Simulation of Separation Processes and Dewatering of Coal

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ABSTRACT

The paper consists of the results of computer simulation phase's interaction kinetics during some mineral processes. The basics of numerical method are presented. The simulation of elementary act of air bubble and coal particle interaction showed the trajectories of elements when the angle of attachment was different. The critical mean of the attachment angle for floating complex existence was determined. Slime coal sediments dewatering during filtration was simulation too. Some sediments structure was considered. It has been showed the positive influence of quick shear for water removing velocity increasing. Simulation of dry separation had show the influence of dilation of the particle's layers in separator's working space upon the efficiency of separation.

Key Words: Simulation, Coal, Separation, Filtration

1. INTRODUCTION

All separation processes are based on the interaction of phases and particles of coal and rock. Typical examples are interaction of coal and rock pieces in air flow separator, or air bubbles with coal particles during froth flotation, or coal slimes with water in sediments during filtration of fine coal in press-filters, centrifuges, etc. There is so hard to investigate those processes because they are dynamical, impacted by long array of physical and chemical factors and occur in a small scale. These processes have been traditionally studied by laboratory experiments or analytical methods of mathematics. But analytical investigations yield idealized results, nature physical experiments need many time and indicate unsatisfactory accuracy. Numerical simulation is one of the powerful alternatives to help us in our aspiration to learn some complicated phenomena in mineral processing. This modern method combines dynamics, accuracy and consideration of sophisticated details and is based on discrete elements. In this paper a computer model will be considered for simulation of kinetics of phase's interaction during mineral processing.

2. BASICS OF NUMERICAL METHOD

Discrete elements method has been originally developed in geomechanics to simulate rock mass behavior under action of ground pressure, according to (Cundall, 1974). This method has been later applied to describe interaction of rock particles and fluid flow, according (Bathurst, 1990; Bruno, 1996). The authors of this paper developed a model for particle interaction during coal preparation (Nazimko, 2006, Nazymko, 2010). A pair of interacting particles indicated in Figure 1. It is the basis of simulating method.

In addition, essential peculiarities of some separation processes have been introduced to simulate dynamics of particles or phases interaction. The more details for model are published in (Garkovenko, 2002).

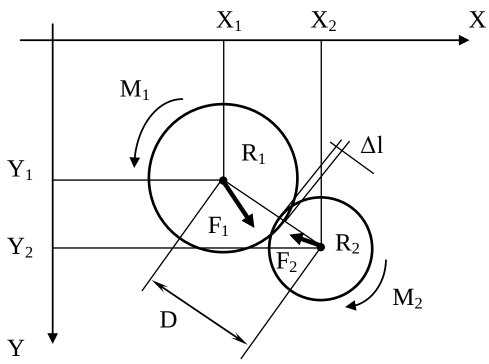

Figure 1. The basis scheme of particles interaction.

A set of computer programs was designed for simulation some processes. There were dry separation for raw coal, froth flotation and coal sediments dewatering. Some imitation experiments were made to validate this model to turn out sufficient useful data. The following computer experiments were investigated:

1. Air bubble take-off from a mineralized plate for different plate inclinations, relative to the horizon.
2. Coal particle residence time on an air bubble for different boundary and initial conditions.
3. Mineral particle's trajectory, velocity and acceleration were identified during the dry separation (Garkovenko, 2002; Nazymko, 2010).

3. ELEMENTARY ACT OF FLOTATION SIMULATION

Air bubble and coal particle interaction was considered for the model, which is pictured in figure 2.

Elementary act of particle-bubble attachment in froth flotation was investigated by Whelan P.F. and Brown D.J. (Whelan, 1956). We repeated their natural experiment in computer realization with model and turned out closed results (Nazimko, 2006).

