should be applied with two-phase medium as a way to identify other factors that may affect on uniform surface loading of multiflux fillings, and the direction of fluid flow.

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# EVALUATION OF THE SEDIMENTATION RATE OF COAL SUSPENSION IMPLEMENTED IN THE MULTIFLUX SYSTEM WITH FLOCCULANT

*© Kowalski W.P., Kołodziejczyk K., Banaś M., Turlej T., 2012*

**The article presents results of the research of the sedimentation process of coal suspension. It shows the possibility and high efficiency of the use of multiflux fillings conjugated with process of flocculation. Conducted preliminary studies indicate the importance of the realization process of flocculation at further sedimentation process.**

**Key words: sedimentation process, coal suspension, flocculation.**

**Подано результати дослідження процесу осідання вугільної суспензії. Це показує можливість і високу ефективність використання багатопотокового наповнення, з’єднаного з процесом флокуляції. Попередні дослідження вказують на важливість проведення процесу флокуляції в подальшому процесі осідання.**

**Ключові слова: процес осідання, вугільна суспензія, флокуляція.**

## Introduction

One of the technique of supporting the sedimentation processes is so-called ‘shallow sedimentary’, which is realized in multiflux fillings [7]. This processes can be applied in conventional settling tanks by filling them, either partially or entirely, with (by use of) multiflux fillings. This process can be also implemented in compact settlers with multiflux fillings.

Additional technique of increasing the efficiency of sedimentation process is flocculation. Process of flocculation is used mainly in the case of suspensions with a relatively high concentration. The purification process of suspension supported with the addition of flocculant allows the use of devices with much less sediment surface.



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The main purpose of the research presented in this article is to investigate and understand the intensification of the sedimentation process through joined application of the two following processes: flocculation and multiflux sedimentation.

This article presents the results from coal suspension sedimentation process carried out with different doses of flocculants and the influence of flocculant doses on sedimentation rate. The process was carried out in the laboratory that imitated a conventional system without the multiflux filling and a system with multiflux fillings. The results presented within this article are obtained from experiments done in the static system.

The aim of the conducted research was to evaluate the sedimentation rate depending on flocculant dose and to present the advantages and benefits coming from the use of the multiflux sedimentation in conjunction with the flocculation process.

## Material

The suspension for the experimental work came from the process of coal enrichment from one of the processing plants. The sample was taken from the treatment system of the duct leading the suspension to the settlers, just before the flocculants dosing point. The concentration of the sampled suspension was in range of 45 +/ – 2kg/m$^3$ (depending on the sample) with granulometry of the solid fraction in range of 1-0 mm. The density of the solid part was 2376 kg/m$^3$.

## Particle size dispersion measurement

Measurements of particle size distribution of the coal suspension were performed using a laser diffractometer Mastersizer 2000, Malvern [Fig. 1].

This analyzer is a modern particle size analyzer, using the phenomenon of diffraction of monochromatic neon-helium laser radiation in discontinuous dispersion for both wet and dry dispersions. It does this by measuring the intensity of light scattered as a laser beam passes through a dispersed particulate sample. A dispersed phase are the particles of the solid phase (grains, flocks, floccules), and the scattering phase can be either air or any liquid (water, any organic solvent). The radiation from the helium-neon laser beam is focused by Fourier transform lens and directed into the measuring cell, where in between the special windows, made of quartz glass, the sample is placed. Solid particles cause diffraction of a coherent beam of laser radiation, which is deflected at the edges of the particles at different angles dependent on particle size. Then, the intensity of the scattered radiation at different angles are measured by sensors located in the detectors chamber. Mastersizer 2000E is equipped in 44 sensors, divided into: the main detector shield (recording the scattered radiation in the so-called "straight" direction), (high) wide-angled scattering sensors and backscatter sensors. A special type of sensor is called obscuration detector. It is positioned in the optical axis of the analyzer and is used to determine the current weakening of the optical radiation passing through the sample, so called obscuration. The signals from the sensors are recorded by an electronic system of the analyzer, and then as a set of intensities of radiation they are transmitted to the control computer, where they are converted into particle size distribution in the sample, using the selected model of radiation scattering (Fraunhoffer or Mie)

