HOOP OF THE FAN MILL

by

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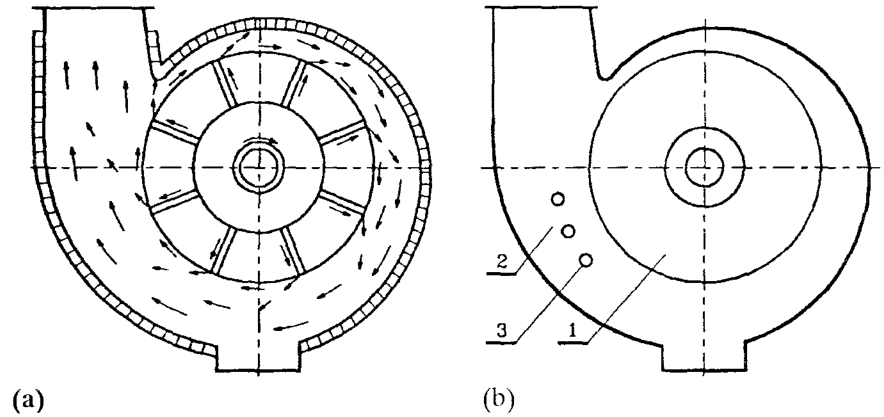
While passing through the fan mill beater wheel, coal particles are mutually ground both by collision and friction. Having left the beater wheel, under the influence of transport fluid flow in the mill chamber spiral, the path of coal particles turns towards the spiral's exit, providing that the collision with the chamber armoured plates occur under the low angle. The process of the coal grinding inside the fan mill is relatively rough, therefore the coal powder separator should be installed behind the mill. The efficiency of after-grinding process in the fan mills may be increased after the installed fixed, hoop-shaped barriers, into the chamber spiral, around the beater wheel. The increase in the hoop's transparency coefficient, which depends on the number and size of barriers, as well as reciprocal value of the mean hoop's diameter, may influence the increase of the grinding efficiency. The barrier's shape and it's installment angle towards the beating wheel also make a significant influence on the grinding quality. As the consequence of the hoop installment there appears the decrease in ventilating efficiency of the corresponding fan mill. They may complete the coal grinding process without coal powder separators because of the increased rate of the grinding quality.

Introduction

Inside the fan mill coal primarily gets ground by striking and friction against the active plates. The speed of coal ground particles, after passing through the mill's beater wheel, is 90–100 m/s. Such a large kinetic energy is needed for further grinding of the mass of coal by striking it against the armor plates set up along the circumference of the mill's body spiral. After leaving the beater wheel, trajectory of the particle is under the influence of the transport fluid's flow inside the spiral, and is shifted in direction of the mixture of fluids and pulverized coal particles flow (Fig. 1a). Due to the way the mill body's spiral is constructed, it is getting more and more away from the beater wheel, therefore coal particles are being decelerated in that space and strike the armor plates under the small angle; consequently, during further grinding of the particles use only small part of the available kinetic energy. In the case of mills of higher capacity, dimensions of which are enlarged, the decrease in the grinding effects behind the beater wheel is very accentuated because of the great distance between the beater wheel and the armor that the coal particles are to go in order to be ground.

In order to use enormous kinetic energy owned by the coal particles and to prolonge the grinding process behind the beater wheel, the authors [1] suggest to set up 3 to 4 obstacles of the circular cross-section at the place where the spiral is at its widest (Fig. 1b). This way, since the set up obstacles are closer to the beater wheel than the armor plates of the spiral, somewhat bigger part of the particles kinetic energy may be used, which would contribute to higher pulverized coal fineness. Therefore, the return of the coarse particles from the classifier to the mill would be decreased, *i. e.* decrease would be the recirculatory index. This would result in total decrease of wearing down of both active elements and the mill armor; furthermore this wearing would partly affect the mounted obstacles.