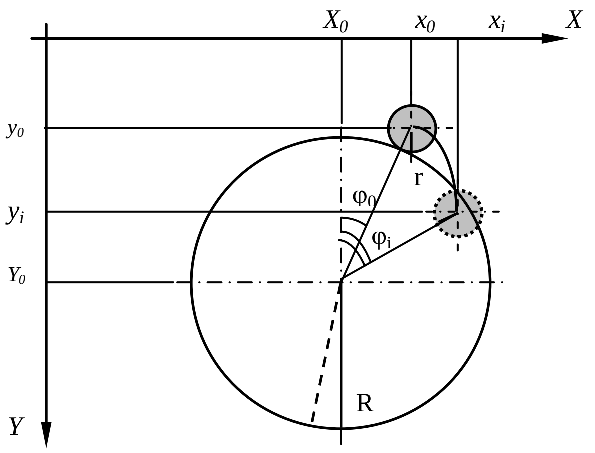

Figure 2. Elementary flotation act: φ_0, φ_i – initial and current angle of particle position.

Computer simulation of particle attachment (Figure 2) has been made for the next conditions. Coal particle 0.29mm in diameter were dropped to a floating air bubble 2mm in diameter. The angle of elements meeting was increasing from 0° to 61°. Figures 3 and 4 are demonstrating the trajectories of air bubble and coal particle for all cases.

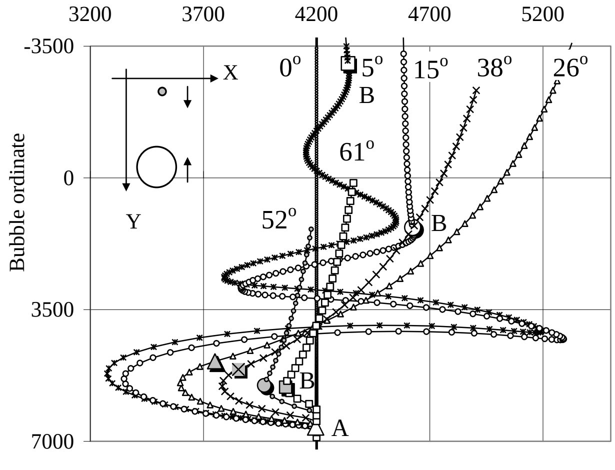

Figure 3. Air bubble trajectories.

Point A on figure 3 is the point when elements came into collision; point B is the point when float complex was destroying.

We can see the angle of attachment more; the point B is more close to point A. The left and the right oscillations of bubble abscise are the result of particle moving on the bubble surface during its sliding. The particle and air bubble are the floating complex so long time and float together when the angle of attachment is 0°. The angle φ_0 = 38° is the angle when the time of complex existence is abruptly decreasing.

Particle trajectory in bubble coordinates is depictured on figure 4.

The section OA is the coal particle road before attachment with air bubble. The section AB is the road of particle sliding on the bubble surface (with float complex), and the section BC is the particle road after complex destruction.

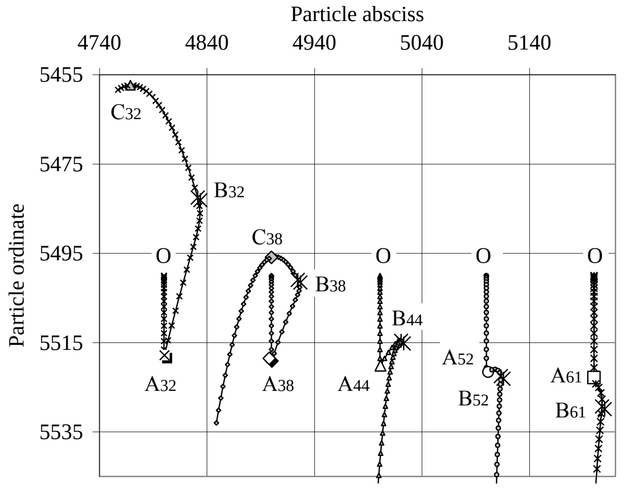

Figure 4. Particle trajectory in bubble coordinates.

There is the left trajectory ($OA_{32}B_{32}C_{32}$), when the angle is φ_0 = 32°. We can see that after float complex was destroying, the particle float up in "fairway" after the floating bubble some time to point C_{32}. This particle can be caught up with another floating bubble in this case. And only after the point C_{32} it begins to move down.

But the time of floating up is less when the angle is φ_0 = 38°, and after point C_{38} the particle was lost. Coal particle can't float up in "fairway" after the floating bubble, when the angle of attachment is more than 38° (see three trajectories in the right). When the float complex was destroying, the particle was sunk right away.