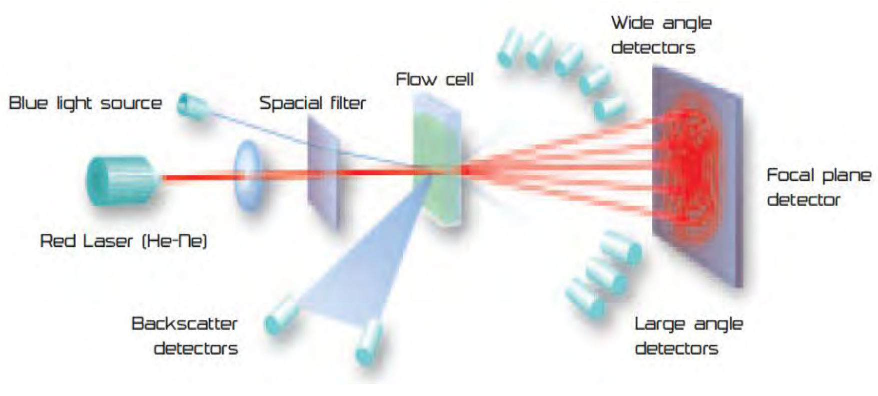


*Fig. 1. Scheme of fundamentals of technology –Mastersize 2000E*



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*Fig. 2. Mastersize 2000E*

The sample is delivered to the main unit of the analyzer from a device called a dispersant or dispersing attachment. The research was performed using standard dispersing attachment Hydro MU, equipped with a rotor pump, controlled manually.

A detailed description of the analyzer and tests methodology of its use is given in manual [Malvern].

**Particle size of suspension**

Into a beaker containing 900 $cm^3$ of degassed water was introduced about 100 $cm^3$ of crude feed, resulting obscuration rate 12.90 %. Pumping the sample into the measuring chamber of the analyzer was performed with a rotor pump with Hydro MU attachment, operating at 2400 rpm speed. To minimize stochastic error test was repeated 15 times, and the result is the mean of these tests.

Designated suspension particle size parameters are as follows: $d_{10}$ = 1.617 m, $d_{50}$ = 11.625 m, $d_{90}$ = 68.706 m.

Distribution of particle size in the sample are shown in the figure (Fig. 3).

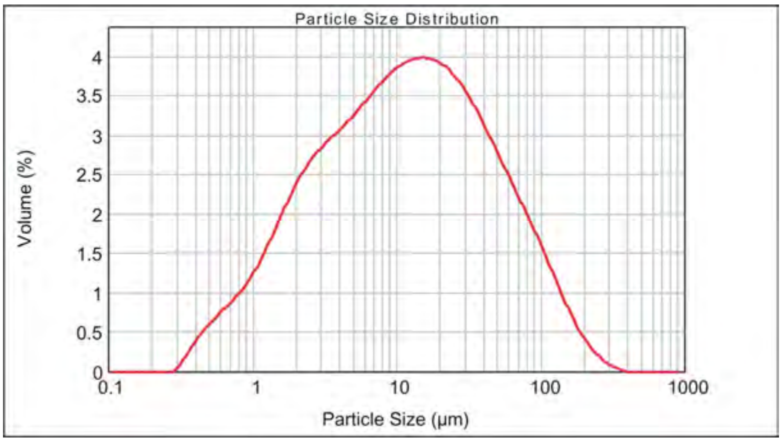


*Fig. 3. The distribution of particle size in suspension*

Chart of particles size distribution (Fig. 3) suggests that it is similar in shape to the often used log-normal distribution. To allow comparison of results with literature values, which are often given in a log-normal parameter particle size distribution of the values frequency histogram of the size of particles are converted on the parameters of the L-N distribution (using authoring software using linear regression). The parameters of L-N distribution for the sample are as follows: m = 2.35, σ = 1.29, value of the correlation statistics indicated a very good agreement with the distribution of the analyzed L-N distribution R = 0.909, F = 2612.

Analyzing the results of determinations of feed particles size (especially graph of frequency) can be explicitly stated that the analyzed suspension is a suspension fine-grained, in which half the particles have a size below 12 microns, which means that the sedimentary section is necessary to clumping small particles into larger particles, such as through the use of flocculation techniques.