(a) (b)

Figure 1. The grinding process behind the rotor
(a) Trajectory of the coal particle inside the fan mill; (b) Fan mill with obstacles
1 – Beater whell; 2 – Spiral of the mill body; 3 – Obstacles

Reconstruction of the combined mill DGS 100 S (located at the TE Nikola Tesla A in Obrenovac, Yugoslavia), and made according the license of a German Company Babcock, aiming to increase the quality of the pulverized coal, covered the installment of 3 flat plates of the rectangular cross-section. The plates, 150 mm wide and 15 mm thick, are set up inside the spiral of the beater part of the mill, as the obstacles, at the place of the exit of the coal/conveying gas mixture at the so-called "nose" of the mill (Fig. 2a). The obstacles occupied the space which corresponded to the central angle of 28° from the nose to the last obstacle. Expanding of this reconstruction meant the installment of 4 profiled plates of the trapezoidal cross-section (average width 100 mm and thickness

20 mm), which were set up at the same place inside the spiral, but used to occupy somewhat bigger space which corresponded to the central angle of 43° [2].

After 900 working hours of the combined mill, at the noticeable abrasion of the active elements and the obstacles, somewhat higher grinding quality and the decreased humidity of the pulverized coal was achieved by these reconstruction's, under constant working parameters of the mill.

Further analyses were developed toward increasing the number of obstacles located inside the spiral of the mill, around the beater wheel. The number of obstacles was limited, since the spiral does not allow their installment at its narrowest parts (Fig. 2b). Analyses were made with 9, 10, 11, 12, 14, 15, 24 and 25 obstacles [3]. They were set up in order, one after the other along the beater wheel, starting at the nose of the mill toward the narrowest part of the spiral, and their number increased, so that hoop with 25 obstacles covered almost complete circumference of the beater wheel. The obstacles were also set up in 2 positions, defined by the corresponding angle which ensured orthogonal particles impact on the obstacle. Spiral body of the laboratory mill was too narrow for correct installment of the hoop; therefore, a part of beater wheel was inactive in the sense of further grinding and usage of the cool particles kinetic energy. By setting up the obstacles into the partial hoop the ideal surface of the pulverized coal was increased compared to the mill without a hoop, and the available fan pressure of the mill was decreased proportionally to the increase in the number of obstacles. Analyses were done without drying, and using the surrounding air (temperature 20 °C) as the transport fluid.

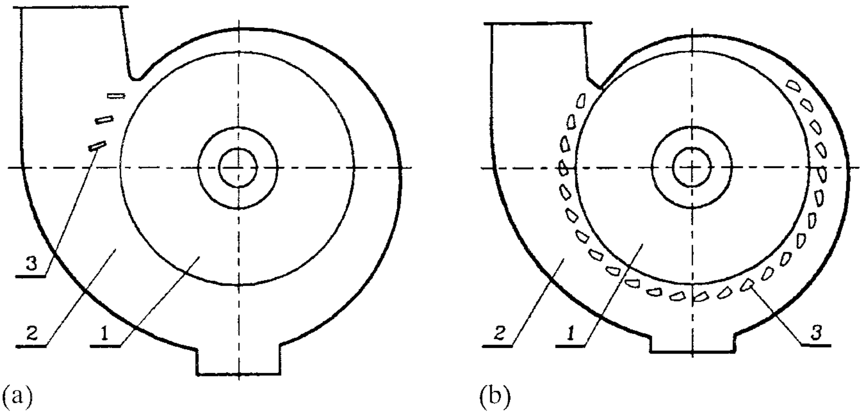


Figure 2. Reconstruction of the fan mill by setting up the obstacles along the spiral of its body

(a) Fan mill with obstacles; (b) Fan mill with partial hoop

1 – Beater whell; 2 – Spiral of the mill body; 3 – Obstacles

Basic hoop characteristics

The latest analyses are made on the model of the fan mill with a hoop, with variable geometry and shapes of the obstacles, and without classifier [4]. Hoop is constructed in such a way that it enables the set up of a large number of various obstacles encircling the beater wheel. Numerous laboratory analyses were performed on this mill in order to determine the relation between the pulverized coal fineness and the hoop geometric characteristics and its shape, *i. e.* increase of the pulverized coal ideal surface as one among more important criteria for determining its quality [5]. Fine brown coal Resavica (Serbia) was used for the analysis which initial ideal surface was $S_i = 14.9$ m^2/kg. The ideal surface is defined as ratio of the pulverized particles area (sphere shape) and unit of mass. Water content in the coal was $W^r = 18.4\%$, while the moisture of pulverized coal was somewhat smaller and was around 17.5%. Drying of the coal wasn't done, while the air ($t_2 = 22$ °C) served as a conveying gas. Hardgrove index was $k_H = 38.6$.

