MARCIN POPCZYK[1]

Optimization of the composition of fly ashwater mixture in terms of minimizing seepage water and the possibility of gravitational hydrotransport into the underground workings

Introduction

The exploitation of hard coal in Poland is inextricably linked with numerous hazards. One of them involves endogenous fires arising in the caving zones formed in longwall mining. These fires are a result of coal residue, which often heats up in contact with the mine air oxygen and a process of slow burning is started after some time. One method of limiting this type of hazard is the fire prevention consisting in introducing fly ash-water hydromixtures into the caving zones by means of hydraulic transport by pipeline installations, most often carried out by means of gravity. The hydromixture in this type of installations is a self-controlled process. This means that flow parameters such as efficiency or hydrotransport velocity result mainly from the spatial layout of the installation route, in particular from the ratio of its length to the difference in the height of the inlet and outlet of the installation. In addition to the shape of the pipeline route, hydrotransport efficiency is also affected by hydromixture parameters, such as the density and viscosity resulting from the proportion of water to the fine-grained material (fly ash). In terms of the pipeline route configuration, as a ratio of its length to the height difference between the inlet and outlet increases, the efficiency parameters of the backfilling mixture decrease, which is a result of the drop in

✉ Corresponding Author: Marcin Popczyk; e-mail: marcin.popczyk@polsl.pl
[1] Silesian University of Technology, Gliwice, Poland; e-mail: marcin.popczyk@polsl.pl

the flow velocity. To ensure stable flow conditions for the mixture, the installation should be characterized by the so-called correct hydraulic profile, i.e. one in which the isobar does not intersect the hydraulic profile of the installation. Otherwise, the flow of the mixture in the installation is disturbed and, in an extreme case, becomes impossible. In case of using ash-water mixtures, the rheological properties such as the viscosity and flow limit of the mixture have a significant impact on the parameters of hydraulic transport, and they should be included in the calculations (Pomykała 2012).

The standard parameter defining the consistency and "transportability" of a hydromixture is the table spread (Popczyk 2002). Based on practical experiments and multiple measurements verified in both laboratory and industrial conditions, it can be stated that mixtures intended for the grouting of goafs (voids characterized by small dimensions) should exhibit a table spread in the range from 180 to 220 mm, and mixtures intended for filling voids of large dimensions, especially those of the nature of a self-consolidating backfill, should feature lower table spread in the range from 140 to 180 mm (Popczyk 2002).

Increasing the table spread of the mixture is achieved by increasing the proportion of water in the mixture. This leads to the reduction of the concentration of solids in the mixture, a reduction of the mixture's density, lower viscosity, and an increase in the setting time, deterioration of the strength properties of the solidified mixture, and in extreme cases even the loss of capacity to solidify. In relation to hydrotransport, the mixture with a lower concentration of solids ensures lower resistance of flow in the installation, and thus provides a higher flow rate and a greater transport range – which is especially important in the case of a significant horizontal distance of operation sites from a backfilling shaft or a small difference in the level between the surface and the location of backfilling operations.

In the caving zone, mixtures with a higher table spread provide greater penetration and better filling of the goaf, especially ones with low porosity.

On the other hand, a high table spread mixture contains a much larger quantity of water than the fly ash in it can bind. Excessive water from the grouting mixture is combined with mine waters, affecting a possible increase in the water hazard and lowering the chemistry indicators of underground waters.

The optimal amount of water in the mixture is strictly dependent on the conditions of use, the type of materials used to prepare the mixture, as well as the characteristics of the caving zone.

The paper presents a method for optimizing the composition of a hydromixture by determining the optimal amount of water in relation to the capacity to safely carry out gravity hydrotransport processes and minimizing the amount of leachate water.

1. Research methodology

1.1. Methodology for determining flow parameters
of fine-grained mixtures in gravity installations

The flow of fine-grained liquids in gravity installations takes place under the influence of gravity. It is assumed that the hydromixture motion is described by the modified Bernoulli equation, while unit energy losses are empirically determined. The notion of the modified Bernoulli equation should be understood as the generalized Bernoulli equation used to describe the motion of actual liquids in the pipelines, containing additional corrective coefficients with the liquid density replaced by the kinetic density of the hydromixture. It should be noted that at a steady flow of the hydromixture in the gravity installation, the pressure at the end of the vertical column, Fig. 1 is approximately equal to:

$$p_B = h_1\rho_m g\eta - \Delta p_{A-B}h_1 \tag{1}$$

In this formula, the symbol ρm denotes the so-called kinetic density of the hydromixture, i.e. the mass of particulate matter and water contained in 1 m^3 of the hydromixture in motion. The coefficient η denotes the corrective coefficient, which was called, although not particularly correctly, the installation hydrodynamic efficiency coefficient.