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## Static tests

The research of static sedimentation are based on performed sedimentation test of suspension, which we obtain by plotting the sedimentation curve of suspension [8]. Implementation of the static test is possible for the suspensions with a relatively high concentration, suspensions for which there is a constrained sedimentation. Depending on the type of suspension occurrence limit of constrained sedimentation is in the range 0.1÷1 % of the volume fraction of suspension solid phase. For suspensions with lower share volume concentration of the disperse phase will occur the free sedimentation. For suspensions, which have a phase dispersion of a particulate limit the occurrence of constrained sedimentation would be closer to top of the range of 1 %, while for suspensions with a fraction of a floc dispersion limit will be placed at the bottom of the compartment. In practice this means that the suspension for which the volume fraction of solid is at least 1 % would be in the range of constraint sedimentation [10]. The suspension used in the study of the solid volume fraction (volume fraction) is calculated on the basis of (1) is 1.89 %.

$$\varphi = \frac{S_z}{\rho_z} = \frac{45\frac{kg}{m^3}}{2376\frac{kg}{m^3}} = 0.0189\frac{m^3}{m^3} = 1.89\% \qquad (1)$$

During the constrained sedimentation process, due to the occurrence of zonal sedimentation, in suspension are formed zones of different concentrations, in particular case is formed the clear liquid zone, that is clearly separated from the suspension layer. Execution of the suspension sediment test depend on the height of the boundary separation between pure liquid and a first zone of thickened sludge, depending on the time [1]. On the basis of the sedimentation curve we can determine for example the speed of sedimentation of the suspension concentration, maximum attainable level of compression, as well as we can determine the size of the settler needed to obtain a pure overflow and underflow with the assumed concentration [1].

Sedimentation tests were conducted during the research to determine the impact of different methods of supporting the sedimentation process (multiflux fillings, flocculation) at the rate of sedimentation and to determine the maximum level of compression during the process of sedimentation in the conventional system and the shallow sedimentary system (with multiflux fillings).

Implementation of the static tests took place on a laboratory designed to study the process of static sedimentation. (Fig. 4). The research was conducted for the two settings of the measuring cylinder – vertical and inclined. The vertical setting of cylinder simulating the sedimentation process occurring in the device without multiflux fillings, while the cylinder set at the angle of 60° relative to the ground – as a typical angle of the multiflux fillings duct in the multiflux sedimentation, imitated the implementation process of sedimentation in the settler with multiflux fillings.

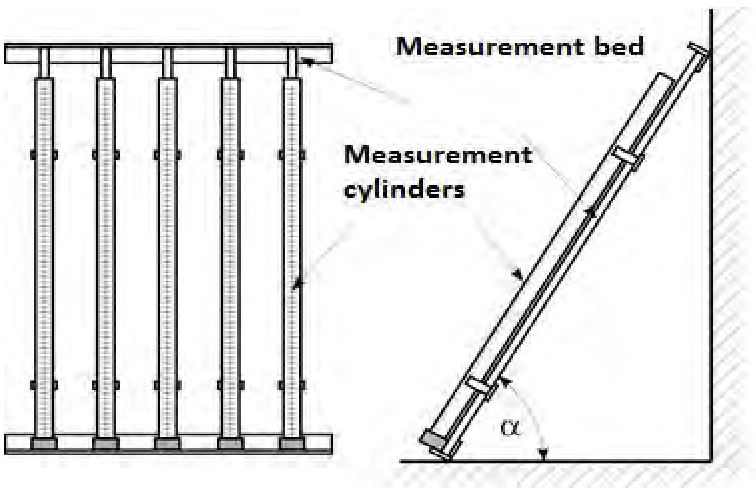


*Fig. 4. Research workplace to multiflux sedimentation process in static conditions*



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The first tests was made in the static tests which sedimentation tests of crude sediment suspension (without the addition of flocculant) were made for vertical and inclined measuring cylinder. These tests provide a point of reference for all tests made later. Sedimentation curves for these measurements are shown in the graph (Fig. 5) – M1a90 curve for the cylinder set vertically, M1a60 – curve for the cylinder set at an angle of 60° relative to the ground.

The next stage of research was carried out for identical layout as the first test with additional use of flocculation to support sedimentation process. In this research flocculation process carried out using flocculant FLOP AN SHU 923. The aqueous solution of flocculant having a concentration of flocculant = 0.102 %, so prepared solution was dispensed in a fixed dose of the suspension.

