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RESEARCH OF DESIGNS OF THE AXIAL DRUM EQUIPMENT OF STONE MATERIAL SORTING

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ABSTRACT

There are studies showing that 10% of the total energy generated in the world is spent on crushing and sifting and sorting processes in mining sectors. 52.7% of the total mining industries extracts metal ores, 36.3% of them extracts coal. It can be seen that there is a need for sorting the materials with particles in these sectors. According to the needs, the energy expenditure is high and the devices and equipment used still maintaining their traditional designs and makes. The process of sorting out the materials with particles is sifted by the flat surfaced, trommel shaped, and cylindrical mesh surfaces positioned in vertical axis. The above methods are still in use, which becomes the basis of mechanical sifting methods. Therefore, the researchers continue to work on perfecting the above methods. The goal of this research work is to survey and determine the possibility of the changes in the designs of sifting equipment with the trommels can improve the influences that are created during the sifting process, the efficiency of sifting and the productivity of device or equipment. By this research work, with the purpose to improve the parameters of sifting of materials with particles, we will change the design of cylindrical trommel of the cross trommel sieve, which is often used in the sifting process to axle to its axis, and in order to confirm the results of experiment by determining the CAD analysis of axle trommel and the movement of one particle inside of it using the ADAMS software, the experiment on the real equipment shall be rationalized by putting into the mathematic modeling, develop the physical modeling using the "EDEM solution" software and process the results.

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Introduction. Granular and powder materials classification and sifting processes are used in many fields such as energy, mining, pharmaceutical, food and chemical technology, agricultural, building materials, waste processing plants, etc. The particles of materials have different types of shapes, mixed and the sizes are different. Sifting of particle materials consists of separating mixed particles, determining the properties of interactions, and the laws of particles and particles mass shifting. Also, correctly planning the features of physical and mechanical designs of rotating trommels and the properties of the materials included in it shall provide the condition for operating the mechanism.

The most efficient method to make the screening process rational is using the mathematical modeling. I assume that using the mathematical modeling defines the rational method of screening process, moreover, it is possible to reduce the number parameters of the experiments to be conducted to determine the reactions from the invented mechanical system during the screening process. It has proven that determining the mass movement law of materials with particles based on the discrete element method (DEM) developed by Cundall and Strack is efficient. [1, 2, 3]. In other words, when applying the same amount of forces to particle materials that differ in density, weight and size, some of them are

mixed and some are distinguished. Many different types of the movements of the flows of particles inside of the trommel such as sliding, rolling, hitting, and centrifuge affect the efficiency of screening [4, 5, 6]. It was determined that the particles moving inside of the trommel are not only in the dry condition, but also in the humid and wet environment and it greatly affect to the movement features or properties; the particle materials move with high speeds harmonizing with the liquid and free surface shall be limited by the extent of trommel [7, 8]. In 2001, the researchers Mellmann et al determined surveying the filling angle and the wall friction coefficient of the particle materials [9]. Also, they have determined that the state of the granular material is correlated to the rotation speed of trommel, the size of the filling, and the size of particles by the experiment [10, 11]. It was surveyed using the experiment and determined the relationship between the rotation of the wheat particle materials and the sharp drop angles in the trommel system spinning by the horizontal axis [12, 13, 14]. In addition, they have conducted the researches to distinguish the particles by the liquid flows and determine the particle sizes sorted out from the trommel screen relating to the design peculiarities [15]. B. Bellocq et al have conducted the survey to improve the efficiency of the trommel screen with multi layers [16]. Looking at the event that the method leaning to the basic axis of trommel is still maintained, it was assumed that it is required to conduct additional surveys and researches furthermore.

1. Changes due to the trommel’s axial angle

It was assumed, during the survey of the parameters such as trajectory, speed and acceleration of movement of particles moving inside of the trommel screen, and the movement activations of the material layers, that the main factors affecting them were the trommel’s axial angles, rotations, and frequency and conducted the CAD (Computer Aided Design) experiment. The following picture shows trommel axis as it is rotating around the Y-axis.