The unit energy losses in the vertical pipeline A-B were assumed to be equal to the unit energy losses of the hydromixture flow in the horizontal pipeline of the same diameter. The generalized Bernoulli equation for the AA, BB cross-sections of the gravity installation shown in Fig. 1 after assuming that the liquid water mixture has been replaced with a nominal uniform liquid with a density corresponding to the average density of actual hydromixture and constant in each cross-section as well as stream point, takes the following form:

$$h_1\rho_m g + p_A = \frac{v_m^2}{2}\rho_m + p_B + \Delta p_{A-B}h_1 \tag{2}$$

☝ $p_A = p_B$ –   atmospheric pressure (barometric).

After the transformation of this equation, the result is

$$p_B = h_1\rho_m g + p_A - \frac{v_m^2}{2}\rho_m - \Delta p_{A-B}h_1 \tag{3}$$

In practice, in gravity installations with a depth greater than 100 m, the value of the formula $p_A - \frac{v_m^2}{2}\rho_m$ is low compared to value of $h_1\rho_m g$ and can be omitted.
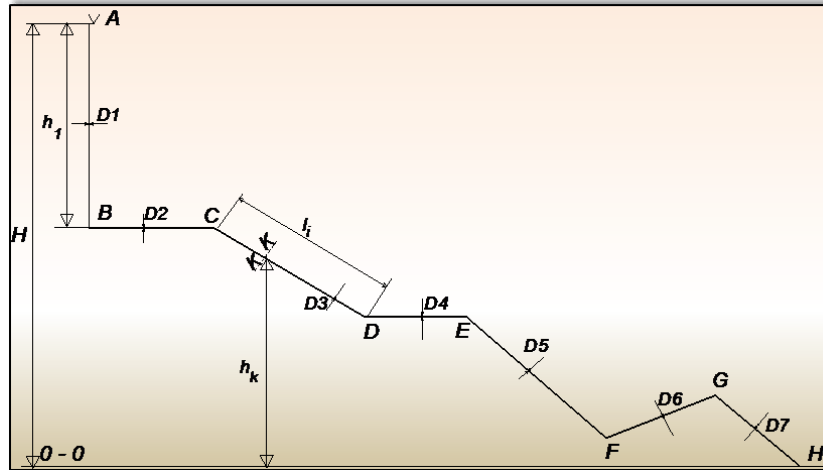
Fig. 1. Diagram of a gravity backfilling installation

Rys. 1. Schemat grawitacyjnej instalacji hydrotransportowej

Allowable flow velocity of the hydromixture in any K-K cross-section will be equal to (Popczyk 2017):

$$v_{mK_{\max}} = \sqrt{2g\left(\frac{p_B}{\rho_m g} - \frac{p_v}{\rho_m g} + H - h_K - \frac{1}{\rho_m g}\sum_A^K L_{A-K}\Delta p_{A-K}\right)}$$ (4)

In the expression under the square root sign the value of energy losses is also a function of velocity. Therefore, when determining the maximum flow rate, one needs to know the equation for energy losses. In practice, the average flow velocity of the hydro-mixture should be within the range:

$$v_{kr} \leq v_m \leq v_{gr}$$ (5)

✥ v_{kr} –   critical velocity below which articulate matter accumulate
          at the bottom of the pipeline,
   v_{gr} –   limit velocity causing excessive wear of pipelines.
          In practice, it is assumed to be <12 m/s.

Knowing the flow velocity allows us to determine the efficiency parameters for the flow of a fine-grained mixture:
   ◆ volumetric flow rate of the mixture Q_m:

$$Q_m = v_m \frac{\pi D^2}{4} \ (\text{m}^3/\text{s})$$ (6)

◆ volumetric flow rate of solids Q_s:

$$Q_s = C_v Q_m \ (\text{m}^3/\text{s}) \tag{7}$$

◆ volumetric flow rate of water Q_w:

$$Q_s = (1 - C_v) Q_m \ (\text{m}^3/\text{s}) \tag{8}$$

Generally, it can be assumed that the voids filling efficiency (Q_p) corresponds to the volumetric flow rate of the mixture reduced by the amount of water, which under given conditions, will not be bound in the solidification process, nor absorbed by the surrounding goafs.

