal mode of process implementation was achieved.

Thus, based on the results of the research on the purification of atmospheric air from catalyst dust, the following results were obtained: a technological line consisting of two-stage cyclone devices of a new design was developed for the purification of atmospheric air from catalyst dust. To determine the optimal (optimal) operating modes of the dust cleaning process on the computer: solid content - 75%; hydraulic resistance of the circulation pipe - 51.3 Pa; the speed of dusty airflow - 21.7 m/s.

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