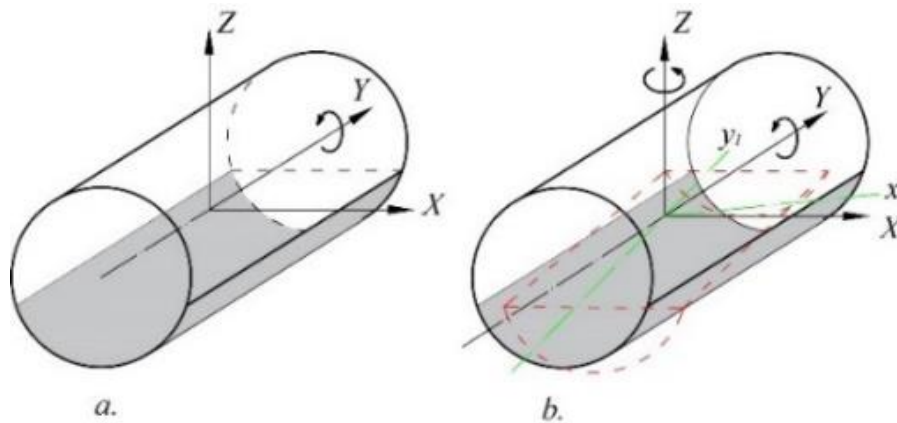


Fig. 1. a. Traditional position, b. Axial position

By the above experiment, the axial trommel results to the volume changes in virtual type and it was shown in the following table.

Table 2. Virtual experiment results

No.	Axial angle °	Area sq.m.	Volume cub. m.	S working area %
0	0	0.415	0.0218	-
1	1	0.424	0.0228	2.1 %
2	2	0.432	0.0238	4.09%
3	3	0.44	0.025	6.02%
4	4	0.448	0.026	7.95%
5	5	0.456	0.0271	9.87%
6	6	0.464	0.0282	11.8%
7	7	0.4715	0.0293	13.6%
8	8	0.4788	0.0303	15.37%
9	9	0.4861	0.0314	17.1%
10	10	0.4931	0.0325	18.8%
11	11	0.5	0.0336	20.4%

By conducting this experiment, the change occurring in the virtual dimensions of the screening surface resulted to the assumption that it is required to determine the properties of the motions of particles moving inside of the trommel. Before conducting the next experiment, in 1927, the scientist Levinson L. B. determined the main parameters such as the trommel diameter D and the height h of the loading material in the trommel relating to the maximum diameter d_{max} of the screening particle material when determining the geometric basic dimensions of the trommel screen.

Determining the particle motion properties.

The particle motion properties were compared by the motion trajectories' difference between the traditional and compared/installed as axial position of trommel screen. To prove this idea, it was experimented by creating the physical model of the trommel on the MSC-ADAMS software.

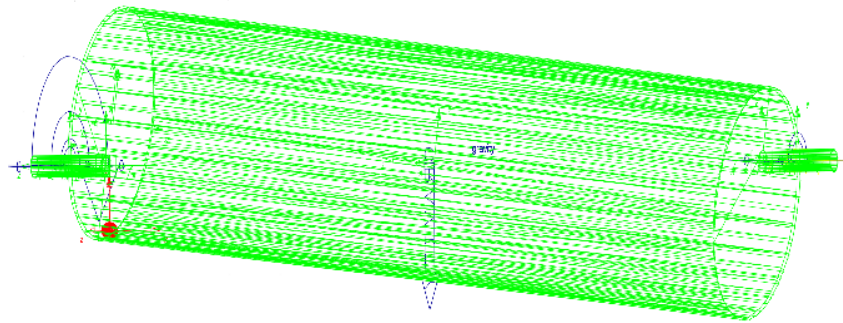


Fig. 3. Physical model of trommel

The experiment was carried out by incorporating the changes in the frequency and angle of rotation of the trommel and the result was a large amount of data parameter and thus, we have included one example by summarizing them.