In order to correctly determine the unit energy losses of the non-Newtonian liquid flow, which include ash-water mixtures with high density, we must know the rheological parameters (Popczyk 2017). The rheological parameters can be determined by designating the flow curve in the laminar flow zone and selecting an appropriate rheological model. The following rheological models are most commonly used to describe the flow parameters of fine-grained mixtures (Izak 2015):

◆ Newton's model

$$\tau = \tau_0 + \eta \frac{\Delta v}{\Delta y} \tag{9}$$

◆ Ostwald de Waele's model

$$\tau = \left(\frac{dv}{dy} \right)^n \tag{10}$$

◆ Bingham's model

$$\tau = \tau_0 + \eta_p \frac{dv}{dy} \tag{11}$$

◆ Casson's model

$$\sqrt{\tau} = \sqrt{\tau_0} + \sqrt{\eta_p \frac{dv}{dy}} \tag{12}$$

☝ τ –   shearing stress (Pa),
τ_0 –   flow limit (Pa),
η –   viscosity (Pa·s),
dv/dy –   shear velocity (s^{-1}),
k, n –   model parameters.

The flow curves of the fine-grained mixtures can be determined using shearing stress measurements as a function of the shear rate in rotational viscometers with coaxial measurement cylinders. Knowing the course of the flow curve and choosing the optimal rheological model it is possible to determine the rheological and unit parameters of the flow resistance for the mixture in the laminar flow zone.

1.2. Methodology for determining
the amount of excess water

The testing of the amount of excess water was carried out in accordance with the PN-G 11011:1998 standard. The test consisted of pouring the prepared mixture into a measuring vessel, leaving it stationary, and determining in the assumed time intervals (until no changes occur) the height of the pure water column, calculated on the % of the original volume of the sample. The amount of excess water allows the volume of water that the material is able to absorb and the amount of water that may drain from the mixture located in the underground void to be predicted.

2. Characteristics of an example
of a gravity hydrotransport installation

For the purpose of calculations and analysis, a gravity pipeline installation was used, extending from the surface to a mining excavation through a technological hole transporting ash-water hydromixtures. The adopted route consists of three mining workings and is not very complicated in terms of the spatial layout. The supply of the pipeline system is carried out with a modern mixing and feeding unit equipped with full monitoring and control system of the production process of the hydromixture produced on the basis of fine-grained power generation waste (fly ash). These factors make this installation a good base for conducting measurements and research related to gravitational hydrotransport. The route diagram is shown in Figure 1, while its basic geometrical parameters have been determined and shown in Table 1. On this basis, the hydraulic profile of the pipeline route was determined and is shown in Figure 2.

As shown in Table 1, the basic geometric parameters of the pipeline installation are:
- pipeline total length L_c = 1199.0 m,
- pipeline diameter D = 0.150 m,
- height difference between the inlet and the outlet of the installation ΔH = 303.11 m,
- the ratio of length to height difference $L_c/\Delta H$ = 3.96.

The presented example of a route of the pipeline for the transport of fine-grained mixtures features a correct hydraulic profile ensuring favorable flow conditions. Considering the relation of the length of the transport route to the height difference between the inlet

