Suggestions for Calculation and Construction of the Fan Mill Barriershoop

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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, behind the beating wheel, 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. While constructing the body it is necessary to profile the spiral correctly in order to achieve the smallest pressure loss during the flow of pulverized coal/conveying gas mixture. The increased rate of the grinding quality enables the coal grinding process performed with no coal powder separators.

***Keywords**: Fan mill, beater wheel, spiral housing, obstacles, barriers hoop.*

1. 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 spiral housing. 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 flow of the mixture of fluids and pulverized coal particles (figure 1a). Due to the way the spiral housing is constructed, it is getting more and more away from the beater wheel, there-fore coal particles are being decelerated in that space and strike the armor plates under the small angle; consequently, during further grinding of the particles used as only small part of the available kinetic energy. In 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 cover in order to be ground.In order that enormous kinetic energy owned by the coal particles be used and prolonged 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 (figure 1b). This way, since the set up obstacles are closer to the beater

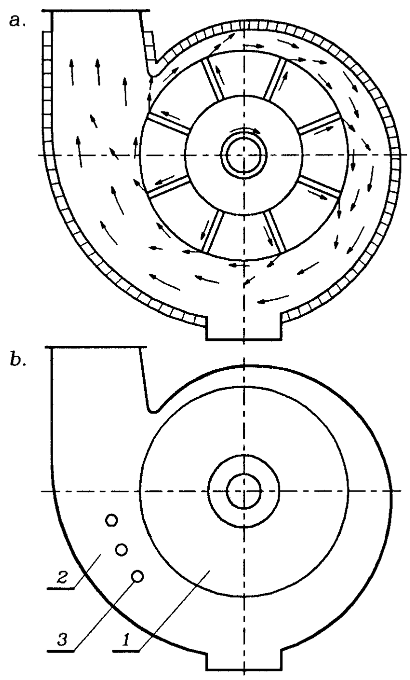

Figure 1. The grinding process behind the rotor
a) Trajectory of the coal particle inside the fan mill;
b) Fan mill with obstacles. 1. Beater wheel; 2. Spiral housing; 3. Obstacles.

wheel than the armor plates of the spiral, somewhat bigger partion of the kinetic energy of the particles 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.

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This would result in total decrease of wearing down of both active elements and the mill armor; furthermore this wearing down would partly affect the mounted obstacles.

Reconstruction of the combined mill DGS 100 S, located at the TE Nikola Tesla A in Obrenovac, Yugoslavia, and made by the Boiler Factory Tlmache from Slovakia following the license of a German Company Babcock, aiming at increase of 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 (figure 2a). The obstacles occupied the space which corresponded to the central angle of 28^o 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^o [2].

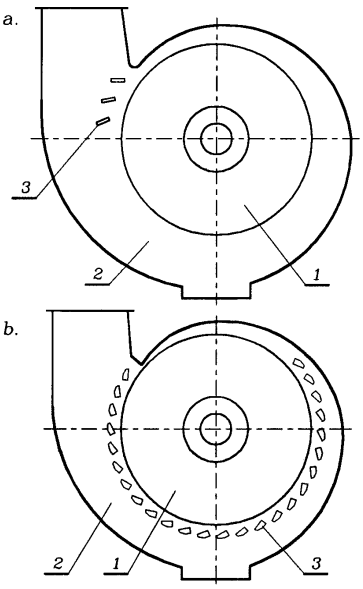

Figure 2. Reconstruction of the fan mill by setting up the obstacles along the spiral housing
a) Fan mill with obstacles;
b) Fan mill with partial hoop. 1. Beater wheel; 2. Spiral housing; 3. Obstacles

After 900 work 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 didn't allow their installment at its narrowest parts (figure 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 at the obstacle. Spiral body of the laboratory mill was too narrow for correct installment of the hoop; herefore, 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 increased was the ideal surface of the pulverized coal in relation to the mill without a hoop, and decreased was the available fan pressure of the mill proportionally to the increase in the number of obstacles. Analyses were done with no cool drying, and using the surrounding air (temperature 20 ^oC) as the transport fluid.

2. 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 with no 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 [8]. Water mass content in the coal was W^r=18.4 %, while the humidity of pulverized coal was somewhat smaller and was around 17.5 %. Drying of the coal wasn't done, while the air (t_2=22 ^oC) served as a conveying gas. Hardgrove index was k_H=38.6 [8].