For this test a flocculation process was carried out in a specially prepared tank in which to the appropriate amount of crude suspension was added the flocculant. The first stage was conducted mixing quickly to complete mixing of flocculant with the suspension, and then applied slow mixing to ensure proper conditions for the precipitation of floccules – so prepared suspension (flocculated suspension having a solid fraction in the form of flocs) were filled cylinders, and then the test was carried out.

Sedimentation curves for the measurement of flocculation is shown in the graph (Fig. 5) – M2a90f curve for the cylinder set vertically with flocculant dose of 200ppm, M2a60f curve for the cylinder set at an angle of 60° relative to the ground with a dose of flocculant 200ppm.

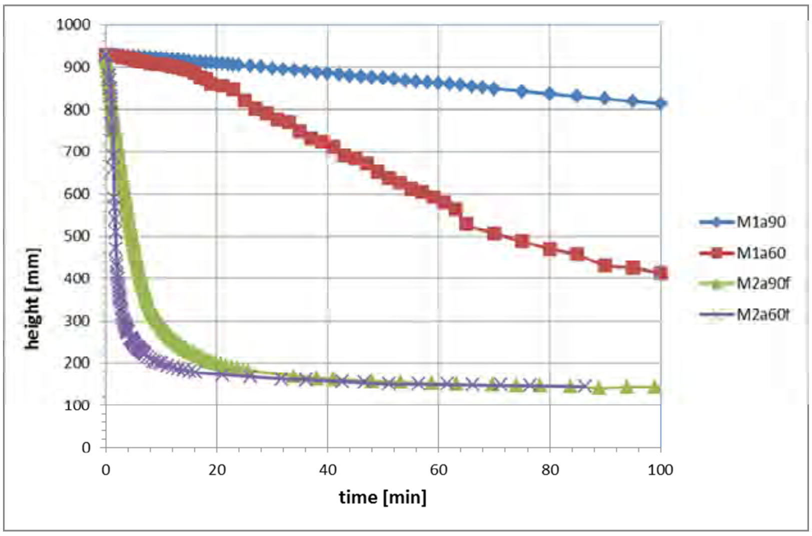


*Fig. 5. Summary of sedimentation curves for the test of M1 without flocculant and M2 with flocculant for the setting of the measuring cylinder vertical (90 °) and at an angle of 60 °*

The obtained results clearly show that the flocculation process significantly affects on the sedimentation rate (presence of flocculant increases the sedimentation rate), also it can be seen that the sedimentation process is much faster in the system of inclined cylinder. This dependence is true for the both systems: with and without flocculant.

For the tests has been appointed the sedimentation rate of suspension (Fig. 6) based on equation (2) where Δh is the increment of height (descending layer separation) and ΔT is the time interval in which this increase occurred. The sedimentation rate determined for the initial straight section of the sedimentation curve is the rate of sedimentation of the suspension to its initial concentration.

$$v_z = \frac{\Delta h}{\Delta t} \qquad (2)$$

The sedimentation rate calculated values are shown at the diagram (Fig. 6) shows that the use of multiflux fillings causes 5.1-times increase in sedimentation rate for the process without the use of flocculation, while in the case of flocculation of this increase is smaller and is 2.8 times the rate of sedimentation of suspensions flocculant.



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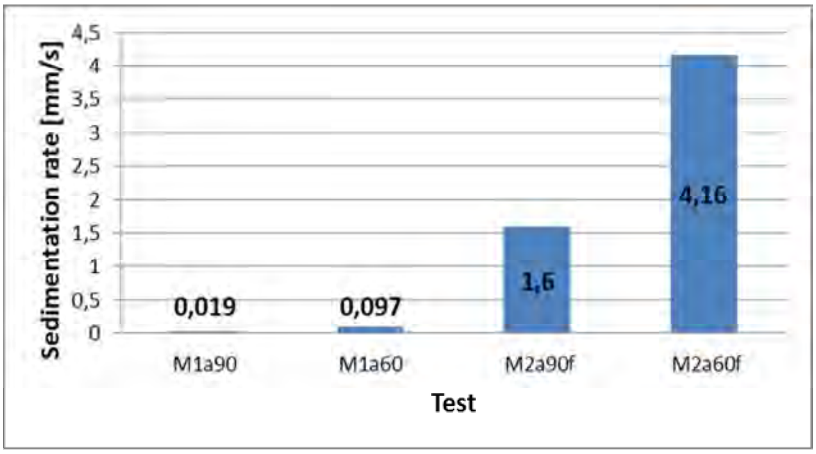


