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Apparatus for fine coal separating water cleaning, and thickening from coal washing waters

Urządzenie do odzysku drobnych cząstek węgla i czystej wody oraz zagęszczania zawiesin odpadów z wód popłóczkowych węgla

Prof. Jozef Szymański, Ph.D., P.Eng.)*

*Prof. Stefan Płaneta, Ph.D., P.Eng.**)*

*Prof. Raymond Sogna Suglo, Ph.D., P.Eng.***)*

Prof. Derek Apel, Ph.D., P.Eng.)*

Abstract: Modern coal preparation plants dispose large quantities of dilute coal tailings what entails socio-economic and environmental problems. By introducing oil and flocculant to these tailings, clean coal and water are recovered, and the amount of solid tailings material to be disposed is reduced. Light oil is used as an agglomeration liquid, and flocculant as a clarification and densification reagent (for rapid settlement). Slurry treated with light oil and flocculant forms three consecutive phases: coal particle micro-agglomerates, clarified water and inorganic material which settles at the bottom. This paper presents a process designed to recover clean coal and washing water by use of oil and flocculant. The results in this work show that up to 60% of the fine coal can be removed from the tailings. This indicates that the proposed method is effective in separating coal from dilute tailings. This process is effectively achieved by simultaneous coal agglomeration, water clarifying, and refuse thickening in one step. In all the experiments conducted, the ash content of coal slimes were drastically reduced which shows the effectiveness of this method.

Treść: W nowoczesnych zakładach przeróbki węgla powstają duże ilości rozcieńczonych drobnych odpadów węgla, które stanowią ekonomiczne i środowiskowe problemy. Wprowadzając olej i flokulanta do zawiesiny w takich odpadach, odzyskuje się czysty węgiel i wodę, przez to ilość materiału do unieszkodliwiania jest zmniejszona. Lekki olej jest stosowany jako płyn do aglomeracji i flokulant jako odczynnik do klarowania oraz zagęszczania nieorganicznego materiału (do szybkiej sedymentacji). W wyniku potraktowania zawiesiny olejem i flokulantem otrzymano trzy kolejne fazy: na górze cząstki węgla „mikro-aglomeraty z olejem", następnie sklarowana woda i oddzielony nieorganiczny materiał na dnie. Na podstawie przeprowadzonych badań laboratoryjnych, przedstawiono koncepcję mającą na celu przemysłowe odzyskanie czystego węgla i wody za pomocą oleju i flokulanta. Wyniki badań zostały przedstawione i omówione, a następnie przedyskutowano i zaproponowano ich zastosowanie na dużą skalę.

*) *University of Alberta, Alberta, Canada, **Laval University, Quebec, Canada, ***Botswana International University of Science and Technology, Gaborone, Botwana

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Słowa kluczowe:
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1. Introduction

Modern coal preparation plants have capacities in excess of 1000 tonnes of coal per hour. A preparation plant with a throughput of 1000 tonnes per hour of raw feed may produce more than 1350 cubic meters per hour of tailings in the form of dilute slurry. Large quantities of water is recycled through a cleaning plant, and the economics dictate that as much of it as possible should be conserved. In addition, depending on the efficiency of the cleaning plant the tailings may contain significant amounts of clean coal, which could possibly be recovered.

The most economical method of recovering clarified water for recirculation is by the use of a clarifier or a thickener. The tailings are treated with a flocculant, which is commonly a high molecular weight polyacrylamide, which causes the fine particles to flocculate into large floes which settle rapidly. This provides a clear supernatant water overflowing the rim of the thickener (or clarifier) for reuse in the plant. The thickened ultra-fine tailings, which can contain appreciable quantities of coal, are difficult and expensive to treat by conventional technology, so they are usually discharged into tailings lagoons. These lagoons not only present environmental problems, but also can represent substantial coal reserves. In many coal preparation plants, the tonnage of discarded coal in the tailings dams exceeds the tonnage of saleable coal. This is because the proportion of fine material below 0.5 mm has increased. This occurs for two reasons. Firstly, modern coal mining techniques have become increasingly mechanized, so preparation plants are producing ever-increasing amounts of fines in waste slurries. Secondly, the quality of mined coal is becoming of poorer and poorer over the years. Poor quality coal usually means that ash and sulphur are very finely disseminated within coal organic matter, and it must be ground to fines to liberate the impurities before upgrading. These fine sizes are not only difficult and costly to clean, but are the, principal cause of problems in tailings disposal.