Table 1.   General geometric parameters of transportation pipeline

Tabela 1.   Parametry geometryczne trasy rurociągowej do hydrotransportu

| Pipeline route (name of working)	Length of pipeline segment (m)	Height of begin/end of pipeline segment		Height difference of pipeline segment Δ_H (m)	Diameter of pipeline segment D_i (m)
		H_p (m)	H_p (m)		
1. Technological hole from the surface	204.00	252.00	50.80	201.20	0.150
2. Ventilation heating in the coal seam	990.00	50.80	−50.53	101.23	0.150
3. Heading in the coal seam	5.00	−50.53	−51.11	0.58	0.150
SUM	1 199.00			303.11	
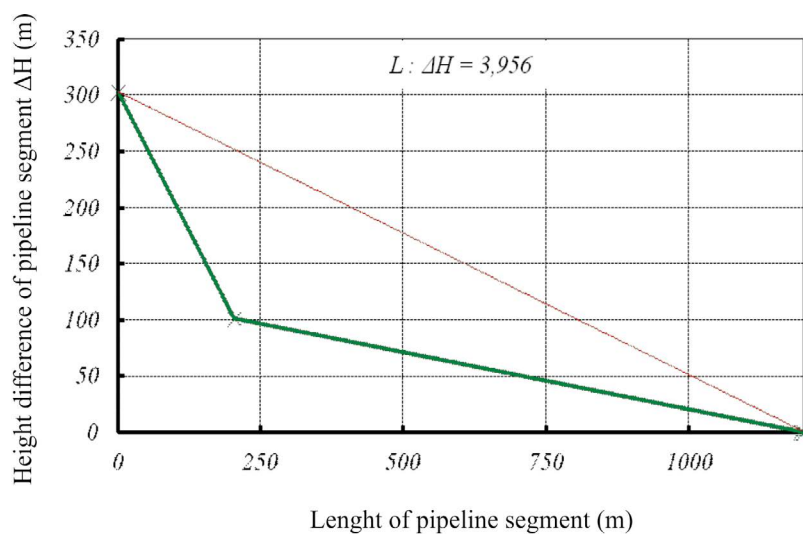
Fig. 2. Hydraulic profile of pipeline installation for transport of fine-grained mixtures

Rys. 2. Profil hydrauliczny instalacji do hydrotransportu mieszanin drobnofrakcyjnych

of the pipeline and the outlet, it can be preliminarily stated that it should provide a safe and effective flow process in the gravity hydrotransport system. This route is features a total pipeline length of 1190 m and a height difference of approx. 303 m which gives a ratio of the length of the equivalent pipeline to a height difference of 3.96.

3. The results of rheological parameters research
and the amount of super-sedimentary water

Depending on the technological requirements and transport capacities in mining, water-ash liquid mixtures with different concentrations of solids are used, which results in a wide variability of rheological parameters of ash-water mixtures. In practice, this has a direct impact on the future parameters of gravity hydrotransport. Table 2 presents the chemical composition and physical properties used for fly ash tests. Fly ash belongs to the group of fine fractional waste, which has a significant impact on the sedimentation process. The sedimentation of these fly ash poisoning occurs for a long time. Figure 3 shows the grain slope of fly ash used for research. The paper exhibits changes in flow the parameters based on an example of a pipeline installation depending on the density and rheological parameters changes in the water mixtures. In order to produce hydromixtures, fine-grained materials were used in the form of energy waste fly ash from waste group 10 01 82 with various proportions of water to solids. In order to define the consistency of a hydromixture in mining, according to PN-G/11011:1998 the table spread parameter is used, understood as the diameter of hydromixture spreading when spilled from a table spread test cup on a horizontal glass

Table 2.   Chemical composition and physical properties of fly ash

Tabela 2.   Skład chemiczny i fizyczny właściwości popiołu lotnego

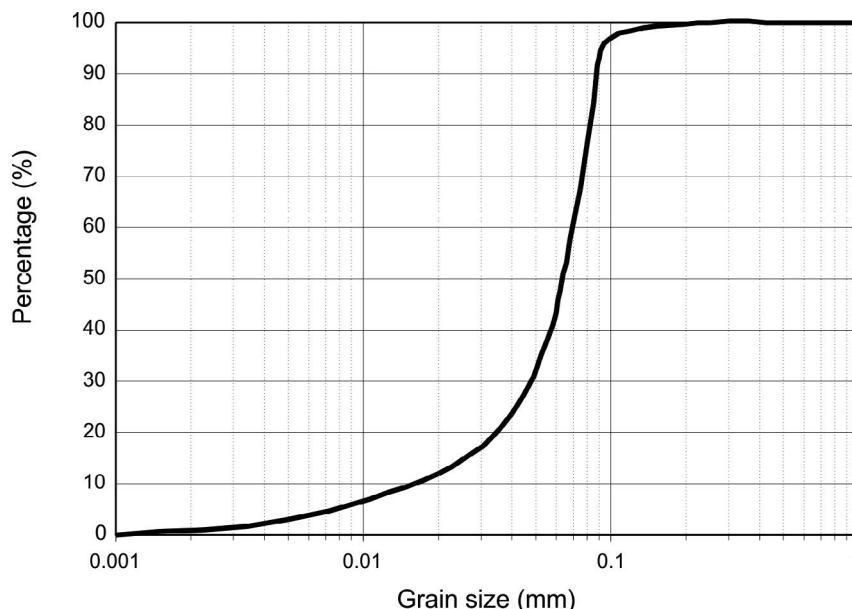| Chemical composition (content converted into initial state)	Value (% mass)
SiO_2	42.30
Al_2O_3	19.70
Fe_2O_3	5.30
CaO	16.50
MgO	2.20
Na_2O	0.60
K_2O	2.10
SO_3	5.38
TiO_2	0.70
P_2O_5	0.56
Mn_3O_4	0.04
Physical properties	
Loss of roasting (% mass)	1.54
Specific density (g/cm^3)	2.12
Free CaO (% mass)	6.07