Table 3. Datas generated by the MSC-ADAMS

No	Time	Part_3.CM position:X	Part_3.CM position:Y	Part_3.CM position:Z	Average
1	0	-323.8	-67	1.84E-14	0.0549
2	0.0033	-323.8	-67.0549	1.84E-14	0.1634
3	0.0067	-323.8	-67.2183	1.84E-14	0.0207
4	0.007	-323.8	-67.239	-2.61E-07	0.015143
5	0.0079	-323.7891	-67.2477	-0.0059	0.040182
6	0.01	-323.7548	-67.2569	-0.0247	0.080075
997	2.3967	290.5354	-148.008	-55.1537	0.164123
998	2.4	290.5559	-147.992	-54.9917	330.679
					1097.094mm

Using the data parameters obtained from the experiment, the lengths of trajectories of a single particle movement were identified and compared. The graph of the three-dimensional trajectory of the particles was generated in the MATLAB software.

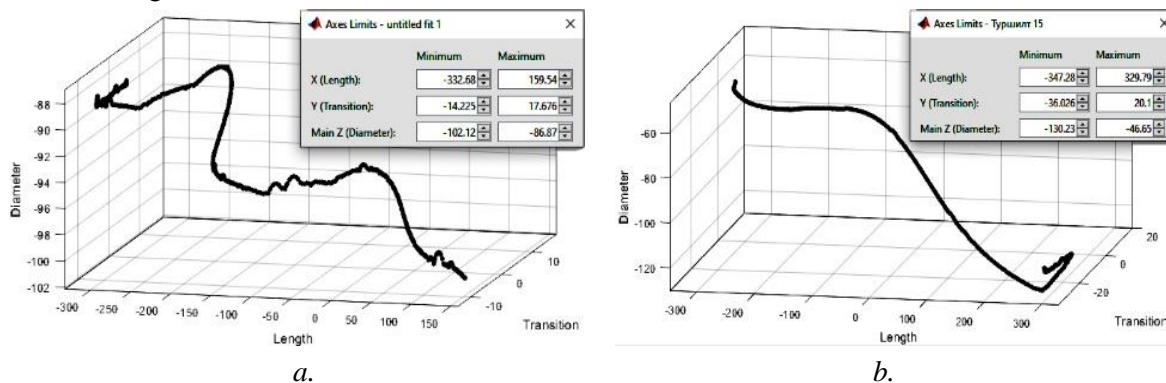


Fig. 4. a. The length of trajectory of particle that shifted at maximum level
 b. The length of trajectory of particle shifter at the time of non-comparing

The shift lengths of particles at the time of compared and non-compared state by the 7 degrees of the trommel with the diameter of 210 mm are shown in the Pictures 3 6a 4 (1097 mm, 983.7 mm). As drawing a conclusion here, it is assumed that the probability to be sifted shall be increased because the difference between the trajectories of the particle movements inside of the trommel is 18%.

The main factors influencing the sifting process are trommel rotation frequency, trommel diameter, tilt angle, or values X_1, X_2, X_3 which have been included in multifactor modeling. In 1976, scientist Adler Yu. P. has made a notice about this issue.

From the above regression, the following equation has been obtained.

$$y = 430.3106 - 7.4649 * x_1 + 6.3423 * x_2 + 7.2129 * x_3 - 15.1796 * x_1^2$$

Basing on the values obtained from the planning matrix, the trommel physical model with 5 different sizes has been obtained for further experiments.

2. CAE (Computer Aided Engineering) analyses made on axial trommel screen.

The method of using DEM (Discrete Element Method) for determining mutual impact between granular-granular, trommel-granular has been widely used in modern research works. The model, initially found by the researchers Cundall and Strack in 1974, and later obtained by Tsui, Hertz-Midlin, has been widely used.

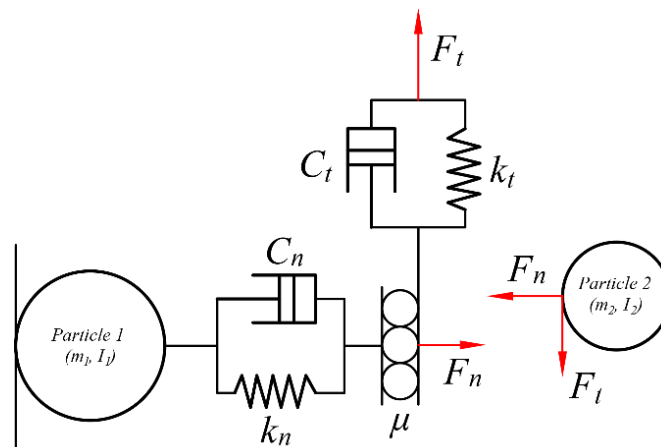


Fig. 7. The model of Tsuji and Hertz-Midlin that improved mutual impacting of granular materials

$$F_{ij}^t = (-k_t \delta_{ij}^t - \eta_t v_{ij}^s)$$

Here: v_{ij}^s - sliding speed at the impacting spot

v_{ij}^t - tangential speed

It is considered that the tangential force creates the condition for mutually interacting granules for sliding with each other or on surface.