A variety of complicated circuits are installed at most modern coal preparation plants for the joint purpose of recovering coal fines, and minimizing the sludge disposal problem [1, 2, 3].

This paper is aimed at improving both the existing fine coal cleaning and water clarification systems, making them more cost effective, and at the same time, removing most of the fine coal particles from the processed tailings. It is hoped that the proposed apparatus will reduce operating costs of existing coal preparation plants and lower the capital expenditures for ultra-fine circuits at such plants.

2. Experimental methods and materials

The coal slimes were used to prepare slurries with 4% solids by weight. Most experiments were carried out on the small scale, and the usual mixtures contained 4 grams coal and 96 grams tap water. The slurry was conditioned for 5 minutes. The oil used predominantly in this experiment was paraffin oil (Saybolt Viscosity 125/135 sec), and an anionic flocculant, AnE10, in powder form, was used at a concentration of 200 parts per million. The oil and flocculant were then added in varying amounts and the slurry was conditioned for a further 60 seconds. In some of the experiments, the slurry, oil and flocculant were mixed for longer periods. However, it was found that the floccs were destroyed to points where the flocculant was no longer effective. With the mixing completed, the slurry was poured as quickly as possible into a separating calibrated cylinder for observation. Readings were taken at the 15, 30, 60, 120, 300, 600 and 900 second marks during the observation period. The readings taken were the heights of the bottom reject bed and the floating clean coal layer. After 15 minutes, the floats and rejects were separated into aluminium pans, the clean water in between the floats and rejects was removed with the rejects. The floats were filtered using a Buchner funnel to remove the majority of the oil in the float. This was necessary because it was difficult to remove the oil from the coal by drying it in an oven, and the coal had to be dried in order that accurate ash analysis could be performed. The aluminium pans were put in an oven to dry overnight (over temperature 100 QC). The dried floats and sinks were then broken up (if they had dried into large cake lumps). These samples were pulverized and homogenized thoroughly so that uniform samples were available for the ash analysis. The ash content was determined using a Fisher Coal Analyser set at 750 ^{o}C.

3. Results

Before performing experiments using both oil and flocculant, some tests were done using oil only. This was done to demonstrate that without the flocculant, water clarification is extremely difficult. In most cases, the water did not achieve much clarity until large volumes of oil were employed. In almost all cases, some fine coal particles remained in suspension indicating the need for the presence of flocculant.

Experiment #1

Experiment #1 involved the analysis on coal floatation slimes from Prince mine. The coal slimes were received in dry form, ground to -60 mesh. The feed of the Prince Mine slimes was determined to contain 44.40% ash. The volumes of oil were 15, 20, and 30 mls, and the flocculant volumes were 1, 2 and 3 ml. These volumes were used in several combinations. The results of the ash analysis are summarized in Table 1.

Table 1. Results of experiment #1
Tabela 1. Wyniki eksperymentu #1

Volume of oil ml	Volume of flocculant, ml	Percent ash in float, %	Percent reduction in ash content, %
15	1	24.62	44.55
20	1	17.06	61.58
20	2	25.46	42.66
20	3	19.67	55.70
30	1	19.67	55.70
30	2	23.03	48.13

The results indicate that the ash content was reduced by amounts ranging from 42.66% (with 20 ml of oil and 2 ml of flocculant) to 55.70% (when 20 ml of oil and 1 ml of flocculant

was added). A general trend that appeared was that the more flocculant added, the higher the ash content in the float. This resulted from no selective flocculation.

Experiment # 2

Experiment #2 involved the analysis on coal floatation slimes from Minto coal slimes, New Brunswick. The coal slimes were received in dry form, ground to -100 mesh. The feed had 20.44% ash. It was found that an optimal amount of flocculant to use was 2 ml, so this was held constant while the volume of oil was varied. The results of the experiments are presented in Table 2.