These imitative investigations of elementary act of air bubble and coal particle interaction allowed come to the following conclusion. The angle of attachment φ_0 = 38° is the critical angle for floating complex existence.

4. DEWATERING PROCESS SIMULATION

Fine slime sediments are complex porous medium with channels and dilations alternation. And water must be removed off for effective dewatering. There are different methods for increasing of water velocity removing. Mechanical methods of influence upon coal sediments have the lower price. In this paper you can see the results of shear influence simulation upon moisture slime sediments.

Idealised mediums are used often in different investigations. We used the spherical particles with cubic and hexagon placement in sediment. These sediments have different porous medium when all particles are equal in size and when they are different in size. The sediment has the biggest porosity in the first case and the lowest porosity in the second.

There are different initial state of sediments (*a*) and final state after shear influence (*b*) on figures 5-8.

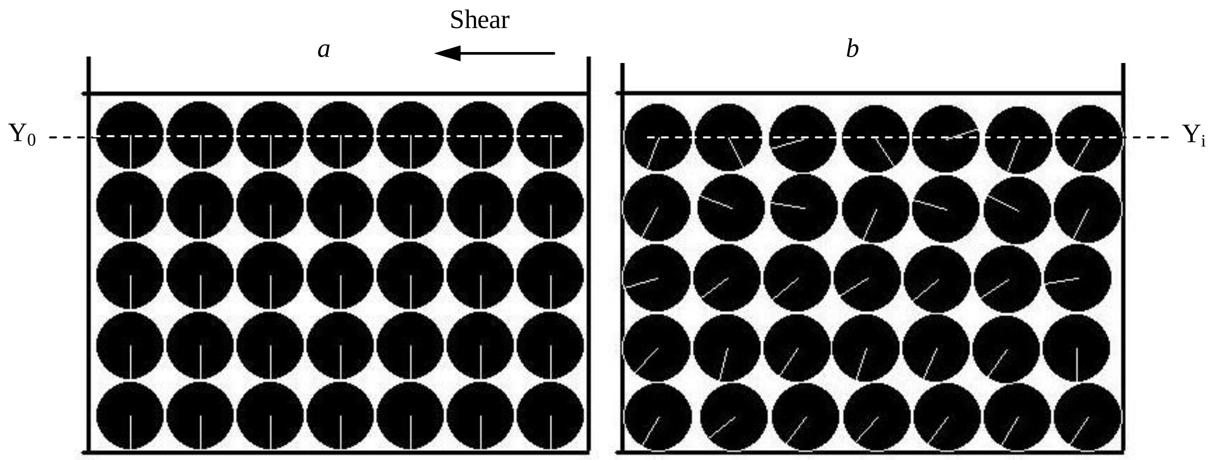

Figure 5. There is the sediment simulation with cubic placement and equal size of particles in initial state (*a*) and after shear influence (*b*). Initial porosity is 0.248.

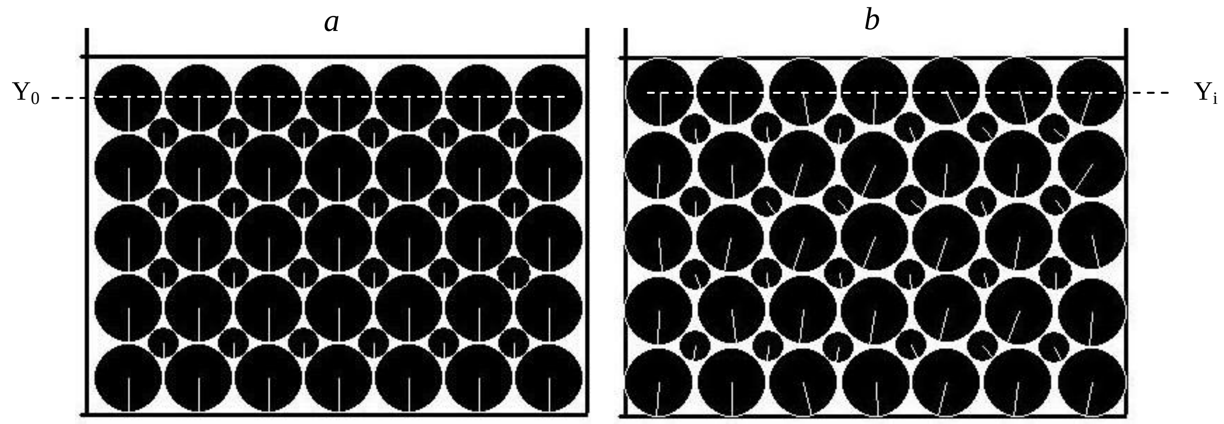

Figure 6. There is the sediment simulation with cubic placement and different size of particles in initial state (*a*) and after shear influence (*b*). Initial porosity is 0.129.