Fig. 3. The graining curve for the fly ash tested

Rys. 3. Krzywa uziarnienia popiołu lotnego wykorzystanego do badań

surface. As experience shows, safe transportation of ash-water hydromixtures by gravity installations is possible with a minimum table spread of approx. 130–140 mm. The upper limit of table spread is not practically defined, but it should be remembered that increasing the table spread results in an increased proportion of water in the mixture and thus an increased drain of excess water to underground workings. Based on practical experience, the range of hydraulic table spread from 130 to 250 mm that is most commonly used in mining industry was applied in the study.

The rheological properties of grouting mixtures were determined by rotational viscometry. Bingham's rheological model, defined by two values: flow limit and dynamic viscosity, was used to describe the rheological properties of fine-grained mixtures. Rheological properties of mixtures of fly ash from hard coal combustion and water may be described with high accuracy by Bingham model (Strozik 2018), which approximates properly wide range of mixtures with finely grained solids. Accordingly to this model a mixture exhibit a yield stress and so called plastic viscosity. Both parameters depend strongly on concentration of solids in mixture. The determined values have been summarized in Table 3. The table also presents the results of tests of the amount of excess water depending on the density and table spread of the hydromixture, which will drain from the mixture to underground workings after its allocation.

As can be seen from Table 3, in relation to table spread of tested mixtures between 130 and 250 mm, their density varies from 1480 to 1370 kg/m^3. Along with the increase

Table 3.   General rheological properties of fly ash – water mixture

Tabela 3.   Podstawowe parametry reologiczne mieszanin popiołowo-wodnych

Table spread R (mm)	Density of a mixture ρ_m (kg/m³)	Volume concentration of a mixture C_V (–)	Dynamic viscosity η_B (Pa·s)	Yield point τ_0 (Pa)	Amount of excess water (%)
130	1 480	0.3195	0.222	17.54	0.2
150	1 455	0.3183	0.209	14.92	4.6
170	1 435	0.3171	0.183	10.52	7.1
180	1 425	0.3160	0.139	7.28	8.6
200	1 410	0.2958	0.109	3.96	10.8
220	1 395	0.2924	0.086	2.58	12.3
230	1 385	0.2743	0.062	0.95	13.0
250	1 370	0.2732	0.058	0.69	14.2

in table spread, the dynamic viscosity of the hydromixtures decreases in the range from 0.222 to 0.058 Pa·s. A similar relation occurs in the case of the flow limit, where it decreases in the range from 17.54 to 0.69 Pa with an increasing table spread. It can be assumed that with an increase of the table spread from 130 to 250 mm, the dynamic viscosity decreases by one order of magnitude and the flow limit by about two orders of magnitude.

As shown in Table 3, the amount of excess water is directly proportional to the table spread of the hydromixture. With table spread increasing from 130 to 250 mm, the amount of excess water increases in the range from 0.2 to 15.0%.

4. Determination of hydrotransport parameters

Based on the determined rheological parameters of ash-water mixtures listed in Table 3 and according to the methodology presented in Chapter 1 of the paper, the basic parameters of gravity hydrotransport were determined for the example of a pipeline route assumed and described in Chapter 2. The obtained values for each of the hydromixtures have been summarized in Table 4. The following flow parameters were determined for each of the hydromixtures considered:

- ◆ flow velocity of the mixture in the pipeline with a diameter of 0.09 m, v_m,
- ◆ volumetric flow rate in the pipeline, Q_m,
- ◆ volumetric stream solids in the mixture Q_s,
- ◆ volumetric stream of water in the mixture Q_w,
- ◆ mass stream of solids in the mixture Q_{sM},
- ◆ backfilling efficiency (volume of solids) Q_p.