*Fig. 6. The rate of sedimentation of suspensions for the test of M1 and M2.*

Comparing the rate of sedimentation of the suspension without the flocculation and with flocculant in the system of vertical cylinder we get 84-times increase in sedimentation rate after flocculant. However, for an inclined cylinder system get 43-times increase in sedimentation rate after flocculant.

From the diagram (Fig. 5) and the calculated sedimentation rate (Fig. 6) clearly shows that the use of multiflux sedimentation results in a several times increase in the rate of sedimentation and flocculation application process allows for even several ten times increase the rate of sedimentation. Simultaneous use of both techniques which increase the rate of multiflux sedimentation and flocculation allows for 220-times increase in sedimentation rate. It should be noted that obtaining such a large increase in sedimentation rate is dependent on a number of elements, starting from the type of suspension, its concentration, the type of flocculant, the dose, multi-kind contributions and process of flocculation and ending at sedimentation process. Each of these elements may be important and significant impact on the final result of the process of sedimentation.

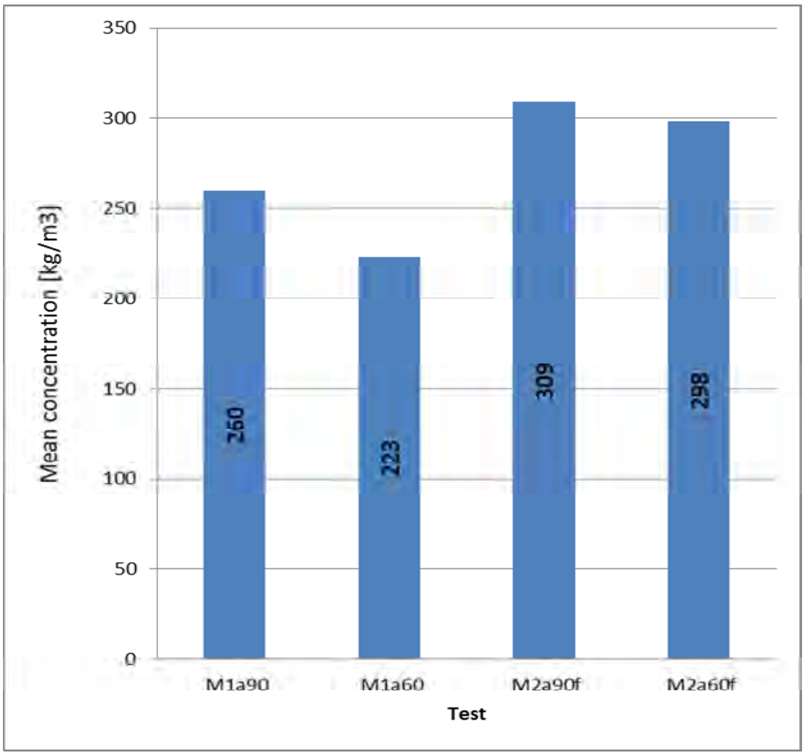


*Fig. 7. Mean concentrations of sediment layers for maximum compressi on level for the tests of M1 and M2*



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Based on sedimentation curve, we can calculate the concentration of the suspension at any point on the curve. Figure 7 shows the converted value of the mean concentration of suspended sediment in the layer for which the maximum level of compression can be achieved through sedimentation. With the use of flocculant is possible to get a higher final concentration.

**Static tests with different doses of flocculant**

The following section provides results of the static sedimentation process of coal suspension static implemented in system of the vertical cylinder and inclined cylinder at an angle of 60° relative to the ground with use of different doses of flocculant. In the tests it was assumed that the maximum dose of flocculant is 200 ppm. Subsequent tests were made using the appropriate doses of flocculant 50 ppm, 100 ppm, 125 ppm, 150 ppm and 1750 ppm. As a comparative test (without addition of flocculant) was adopted by M1 tests described in the previous section.