Obstacles with variable characteristic dimension d_o [m], and circular, semicircular, and rectangular cross-section were set up around the beater wheel of the experimental mill at different distances h_o [m] from the external radius of the beater wheel, defined by the mean hoop radius D_o [m] (Fig. 3). Number of obstacles in the hoop, z_o varied, and it was possible to set up obstacles under the angle β toward the beater wheel. Step between the obstacles, t_o, depended on the number of obstacles in a hoop, which occupied the space in the spiral defined by the distance h_z [m] in relation to the external radius of the

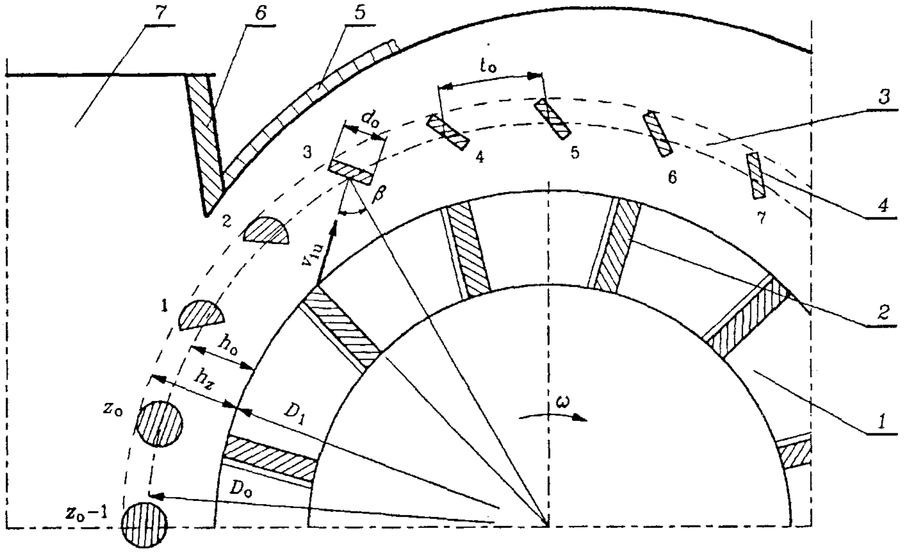


Figure 3. Laboratory fan mill with a hoop
1 – Beater whell; 2 – Betaer plate; 3 – Hoop; 4 – Obstacles; 5 – Mill body; 6 – Mill nose; 7 – Pulverized coal/conveying gas mixture

beater wheel D_1 [m]. By changing the number of revolutions of the driving shaft on which the beater wheel was installed, the change of tangential velocity, v_{o1} [m/s], was performed. The most important hoop geometric characteristics d_o, z_o and D_o may be defined using the coverability coefficient of the hoop by the obstacles which is

$$K_z = 1 - k_{pz} = 1 - e^{\frac{d_o z_o}{D_o}} \qquad (1)$$

where k_{pz} is free flow space coefficient of the hoop [5].

Based on the results of numerous analyses [6] during the coal grinding in the fan mill with hoop, consisting of obstacles having circular cross-section, Fig. 4 shows the dependence of fan pressure on its free flow space coefficient and tangential velocity of the beater wheel.

During the analyses, concentration of pulverized coal in conveying gas was μ = 0.50–0.53 kg/kg. The increase of the free flow space coefficient resulted in the increase of the fan pressure up to its maximum value that was reached at the free flow space coefficient k_{pz} = 1. This means that the mill operated without hoop, like classic fan mill. After increasing the tangential velocity of the beater wheel and at the constant free flow space coefficient, higher fan pressure of the mill with hoop was achieved.

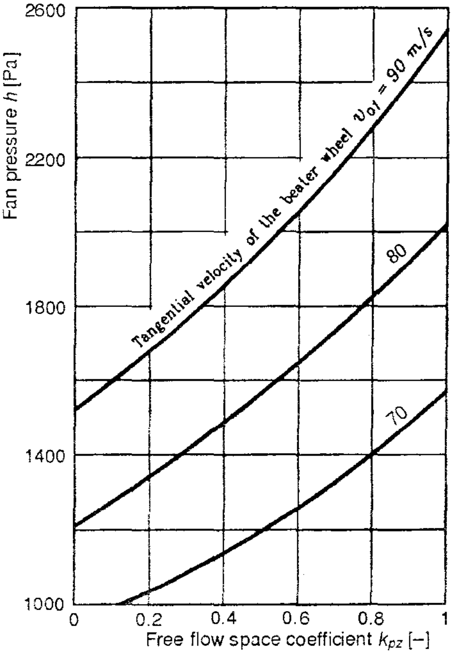


Figure 4. Dependence of the pressure of the fan mill with hoop from its free flow space coefficient and tangential velocity of the beater wheel