Table 4.   Parameters of hydraulic transport of mixtures in an exemplary transport pipeline

Tabela 4.   Parametry hydraulicznego transportu hydromieszani dla przykładowej instalacji rurociągowej

Table spread R (mm)	Density of a mixture ρ_m (kg/m^3)	Flow velocity v_m (m/s)	Volumetric flow rate (m^3/godz)			Fell efficiency Q_p (m^3/h)
			mixture Q_m	solid parts Q_s	water Q_w	
130	1 480	4.137	263.18	85.19	188.99	96.4
150	1 455	4.607	293.08	81.99	209.36	102.7
170	1 435	4.684	297.98	88.62	214.09	106.8
180	1 425	4.834	307.53	80.98	226.55	110.1
200	1 410	5.241	333.42	84.70	248.72	112.1
220	1 395	5.462	347.48	85.04	262.44	114.2
230	1 385	5.677	361.16	86.15	275.01	114.3
250	1 370	6.053	385.08	88.28	296.80	114.7

By analyzing the results of calculation of ash-water mixtures flow parameters in the pipeline installation described in Chapter 2 of the paper and presented in Table 4, it may be concluded that the installation provides favorable conditions for the flow of mixtures in a wide range of solids concentrations. The flow rate of the fine-grained mixtures in the flow range from 130 to 250 mm ranges from approx. 263 to 385 m^3/h, while the backfill efficiency, i.e. the approximate backfilling efficiency, ranges from approx. 96 to 114 m^3/h. With the mixture table spread in the range from 130 to 250 mm, the variation in the flow velocity changes from approx. 4.14 to 6.1 m/s.

5. Analysis of research results in terms of optimization of the hydromixture composition

As it has been exhibited, the selection of the table spread of fine-grained mixture (concentration of the mixture) has a slight influence on the achieved efficiency of void filling and the consumption of industrial waste for the production of the mixture. As the table spread of the mixture increases, the amount of water necessary for its production also increases and the migration properties of the mixture change as well. In relation to the effectiveness of fire prevention with the use of the above mentioned mixtures, it should be emphasized that it is unfavorable to use mixtures with excessive concentrations (low table spread range, quick loss of goafs absorbency) as well as ones with insufficient concentrations (flooding of goafs with water without leaving a fill to permanently insulate). Therefore, when using ash-water hydromixtures, it is always necessary to analyze the parameters of gravitational hydrotrans-

port for a given installation, taking the amount of excess water which will drain to underground workings into account. In order for the optimization to be conducted, it is necessary to combine these two relations and determine the optimal composition of the hydromixture. These have been shown in Figure 4.

As shown in Figure 4 the void filling efficiency with granular material of 100 m^3/h in the selected route of the pipeline installation is already reached at the table spread of the hydromixture of approx. 140 mm. With this table spread, the amount of excess water will be equal to approx. 3% which is a very low value and fully acceptable from the point of view of the excavation drainage system. Although a further increase in table spread results in efficiency increasing to nearly 115 m^3/h, a drastic increase in the amount of excess water draining to underground workings is also noted. In practice, it is assumed that the amount of excess water of up to 5% is fully acceptable and desirable from the point of view of the underground mine drainage system. It should be mentioned that increasing the table spread also results in the increase of the hydromixture velocity in the transport pipeline, which causes its excessive wear by mechanical abrasion resulting in a shorter life span of the transport pipeline. Taking the above into account, from the point of view of gravitational hydrotransport parameters and the amount of excess water, an optimal hydromixture is considered to be the one with a table spread ranging from 130 to approx. 145 mm as indicated by the field in Figure 4.
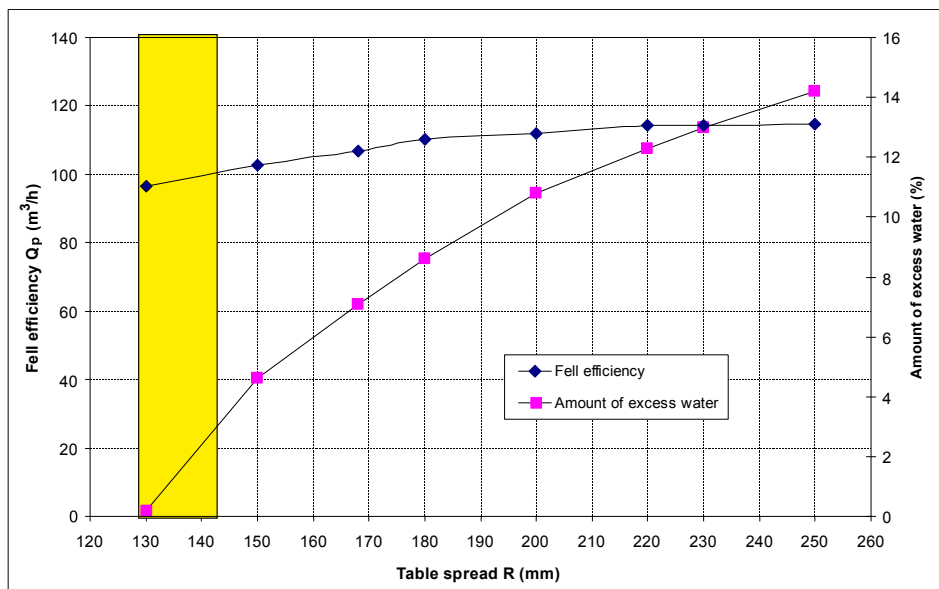