The research in this chapter uses a slightly different way of carrying out the process of flocculation. The methodology carry out the flocculation process was the introduction of suitable dose of flocculant directly into the measuring cylinder (according to the dose prescribed for the test). Completion of the mixing lasted several minutes, and then the test of static sedimentation. This way of carrying out flocculation process simplifies the test and also protects against possible sedimentation in flocculation tank and against smashing floccules generated during the filling of the measuring cylinder. Unfortunately, its different from typical the process of flocculation in real systems – apart from the flocculation chamber.

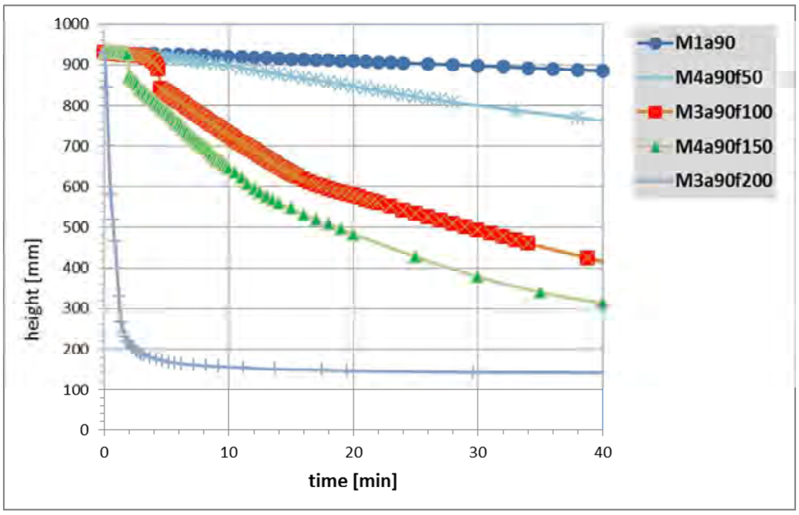


*Fig. 8. Sedimentation curves for tests with different dose of flocculant to the vertical position of the measuring cylinder*

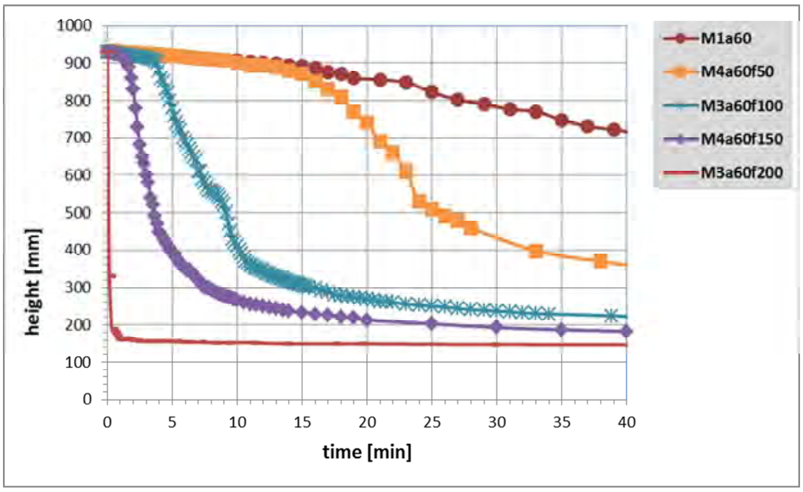


*Fig. 9. Sedimentation curves for tests at different dose of flocculant for measuring cylinder set at an angle of 60 ° relative to the ground*



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The results of sedimentation tests using different doses of flocculant in value in range od 0÷ 200 ppm for the vertical position of the measuring cylinder (the process of sedimentation as a conventional system without filling) is shown in the figure (Fig. 8). While the figure (Fig. 9) is given by setting the sedimentation curves of sedimentation cylinder inclined at the angle of 60° relative to the ground for doses of flocculant described above.

From the posted result that depending on the dose of flocculant will receive a different sedimentation curve. With increasing doses of flocculant sedimentation rate increased, both for a cylinder: vertical and inclined.

Figure 10 shows the value of coal suspension sedimentation rate calculated from equation (2) for the tests. The maximum rate of sedimentation, obtained at the highest dose of flocculant (200 ppm) implemented in the inclined measuring cylinder is tilted up to 37 mm/s and is almost 2000 times higher than the rate of sedimentation in the system of vertical cylinder without flocculation which is 0,019mm/s.