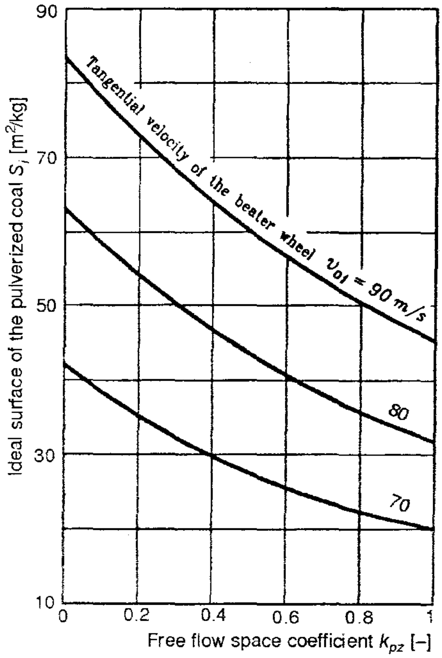


Figure 5. Dependence of the pulverized coal ideal surface from free flow space coefficient of the hoop and tangential velocity of the beater wheel

During the analyses, the control of the fineness of pulverized coal under the same concentration in the conveying gas was being performed, and its ideal surface was being determined. Increase in the ideal surface of the pulverized coal is shown in Fig. 5 also in relation to the free flow space coefficient of the obstacles having circular cross-section and to tangential velocity of the beater wheel.

By decreasing the free flow space coefficient and increasing the tangential velocity of the beater wheel, resulting automatically in increased speed of pulverized coal particles at the exit point of the beater wheel which reached the maximum value of 99 m/s, the overall increase in the pulverized coal ideal surface was achieved, which was on the average twice bigger than in case of the classic fan mill.

Increase in the pulverized coal ideal surface for various tangential velocities, depending on the free flow space coefficient is shown on the Fig. 6. At normal tangential velocity of the beater wheel from 80-90 m/s and for the hoop having free flow space coefficient, k_{pz} = 0.20-0.25, the expected increase in the ideal surface of the pulverized coal is 70%.

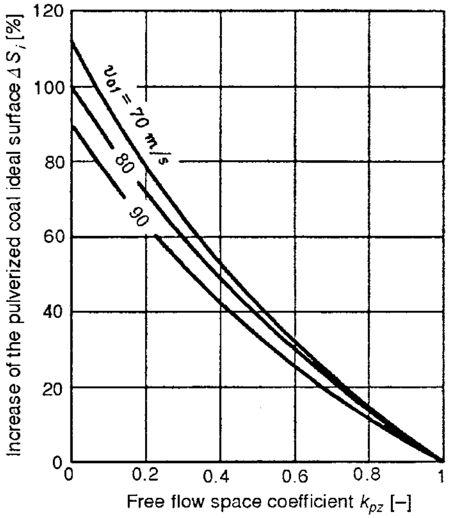


Figure 6. Increase of the pulverized coal ideal surface depending on tangential velocity of the beater wheel and free flow space coefficient of the hoop

Further analyses of the fan mill with hoop were done after changing its shape. Varied were both the cross-section of the obstacle into circle, semicircle or rectangle, and the angle of the obstacle setting up in relation to the direction of the pulverized coal particles flow when leaving the beater plate [7].

During determining the influence of the hoop shape on the fan mill pressure and ideal surface of the pulverized coal, analyses were made at the constant tangential velocity of the beater wheel of v_{o1} = 77.6 m/s for the unchanged geometry of the hoop, with the free flow space coefficient of k_{pz} = 0.34.

It is clear that, during grinding with the hoop the fan mill pressure is smallest when the obstacles-having the semicircular (2) or rectangular (3) cross-section are set up at the angle of 55° (Fig. 7). In the case of the circular cross-section (1), the highest fan pressure is achieved due to its most convenient aerodynamic shape.