Fig. 4. The characteristics of the backfilling efficiency and the amount of excess water depending on the table spread of the ash-water hydromixture

Rys. 4. Charakterystyka wydajności podsadzania i ilości wody nadmiarowej w zależności od rozlewni hydromieszaniny popiołowo-wodnej

Summary and final conclusions

Presently, ash-water hydromixtures transported to underground workings by a gravity fed pipeline, are commonly used for fire prevention in Polish underground hard coal mines. The flow in such installations is a self-controlled process, which means that the flow parameters such as efficiency or velocity of the hydrotransport result mainly from the spatial layout of the installation route, in particular from the ratio of its length to the difference in the inlet and outlet height of the installation. In addition to the shape of the pipeline route, hydrotransport efficiency is also affected by the hydromixtures parameters, such as the density and viscosity resulting from the proportion of water to the fine-grained material (fly ash). Satisfactory hydrotransport parameters can be achieved in a very wide range of hydromixture table spread, however, the higher water content in the hydromixtures increases the drainage of water to underground workings, which is an additional burden on the drainage system. The optimal solution would consist in the hydromixture being deprived of leachate water but in such a case its thick consistency would prevent its transportability in the gravitational pipeline. This paper presents an example selection of the consistency (composition) of a hydromixture taking its transportability in an example of a gravitational pipeline installation, including the amount of excess water into account. The following conclusions may be formulated based on the calculations presented herein:

1. The tested pipeline route for the transport of fine-particle mixtures provides the correct geometrical parameters allowing for the effective gravity transport of fine-grained mixtures in the entire assumed flow range from 130 to 250 mm.
2. In the tested range of hydromixture table spread from 130 to 250 mm the density varies from 1480 to 1370 kg/m^3.
3. Along with the increase in table spread, the dynamic viscosity of the hydromixtures decreases in the range from 0.222 to 0.058 Pa·s. and the limit is reduced in the range from 17.54 to 0.69 Pa.
4. The analysis of the ash-water mixture flow parameters obtained based on the determined rheological parameters allows to conclude that the backfill efficiency, i.e. the approximate voids filling efficiency increases with the increase in table spread and in its range 130–250 mm it ranges from approx. 96 to 114 m^3/h.
5. Laboratory tests concerning the amount of excess water have shown that in the tested flow range from 130 to 250 mm the amount of excess water increases from 0.2 to 14.2%.
6. Based on the obtained results of the hydromixture flow parameters in the example of the installation and the research on the amount of excess water, it should be stated that the optimal table spread of the hydromixtures is within the range of 130–145 mm, which corresponds to a density in the range from 1480 to approx. 1500 g/dm^3. The hydromixture in this density range will exhibit safe transportability and the necessary minimal amount of excess water.
7. The production of ash-water hydromixture in such a small density range is possible only using modern mixer installations with a fully automatic dosing and mixing processes.

In summary, it should be noted that when choosing the composition of ash-water hydro-mixtures for transport in gravity pipelines, not only its rheological and transport parameters should be taken into account for its safe transport but also the amount of excess water that will drain into underground workings, as determined via laboratory tests. By optimizing the liquid hydromixture in view of the amount of excess water, the following benefits are also achieved:

- the use of technological water is limited,
- the life of the transport pipeline is extended by lowering the flow velocity,
- the amount of water inflow to the drainage system is limited, which reduces the costs of pumping water from underground workings,
- the time of filling the assumed voids is decreased while increasing the filling efficiency.