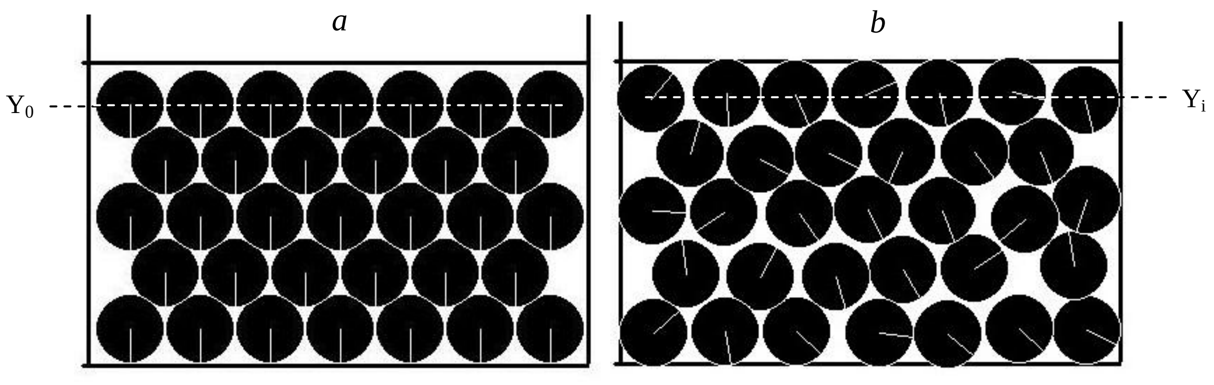

Figure 7. There is the sediment simulation with hexagon placement and equal size of particles in initial state (*a*) and after shear influence (*b*). Initial porosity is 0.160.

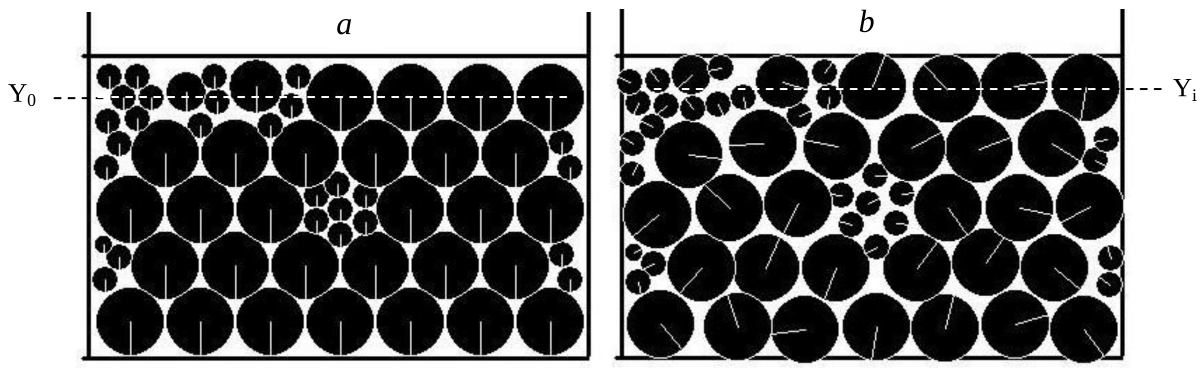

Figure 8. There is the sediment simulation with hexagon placement and different size of particles in initial state (*a*) and after shear influence (*b*). Initial porosity is 0.124.

All particles are in closed vessel and immoveable in initial moment of time. When the shear acts to the highest layer particles are beginning to interaction with each other. Their placement and channels between them and the size of pores are changed during some time.

The constant similar features of particles were used in all simulation experiments. Compact sediments are named as over-consolidate in mechanic of soil and geomechanics (sediments like in figures 7-8).