The obstacle's position angle toward the beater wheel also influences the increase in the pulverized coal fineness. This is important for the obstacles having semicircular or rectangular cross-section, the correct set up of which inside the hoop influences the achievement of larger ideal surface of the pulverized coal, S_i [m^2/kg]. The largest values of the ideal surface for both cross-sections are achieved when the obstacle position angle toward the beater wheel is around 55° (Fig. 8). This means that the obstacles are set up normal to the direction of the flow of the largest pulverized coal particles inside the hoop, which didn't manage to get properly ground in the grinding process inside the beater wheel [8].

By changing the hoop shape, *i. e.* the obstacle cross-section, from circular to semicircular or rectangular one at the correctly selected angle of the set up, the ideal surface of the pulverized coal increases comparing to the circular obstacle (1), S_i = 41.5 m^2/kg, 5.1% in case of the semicircular obstacle (2), and 6.5% for rectangular cross-section (3). Concentration of the pulverized coal in the conveying gas during the analyses of the influence of the hoop shape was μ = 0.54–0.57 kg/kg [37].

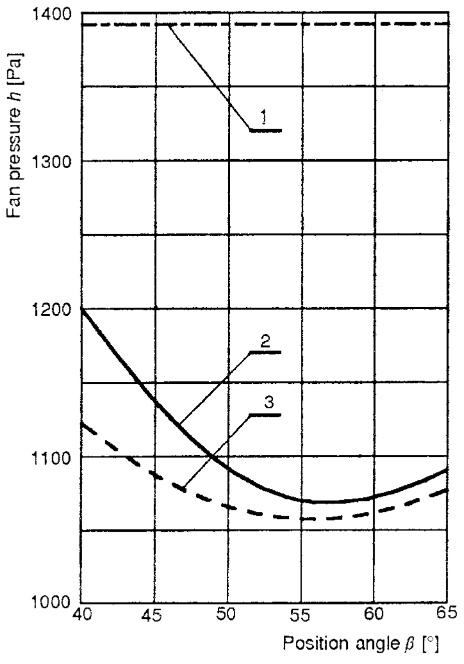


Figure 7. Dependence of the pressure of the fan mill with hoop on the obstacle cross-section and the position angle

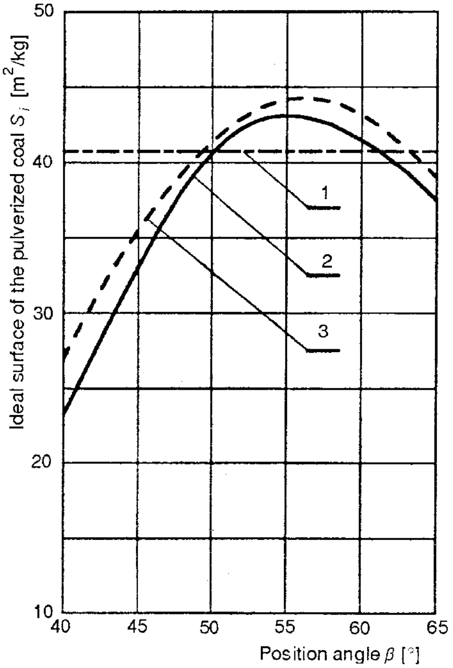


Figure 8. Dependence of the ideal surface of the pulverized cool from the obstacle cross-section and the position angle

Determination of the pulverized coal fineness during the grinding in the fan mill with hoop without the classifier compared to the grinding in the classical fan mill with the classifier may be achieved if the ideal surface of the pulverized coal is shown in relation to the number of influx of the pulverized coal mass through the mill. Based on the made analyses [4], in Fig. 9 is presented this dependence for the case of the fan mill. With the increase in the number of influxes of the pulverized coal mass, N_m the ideal surface of the pulverized coal is increased. The diagram shows that the rate of increase of the ideal surface between two runs, decreases with the increase of the number of runs.

For the case of the fan mill with the hoop, on the same diagram with the dotted line the mean value of the ideal surface of the pulverized coal is shown, achieved during one run of the coal mass with $z_o = 24$ obstacles of the rectangular cross-section, each set at the angle of $\beta = 55°$, which free flow space coefficient was $k_{pz} = 0.34$. The point of intersection gives the same ideal surface of the pulverized coal, which is, in the fan mill with the hoop achieved in one run, while with the classical ventilator mill the same ideal surface may be achieved in 1.7 runs.