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] (figure 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 beater wheel D_1 [m]. By changing the speed 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

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

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, figure 4 shows the dependence of fan pressure from its free flow space coefficient and tangential velocity of the beater wheel.

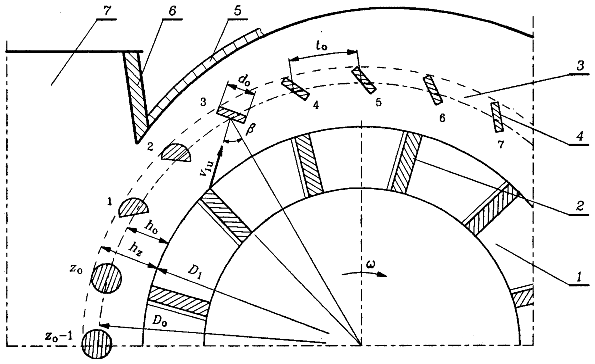

Figure 3. Laboratory fan mill with a hoop. 1. Beater wheel; 2. Beater plate; 3. Barriershoop; 4. Obstacles; 5. Housing; 6. Mill nose; 7. Pulverized coal/conveying gas mixture.

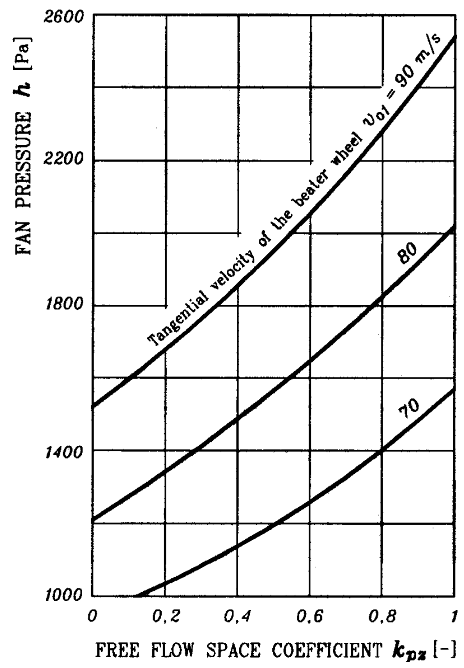

Figure 4. Dependence of the pressure of the fan mill with hoop from its free flow space coefficient and tangential velocity of the beater wheel.

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.

During the analyses, the control of the fineness of pulverized coal under the unchanged 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 figure 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, achieved was the overall increase in the pulverized coal ideal surface, 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 figure 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 %.

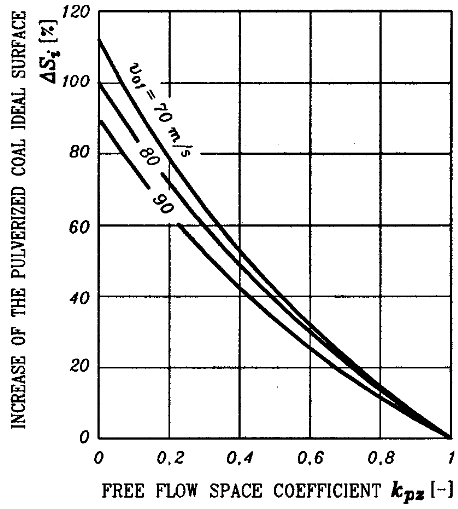

Figure 6. Increase of the pulverized coal ideal surface depending on tangential velocity of the beater wheel and free flow space coefficient of the hoop.

Further analyses of the fan mill with hoop were done after changing its shape. Changed 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].

While 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° (figure 7). As of the circular cross-section (1), the highest fan pressure is achieved due to its most convenient aerodynamic shape.

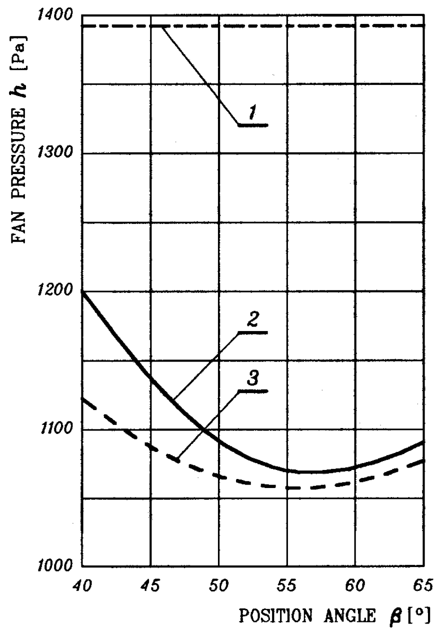

Figure 7. Dependence of the pressure of the fan mill with hoop on the obstacle cross-section and the position angle 1. Circular cross-section; 2. Semicircular cross-section; 3. Rectangular cross-section.