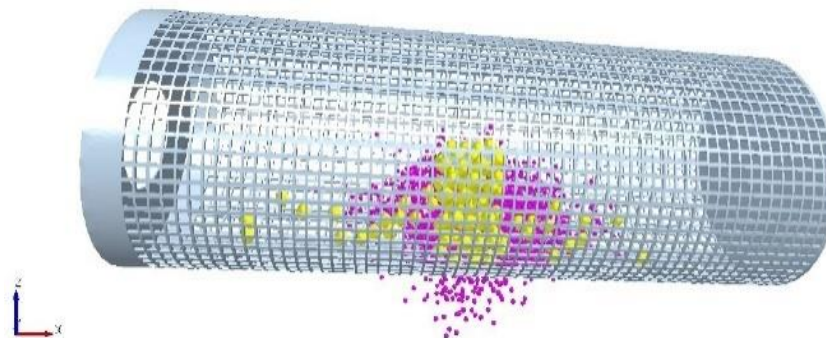


Fig. 8. Model for loading material to axial trommel using EDEM program

The results of EDEM analyses have been shown using data and graphs. The gained results show that the axial trommel is more efficient than the traditional trommel. Hence, the experiment has been made on real equipment and approved.

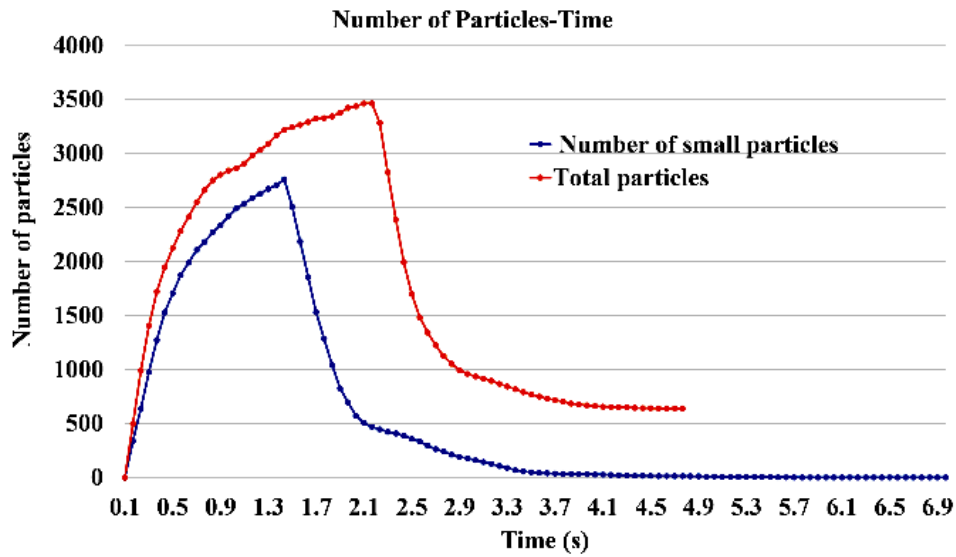


Fig. 9. Emission properties of the material

3. Experiment with axial trommel screen

Table 5. Test results and planning matrix

Experiment's no.	Standard value of the impacting factor		Working matrix		Average value
			N, rpm	D, mm	
	x_1	x_2	X_1	X_2	\bar{Y}_{u1}
1	+1	+1	45	260	160.4
2	-1	+1	25	260	171.4
3	+1	-1	45	160	71.2
4	-1	-1	25	160	78.2
5	-1.414	0	20.86	210	112.6
6	1.414	0	49.14	210	106.2
7	0	-1.414	35	139.3	49.6
8	0	1.414	35	280.7	172
9	0	0	35	210	85.4
10	0	0	35	210	84.4
11	0	0	35	210	84.2
12	0	0	35	210	83
13	0	0	35	210	86.8