In case of the fan mill with the classifier, this fineness of the pulverized coal would be achieved at the recirculatory index of $C_s = 1.7$ [8].

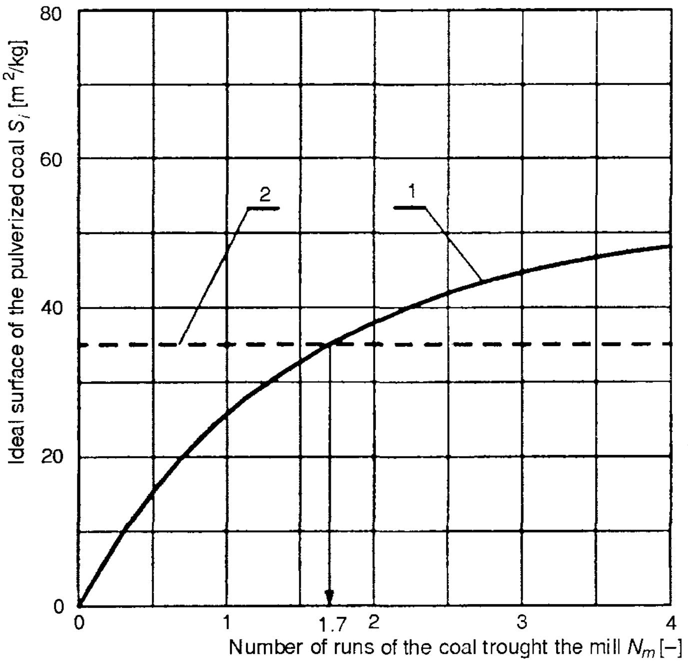


Figure 9. Dependence of the ideal surface of the pulverized coal on the number of the coal mass runs through the mill – evaluation of the performance of the mill with the hoop
1 – Fan mill; 2 – Fan mill with the hoop

In order to determine correctly the grinding quality, for both types of the mill, it is necessary to evaluate their fanning capabilities.

Conclusion

Based on performed measurement and analyses, one can conclude that the increase in the number of obstacles inside the fan mill hoop, positioned as close to the beater wheel as possible, leads to the increase in the number of possible impacts of the coal particles. This results in the increase of the pulverized coal ideal surface and contributes to greater effectiveness of the grinding behind the beater wheel for this type of mill. By changing the hoop shape, obstacle cross-section and its positioning angle in relation to the beater wheel, further increase in the pulverized coal finess is achieved, *i.e.* attained is the new expansion of its ideal surface, by which qualitatively improved is the drying process. In this way the quality of the pulverized coal is improved, which is the final goal.

Increase in the grinding effectiveness by impact behind the beater wheel results in the decrease in the fanning capability of the fan mill with hoop. With these mills, because of the increased fineness of the pulverized coal, it is possible to perform the grinding process in one run without the classifier. The decrease of the fanning capability caused by the presence of hoop can be compared to the pressure loss at the classical fan mills, caused by the flow of pulverized coal/conveying gas mixture through the classifier, which for the completed constructions is equal to 300–500 Pa and even more, depending on the position of regulating dampers.

The grinding process in one run at the fan mill with hoop enables to avoid the unnecessary recirculation of the mineral particles from the coal, metal particles, as well as the part of the conveying gas from the classifier to the mill. This way, decreased is the abrasion of the mill's active elements, particularly of the beater wheel, since a part of the process has shifted to the obstacles of the hoop, thus expanded is the availability of these mills.

Nomenclature

β[o] – angle to set up obstacles
C_s [-] – recirculatory index
d_o [m] – characteristic dimension
D_o [m] – mean hoop radius
D_1 [m] – external radius of the beater wheel
h [Pa] – fan pressure
h_o [m] – distances from the external radius of the beater wheel
h_z [m] – distance in relation to the external radius of the beater wheel
k_{H} [-] – Hardgrove index
k_{pz} [-] – free flow space coefficient
K_z [-] – coverability coefficient of the hoop by the obstacles
μ [kg/kg] – concentration of pulverized coal in conveying gas

N_m [-] – number of runs of the coal trought the mill
S_i [m^2/kg] – ideal surface of the pulverized coal
t_o [m], [o] – step between the obstacles
z_o [-] – number of obstacles in the hoop
v_{o1} [m/s] – tangential velocity of the beater wheel
W^r [%] – water content in the coal

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