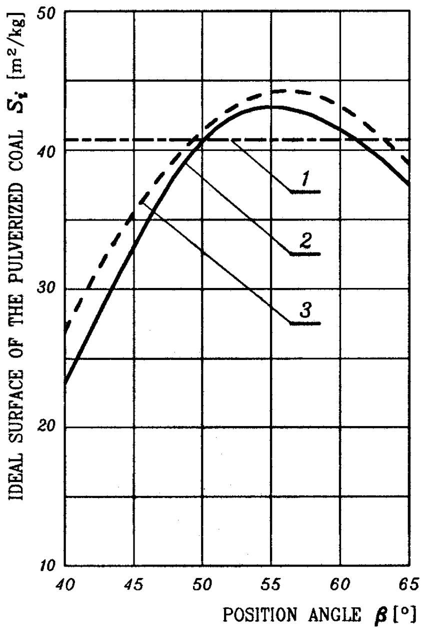

Figure 8. Dependence of the ideal surface of the pulverized cool from the obstacle cross-section and the position angle 1. Circular cross-section; 2. Semicircular cross-section; 3. Rectangular cross-section

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^o (figure 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 in relation to the circular obstacle (1), S_i=41.5 m^2/kg, 5.1 % in case of the circular obstacle (2), and 6.5 % for rectangular cross-section (3). Concentration of the pulverized coal inside the conveying gas during the analyses of the influence of the hoop shape was μ=0.54-0.57 kg/kg [4].

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, achieved is further increase in the pulverized coal, i.e. attained is the new expansion of its ideal surface, by which qualitatively improved is the drying process. In this way improved is the quality of the pulverized coal, which is the final goal.

3. SUGGESTIONS FOR THE HOOP CONSTRUCTION

The fan mill barriershoop is positioned inside the spiral housing, along the circumference of the beater wheel (figure 3). The space occupied by hoop inside the spiral of the mill should be as small as possible in order to avoid too large body's overall dimensions. The obstacles making up hoop should be set up at the correct angle toward the beater wheel, in order to enable the largest coal particles to impact normally to the active surface of the obstacle.

The fan mill hoop is defined by the most relevant geometric characteristics that practically determine the free flow space coefficient. They are: the mean radius of the hoop, characteristic dimension (obstacle width) and the number of obstacles.
The mean hoop radius needs to be larger than the external radius of the beater wheel D_1 [m], and it is calculated following the formula

$$D_o = (1.10 \div 1.15)\, D_1 \ \ [\mathrm{m}]\,, \qquad (2)$$

Larger values are adopted for the mills of smaller capacity. The mean radius needs to provide the correct gap between the external radius of the beater wheel and the closet edge of the obstacles inside the hoop. This distance is not supposed to be larger than 50 mm.

Characteristic dimension of the obstacle is also determined by the external radius of the beater wheel:

$$d_o = (0.04 \div 0.06)\, D_1 \ \ [\mathrm{m}]\,, \qquad (3)$$

while the product of the dimension and the number of obstacles is adopted as:

$$d_o z_o = (1.8 \div 2.2)\, D_1 \ \ [\mathrm{m}] \ , \tag{4}$$

from which the number of obstacles z_o in the hoop is determined. Central angle between two obstacles $360/z_o$ needs to be within the interval from 7.5^o to 12^o.

This way the large covering of the cross-section with obstacles is achieved for the flow of the pulverized coal/conveying gas mixture, determined by the corresponding coefficient given by the formula (1), which needs to be K_z=75-80 %. In this case, free flow space coefficient is k_{pz}=20-25 %.

Shape of the obstacle should be determined in such a way to be the most fitting in aerodynamic sense in order for the pressure loss through the hoop to be as small as possible [7]. This way the hoop geometry can be adopted with the coefficient of coverability with obstacles, K_z, being as large as possible.