Friable sediments are named as under-consolidate (sediments like in figure 5). Its initial porosity was the biggest and had a mean of 0.248.

Under-consolidate sediment became to some consolidation after shear influence (see figure 5). Digital file, which consists of abscises and ordinates of gravity centre for each particle, showed that the highest layer ordinates were increased. It means that particles pull down. We can determine $Y_i - Y_0$ is from 1.99 to 3.73 (see the direct of axis Y in figure 1).

The sediment in figure 6 with cubic placement and different size of particles had the initial porosity 0.129. It is less then the under-consolidate sediment in figure 5 near two times. We can determine $Y_i - Y_0$ is from -5.23 to -5.69 from digital file after shear influence. It means that particles had lifted upper. This sediment became to some small deconsolidate state. The porous channels became to increasing in this state. And the velocity of water removing may be more.

The sediments with hexagon placement and equal or different size of particles had the more consolidate initial state (see figures 7 and 8). Their porosity is smaller and means 0.160 and 0.124 accordingly. These sediments became to some deconsolidate state after shear influence. We can determine $Y_i - Y_0$ is from -1.99 to -10.83 from digital file for sediment in figure 7 and $Y_i - Y_0$ is from -3.03 to -12.07 for sediment in figure 8.

The sediment with hexagon placement and different size of particles has the lowest porosity in initial state. But the shear influence brought the more positive results. The porous medium can be more increase.

We can see the positive influence of shear for over-consolidate sediments with compact structure.

But what may be the shear velocity – quick shear or slow shear? The new initial state of model was created to investigate water removing velocity when the shear acts with some velocity (see figures 9 and 10).

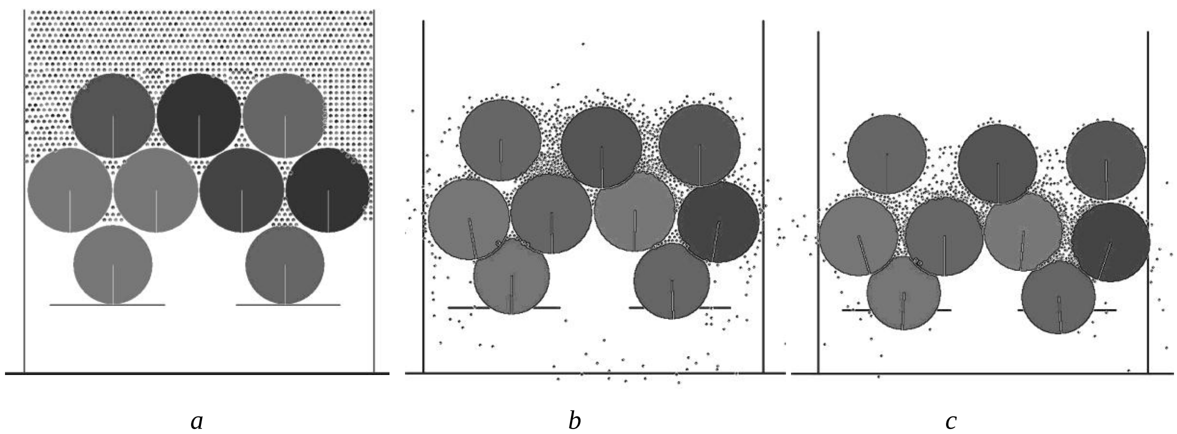

Figure 9. The state of sediment fragment with hexagon particles placement when the shear acts with low velocity (slowly shear SS): *a* – initial state, *b* – after 2 seconds simulation, *c* - after 4 seconds simulation.