It should be kept in mind that various types of fly ash are produced depending on the place of their production and the desulphurisation processes used. This results in the variability of their physical properties, which means that they may exhibit properties far from those presented in the paper. Therefore, each time when using other types of materials for preparing hydromixtures or changing the route of pipeline transport, it is necessary to carry out tests regarding their rheological properties to determine the hydrotransport parameters and perform laboratory tests regarding the amount of excess water. This will allow their optimal range for effective hydrotransport and to meet the technological requirements to be determined.

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OPTIMIZATION OF THE COMPOSITION OF FLY ASHWATER MIXTURE IN TERMS OF MINIMIZING SEEPAGE WATER AND THE POSSIBILITY OF GRAVITATIONAL HYDROTRANSPORT INTO UNDERGROUND WORKINGS

Abstract

For years, the Polish hard coal mining has been struggling with the problem of fire hazards in areas with coal residue, mainly in goafs. Currently, a common method of limiting this hazard is the fire prevention involving use of fine-grained hydromixtures based on power generation waste, mainly fly ashes. The hydromixture is introduced into the caving zone created by the advancement of exploitation face and its task is to fill in voids, limiting the possibility of access to the mine air oxygen to a minimum. The first part of the article presents theoretical fundamentals of determining the parameters of gravitational hydraulic transport of water and ash hydromixtures used in the mining pipeline systems. Each hydromixture produced based on fine-grained wastes is characterized by specified rheological parameters that have a direct impact on the future flow parameters of a given pipeline system. Additionally, the gravitational character of the hydraulic transport generates certain limitations concerning the so-called correct hydraulic profile of the system in relation to the applied hydromixture characterized by required rheological parameters that should ensure safe flow at a correct efficiency. This paper shows an example of optimisation of the composition of a selected fly ash-water hydromixture in relation to its capacity for hydrotransport in gravity pipeline installations, as well as the amount of excess water that will always drain from the location of feeding the hydromixture to the underground workings.

Keywords: hydrotransport, mining, waste recowery

OPTYMALIZACJA SKŁADU HYDROMIESZANINY POPIOŁOWO-WODNEJ POD KĄTEM MINIMALIZACJI WODY NADMIAROWEJ I MOŻLIWOŚCI HYDROTRANSPORTU GRAWITACYJNEGO DO WYROBISK PODZIEMNYCH

Streszczenie

Polskie górnictwo węgla kamiennego od lat boryka się z problematyką zagrożenia pożarowego powstającego w miejscach pozostawienia resztek węgla głównie w zrobach zawałowych. Obecnie

powszechną metodą ograniczenia tego zagrożenia jest stosowanie profilaktyki pożarowej wykorzy-
stującej hydromieszaniny drobnofrakcyjne wykonane na bazie odpadów energetycznych, głównie
popiołów energetycznych. Hydromieszanina taka wprowadzana jest do przestrzeni zawałowej po-
wstałej za postępem frontu eksploatacyjnego, a jej zadaniem jest wypełnienie wolnych przestrzeni
przy ograniczeniu do minimum możliwości dostępu do tlenu z powietrza kopalnianego. W artykule
w pierwszej części przedstawiono podstawy teoretyczne wyznaczania parametrów grawitacyjnego
hydrotransportu hydromieszanin popiołowo-wodnych stosowanych w kopalnianych instalacjach
rurociągowych. Każda hydromieszanina wykonana na bazie odpadów drobnofrakcyjnych charak-
teryzuje się określonymi parametrami reologicznymi, które mają bezpośredni wpływ na przyszłe
parametry przepływu w danej instalacji rurociągowej. Dodatkowo charakter grawitacyjny hydro-
transportu generuje jego ograniczenia związane z tzw. poprawnym profilem hydraulicznym instalacji
w odniesieniu do zastosowanej hydromieszaniny o wymaganych parametrach reologicznych, które
powinny zapewniać bezpieczeństwo przepływu z odpowiednią wydajnością. W artykule przedsta-
wiono przykład optymalizacji składu wybranej hydromieszaniny popiołowowodnej z punktu widze-
nia możliwości jej hydrotransportu w grawitacyjnych instalacjach rurociągowych, a także ilości wody
nadmiarowej, która zawsze będzie odciekać z miejsca podawania hydromieszaniny do wyrobisk pod-
ziemnych.

S ł o w a   k l u c z o w e : hydrotransport, górnictwo, odzysk odpadów