4. CONSTRUCTION OF THE BODY'S SPIRAL OF THE FAN MILL WITH A HOOP

The fan mill body has two basic functions. It is used as the grinding space for the coal mass, and for the deceleration of the flow of the pulverized coal/conveying gas mixture and transforming dynamic fan pressure into the static one. Besides, construction of the body needs to provide the absolute compactness and stiffness of the mill, as well as to protect the casing wear plates from the extreme abrasion; it is also used as thermal and sound insulation. While constructing the body it is necessary to profile the spiral correctly in order to achieve the smallest pressure loss during the flow of pulverized coal/conveying gas mixture.

Profile of the body's spiral is constructed based on the so-called constructive square, and the way of constructing is shown an figure 9 [9]. Spiral of the body of the fan mill with a hoop needs to be formed above the space occupied by the hoop, defined by the diameter D_s=D_1+2 h_z [m].

Side of this square is determined by the formula:

$$n = \frac{a}{4} \ \ [\mathrm{m}] \ , \tag{5}$$

where a [m] is the maximum width of the spiral, and is determined by the expression:

$$a \cong \frac{2}{3}(D_1 + 2\,h_z) \ \ [\mathrm{m}] \ , \tag{6}$$

in which D_1 [m] is the external radius of the beater wheel, and h_z [m] is the height occupied by the hoop inside the spiral of the body.

During the construction of the spiral first is, by radius R_1, which is

$$R_1 = R_4 - n + a \ \ [\mathrm{m}] \ , \tag{7}$$

constructed the first quarter of the spiral, then followed by the construction of the second and the third quarter by radii R_2 and R_3, which are expressed by:

$$R_2 = R_1 - n \ \ [\mathrm{m}] \ , \tag{8}$$

$$R_3 = R_2 - n \ \ [\mathrm{m}] \ , \tag{9}$$

while the last quarter of the spiral is constructed by radius R_4

$$R_4 = \frac{1}{2}n + \frac{1}{2}D_1 + h_z \ \ [\mathrm{m}] \ , \tag{10}$$

The width of the spiral corresponds to the active width b [m] of the beater plates of the mill.

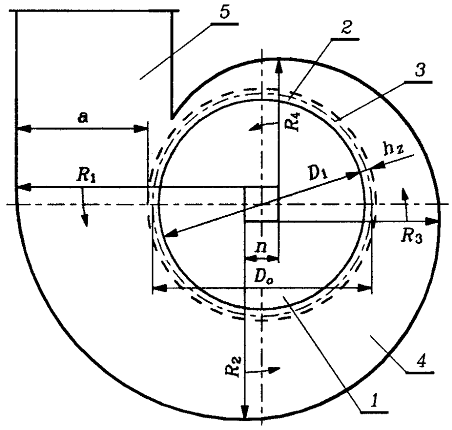

Figure 9. Construction of the barriershoop and the spiral housing 1. Beater wheel of the fan mill external radius; 2. Barriers hoop; 3. Mean hoop radius; 4. Spiral housing; 5. Discharge area for the pulverized coal/conveying gas mixture.

5. CONCLUSION

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.

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ПРЕПОРУКЕ ЗА ПРОРАЧУН И ПРОЈЕКТОВАЊЕ ЗАКОЛА ВЕНТИЛАТОРСКОГ МЛИНА

Т. Живановић

Честице угља се приликом проласка кроз ударно коло вентилаторског млина мељу ударом и трењем. Путања честице угљеног праха после напуштања ударног кола се повија према излазу из спирале услед чега се судар са панцирним плочама кућишта одвија под малим углом. Млевење угља у вентилаторском млину је релативно грубо због чега се иза млина поставља сепаратор.

Ефикасност накнадног млевења иза ударног кола, код ових млинова, може се повећати постављањем непокретних препрека у виду закола, у спиралу кућишта млина, око ударног кола. Повећањем коефицијента прозрачности закола, који зависи од броја препрека, димензије препреке и реципрочне вредности средњег пречника закола, може се повећати ефиканост млевења. Значајног утицаја на повећање финоће млевења такође има облик препреке и угао њеног постављања према ударном колу. При конструисању закола код овог млина потребно је извршити одговарајуће профилисање саме спирале, како би се остварио најмањи пад притиска при струјању сушећег флуида и самлевених честица угља.

Због побољшаног квалитета угљеног праха код ових млинова, може се остварити проточни процес млевења угља без сепаратора.