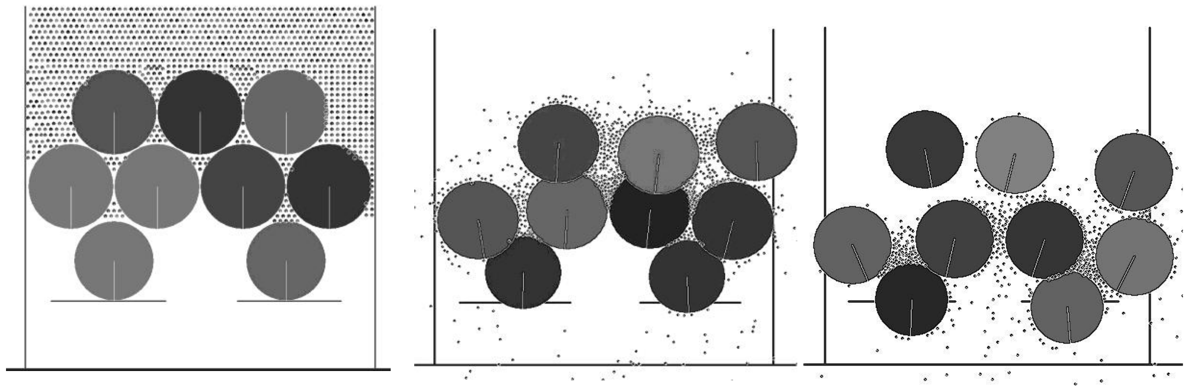

Figure 10. The state of sediment fragment with hexagon particles placement when the shear acts with high velocity (quick shear QS): *a* – initial state, *b* – after 2 seconds simulation, *c* - after 4 seconds simulation.

New creating model consists of 1800 particles. Nine big particles was the fragment of sediment with hexagon particles placement. Other small particles were simulated filtrate water with the smallest soil particles. The velocity of filtrate removing was determined as the quantity of the smallest particles, which was out of vessel to some moment of time. The diagram of filtrate removing velocity is presented in figures 11 and 12.

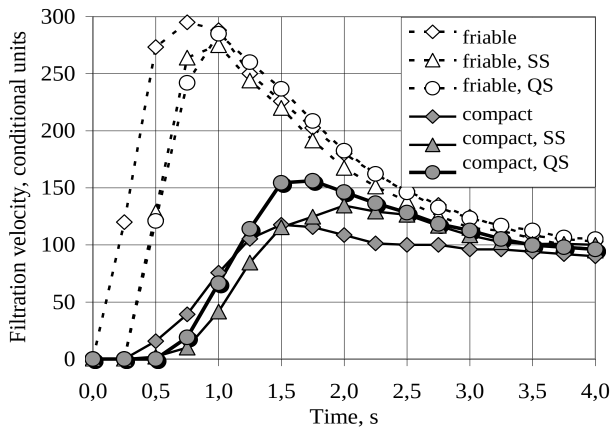

Figure 11. Velocity of filtrate removing.

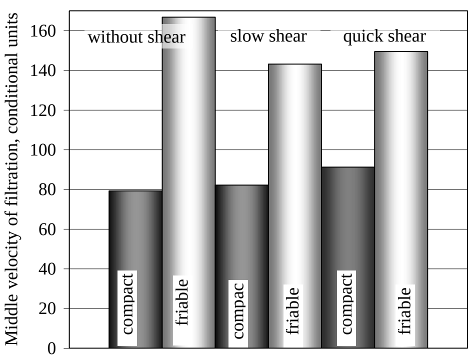

Figure 12. Middle velocity of sediments filtration.

Diagrams in figure 11 shows the friable sediment has the highest filtration velocity without shear, which equal 295 cond. un. Slow shear (SS) gives lesser filtration velocity in the reason of some compaction of friable sediment. We can see some increasing of it near 3% when quick shear (QS) acts, but it is lesser in comparison with conditions without shear influence.

Filtration velocity is smaller for compact sediment in near 2.5-3 times in all cases in comparison with friable sediments. It maximum means is 118 cond. un. without some shear. It needs some time for shear influence development. The moment of high filtration velocity achievement is in connection with shear type. The maximum means of velocity is 134 cond. un., when slow shear (SS) acts and time was 2s. And quick shear (QS) influence gives us the biggest velocity of filtration which means 156 cond. un. at 1.75s. Thus the quick shear creating promotes to achieve filtrate removing velocity increasing for over-consolidate sediments.

Velocities of filtration are near one another at the end of process.

Histograms in figure 12 demonstrate the middle velocity of filtrate removing during all kinds of shear and sediments. We can see the friable sediment gives the highest middle velocity without shear which equal 167 cond. un. Slow and quick shear ensures some decreasing of filtration velocity to 143 or to 149 cond. un. accordingly in the reason of sediment compaction. Thus the quick shear decreases filtration velocity less than slow one.