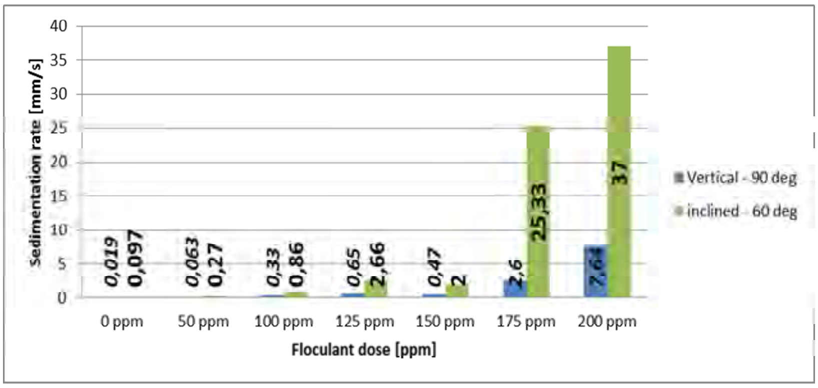


*Fig. 10. Dependence of sedimentation rate of flocculant dose for the cylinder set vertical and inclined*

According to the theory with increasing doses of flocculant (within a certain range) the rate of sedimentation increases. As well, we see that for an inclined cylinder system the sedimentation rate increases several times faster than the process followed in a vertical cylinder. Regardless of the doses of flocculant, the full scope of the performed tests we obtain the increase rate of sedimentation.

Obtained results draw us the conclusion that, regardless of supporting sedimentation process by flocculation and regardless of the used dose of flocculant, multiflux fillings cause, in any case, an increase in sedimentation rate. In addition, using the conjunction of supporting sedimentation process by flocculation and multiflux fillings at the same time we received an effect of multiplying the sedimentation rate. The effect which cannot be obtained with executing these processes separately.

Although the results presented that the observed exponential increase in sedimentation rate with increasing dose of flocculant, in practice, beyond a certain limit dose of flocculant (not made visible in these studies – achieved) further increasing the dose will not work polyelectrolyte effect of the increase in sedimentation rate.

**Summary**

Research of the sedimentation process of coal suspension show the possibility and high efficiency of the use of multiflux fillings conjugated with process of flocculation.

The final result obtained by using both techniques of supporting the sedimentation process at the same time cause that the final result obtained by one method is multiplied by the effect contributed by the second method.

Sedimentation rate was reached several hundred times more increased relative to the classical sedimentation process without the use of multiflux fillings and flocculation.

Conducted preliminary studies indicate the importance of the realization process of flocculation at further sedimentation process. All the elements associated with the mixing of the liquid have a significant impact on the obtained results, ie the time and speed of mixing, as well as the type of used mixer. The



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deviations from the intended results are related to the fact that the suspension arising in the process of flocculation has got highly unstable character.

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# COMPUTER SUPPORT OF INNOVATION IN ENGINEERING DESIGN

© *Wróbel J., Okulicz K., 2012*

**The article presents non classical approach to computer support of conceptual work in initial steps of machinery design process. The computer support of innovation process in modernization of Personal Electric Vehicle (PEV) design has been considered in the article as an example of this approach.**

**Key words: CAD/CAM systems, virtual reality technology, Personal Electric Vehicle (PEV).**

**Описано некласичний підхід до комп'ютерної підтримки концептуальної роботи на початкових етапах процесу проектування механізму. Як приклад цього підходу у статті розглянуто комп'ютерну підтримку інноваційних процесів у модернізації проектування особистого електротранспорту.**

**Ключові слова: CAD/CAM, технології віртуальної реальності, особистий електро-транспорт.**

## Introduction

In recent years computer technologies – but specially CAD systems, optimization and virtual reality systems – play a significant role in an every design process [1].

Computer technologies can be also applied in the support of technical innovation processes. Innovations play a significant role in any design process. The object of design can be a car, a part of car's body, and also a factory, its department, a manufacturing line or even a single production process. Additionally an essential element of a design process is simulation. The simulation allows to support innovation process. Currently on the market don't exist not too many applications dedicated to innovation processes that are integrated with CAD/CAM systems.



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