Let us determine the regressive dependence of the experimental results from the input value using MATLAB program by the tasks of the above experiment.

$$F(x,y)=352.15-10.33 \cdot x-1.66 \cdot y-0.002 \cdot x \cdot y+0.15 \cdot x^2+0.0062 \cdot y^2$$

That regressive dependence has come out and the maximum and minimum screening differing values have been determined using the MATLAB code.

```
[x,y]=meshgrid(20:2:50,140:2:280);
f=(352.15-10.33.*x-1.66.*y-0.002.*x.*y+0.15.*x.^2+0.0062.*y.^2);
```

```
figure(1) surf(x,y,f)
```

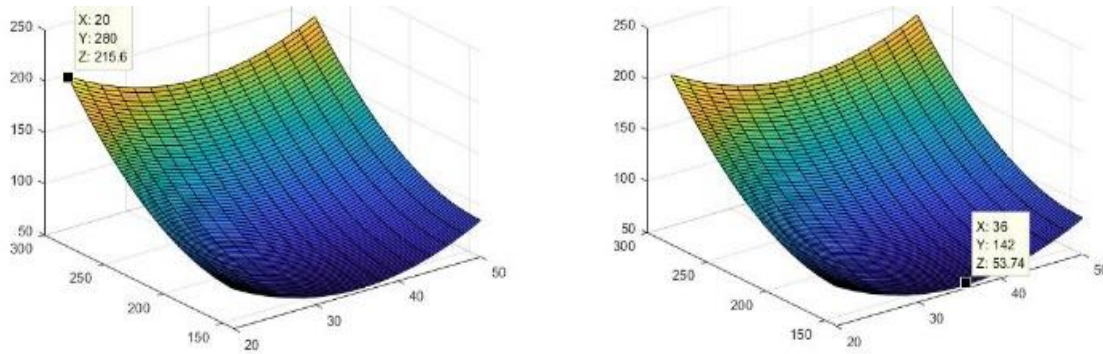



Fig. 13. Maximum and minimum values of the material screening

```
function f=ganbaafunc(x)
f=(352.53-10.33.*x(1)-1.66.*x(2)-.0019.*x(1).*x(2)+0.15.*x(1).^2+0.0062.*x(2).^2);
>> [x, fval]=fminsearch(@ganbaafunc,[20 50;140 280])
x =
35.3155  25.9964
139.2822  265.7918 val =54.5214
```

This value is the experimental truth coming out with a slight difference when calculating using the Lagrange's method of the lowest energy, and the optimization's highest value in the regression equation is at $x_1 = 25.9964$, $x_2 = 265.7918$:

```
x=25.9964;
y=265.7918;
f=(352.15-10.33*x-1.66*y-0.002*x*y+0.15*x^2+0.0062*y^2);
>> f
f =167.9462
```

As a result of the optimization, the minimum value for screening deviated from the real experimental value.

Conclusions. The ratio between the axial trommel diameter for launching experiment and length shall be 1:3 whereas axle angle incline shall not overcome 7 degree. The most trajectory of one granule's movement in an axial trommel has been determined as $n=25$ rpm, $d=260$ mm, $\alpha=7^\circ$ by making simulation with the main values of the axle trammel in the MSC.ADAMS program. The trajectory of one granule's movement in an axial trommel shows a ratio of 18-21% compared to the one granule's movement in a traditional trommel screen. The result of the granule's emission coming out from EDEM simulation program is by 18.5% higher than that of the screen with traditional trommel.

Moreover, the real experimental axial trommel weighs 112 gram, and the traditional screen 88.4 gram, which shows 26,7% higher screening efficiency.