Compact sediments are with minimum velocity of water removing without shear, which equal 79 cond. un. The slow shear gets velocity increasing near 4%. And quick shear increases it near 11-15% to the means of 91 cond. un. Thus the quick shear influence ensures increasing of filtration velocity for compact over-consolidate sediments.

These computer simulations show the positive influence of quick shear in all states of sediments, especially for compact over-consolidated sediments. These results are needed to be control with nature physical investigations for different sediments.

. DRY SEPARATION SIMULATION

There are many examples of dry coal preparation applications today (Bert, 1990; Nazymko, 2010). Rock and coal particles have differences in form, density, friction coefficient and other properties. And dry separation method is based on the differences in these properties. Particles are separated due to the difference in particle motion trajectory in the air current. Particles motion simulation was done with basic model and the rational dilation (m) of the particle's layers was determined.

Air flow velocity was so, which can bring up coal particles and get down rock ones. The scheme of particle's initial state and trajectories are pictured in figure 13-15.

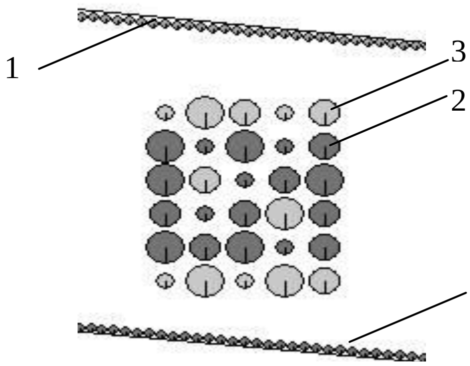

Figure 13. Initial material state for high dilation (m = 0.9): 1 – separator's walls, 2 – coal, 3 – rock.

Particles hover with airflow and rotate, collide to each other and to the walls of separator.

We can see separation process is over during of time of simulation because coal and rock particles were moving upper and down accordingly (figure 14).

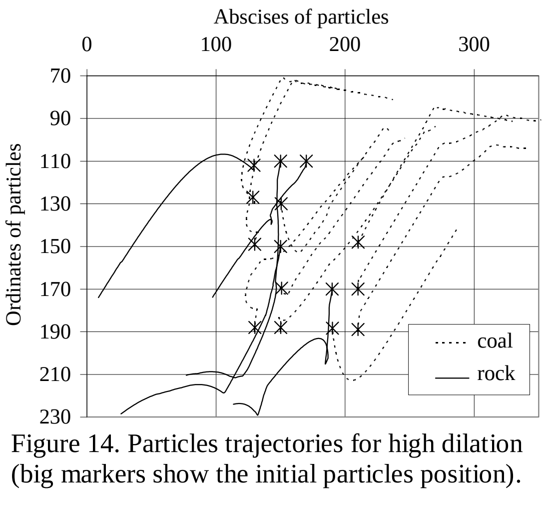

Figure 14. Particles trajectories for high dilation (big markers show the initial particles position).

But when the dilation has small mean (m = 0.2) some circulation of particles take a place in the working space of separator, see figure 15. These circulations provoke time of separation process increasing and the low quality of products. Separator productivity becomes lower in this case too.

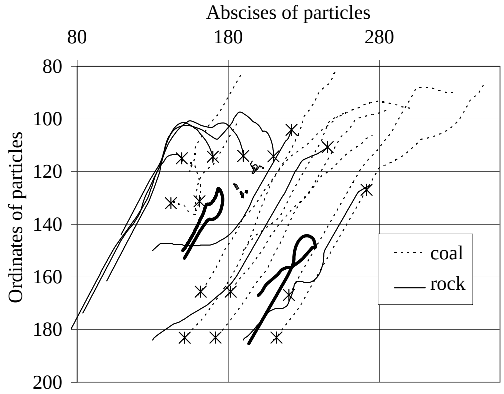

Figure 15. Particles trajectories for low dilation (trajectories of circulating particles are bold).

Thus researcher must find that regime, when results satisfy consumer's demands without productivity and quality decreasing.

6. CONCLUSIONS

A numerical model has been developed which is based on particles interaction. This model can be effective tool for investigation different situations and wide array of processes during coal preparation and mineral processing and was used to determine the best regime of coal separation.

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