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Appendix no. 1

Summarized results of the EDEM simulation (graph`s value, 100 lines)

№	Diameter	140	160 4 35	160 7 35	160 10 35	210 2.758 35	210 4 35	210 7 35	210 11.2 35	260 4 35	260 7 35	260 10 35	280 7 35	Traditional
	Time (s)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)	Mass (kg)
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.070047	0.037719	0.037496	0.03783	0.03783	0.037496	0.037719	0.037608	0.037941	0.037496	0.037719	0.037608	0.037941	0.038053
3	0.140023	0.076216	0.076328	0.07655	0.07655	0.076439	0.076661	0.07477	0.076661	0.075883	0.076661	0.076216	0.076884	0.076884
4	0.21	0.1126	0.111821	0.113713	0.113935	0.113824	0.114603	0.105924	0.113713	0.113268	0.114269	0.114269	0.11438	0.114158
5	0.280047	0.142975	0.143086	0.145089	0.145757	0.1452	0.148316	0.128956	0.145423	0.146091	0.146424	0.145979	0.146647	0.145089
6	0.350024	0.168566	0.167008	0.17068	0.17335	0.172349	0.176243	0.147092	0.172127	0.171681	0.170903	0.171125	0.171014	0.172015
7	0.420001	0.191042	0.187036	0.193489	0.196271	0.193267	0.197161	0.159109	0.192933	0.192265	0.189929	0.18915	0.188928	0.190263
8	0.490047	0.210513	0.201723	0.212293	0.21463	0.211403	0.212738	0.170569	0.212404	0.205729	0.201612	0.20584	0.201389	0.204171
9	0.570031	0.228538	0.216187	0.228538	0.233545	0.22787	0.228983	0.184143	0.230541	0.213517	0.213406	0.215297	0.212516	0.218413
10	0.640007	0.242001	0.229317	0.244894	0.24545	0.23844	0.240777	0.194825	0.243559	0.220527	0.223308	0.221528	0.21908	0.226424
11	0.710054	0.254685	0.240443	0.255686	0.255575	0.248454	0.250902	0.20673	0.25246	0.225089	0.229317	0.227314	0.22609	0.239998
12	0.780031	0.266145	0.250791	0.26659	0.263252	0.257912	0.2578	0.218079	0.262919	0.231097	0.23488	0.231431	0.230541	0.248899
13	0.850008	0.274156	0.263475	0.27449	0.269483	0.264921	0.267147	0.228093	0.267814	0.232877	0.240666	0.235659	0.235881	0.257912
14	0.920054	0.286062	0.269817	0.282724	0.278162	0.272932	0.275937	0.23488	0.277272	0.237773	0.245561	0.242001	0.241111	0.265033
15	0.990031	0.295408	0.275937	0.290401	0.284838	0.277494	0.285839	0.242668	0.286618	0.244115	0.249901	0.246563	0.245005	0.273155
16	1.06001	0.302863	0.283503	0.297077	0.294073	0.283057	0.295297	0.248565	0.292404	0.250791	0.255575	0.251125	0.250123	0.278384
17	1.13005	0.310651	0.29118	0.301639	0.30086	0.290067	0.301082	0.250791	0.301527	0.255464	0.262251	0.251681	0.253684	0.282946
93	6.51001	0.006676	0.004228	0.004339	0.004117	0.008345	0.007343	0	0.007121	0.005563	0.003894	0.002337	0.004117	0.010014
94	6.58005	0.006565	0.003894	0.004228	0.004006	0.008122	0.00701	0	0.006676	0.005452	0.003672	0.002114	0.003783	0.009791
95	6.65003	0.00612	0.003338	0.003894	0.003894	0.008122	0.006787	0	0.006231	0.005341	0.003672	0.002003	0.003672	0.009569
96	6.72001	0.005786	0.003115	0.00356	0.003672	0.0079	0.006453	0	0.005675	0.005341	0.003672	0.00178	0.00356	0.009346
97	6.79006	0.005563	0.003115	0.003449	0.00356	0.0079	0.006342	0	0.005341	0.005341	0.00356	0.00178	0.003449	0.009346
98	6.86003	0.005341	0.003115	0.003338	0.003338	0.007789	0.00612	0	0.005341	0.005341	0.003449	0.001669	0.003004	0.009124
99	6.93001	0.005229	0.003115	0.003115	0.003004	0.007566	0.005897	0	0.005118	0.005007	0.003227	0.001446	0.002893	0.00879