Table 2. Results of experiment #2
Tabela 2. Wyniki eksperymentu #2

Volume of oil ml	Volume of flocculant, ml	Percent ash in float, %	Percent reduction in ash content, %
5	2	11.11	45.65
10	2	12.62	38.26
15	2	9.77	52.20
20	2	6.97	65.90
25	2	9.9	51.57

Here, the results indicate that the reduction in ash content ranged from 38.26% (when 10 ml of oil and 2 ml of flocculant were added) to 65.90% (when 25 ml of oil and 2 ml of flocculant were added). The results tend to suggest that the larger the amount of oil used, the higher the reduction in ash content. However, it appears that the effect of unused amount of oil levels off after 20 ml as shown in Figures 1 and 2.

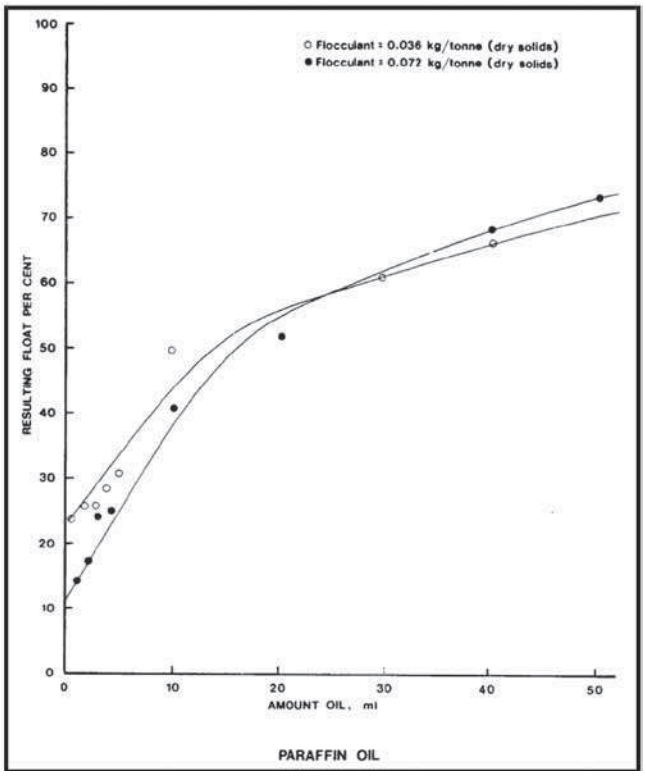

Fig. 1. Effect of the flocculant dosage on the resulting float percent
Rys. 1. Wpływ dozowania flokulanta na procentowy uzysk węgla z odpadów

4. Apparatus

The object of this investigation is to achieve the combination of fine saleable coal recovery, water clarifying, and refuse thickening into one step. This will result in the agglomerated coal fines, solids-free water, and the mineral matters bed [4].

The following is a concept of the apparatus for a practical application of the described process. In this device, the three operations - agglomeration, clarification, and thickening occur simultaneously. This means that the fines in suspension migrate to either the clean coal layer or the sludge bed, leaving in between them water which is substantially solids-free (clarification process).

Figure 3 is a schematic, sectional side view, and plan view of a proposed apparatus for fine coal separating, water clarification, and refuse thickening from coal washing waters. The feed (a suspension of fine coal and other material) is mixed with the flocculant and oil, and enters the tank (18) near the bottom. A very deep feed well (3) introduces material in the form of slurry below the level of the sludge bed where it is deflected horizontally into the sludge bed by means of a baffle plates (9). Light oil, as an agglomeration liquid, and having a specific gravity of less than 1 g/cm^3, is pumped from the drum (14) and first passes through an emulsification stage, a homogenizer (16) and is then injected into the apparatus feed port (3).

The mineral matter suspended in water is treated with flocculant (0.04 kg/ton of dry solids) which passes through an oil homogenizer (16) to a cleaner/clarifier/thickener from a flocculant dosing system comprising of: mixing tanks (10 and 11), a main tank (12), and flocculant dosing pump (13). The fine tailings and water are fed into the cleaner/clarifier/thickener's tank (18) where the solids are classified. The fine coal particles are agglomerated by a bridging liquid (light hydrocarbon oil) in the form of micro-agglomerates. The coal particle agglomerates float off and continuously overflow the periphery of the tank into the launders (5). The hydrophilic gouges incapable of forming agglomerates are flocculated, and rapid settlement takes place. These particles gravitate to the

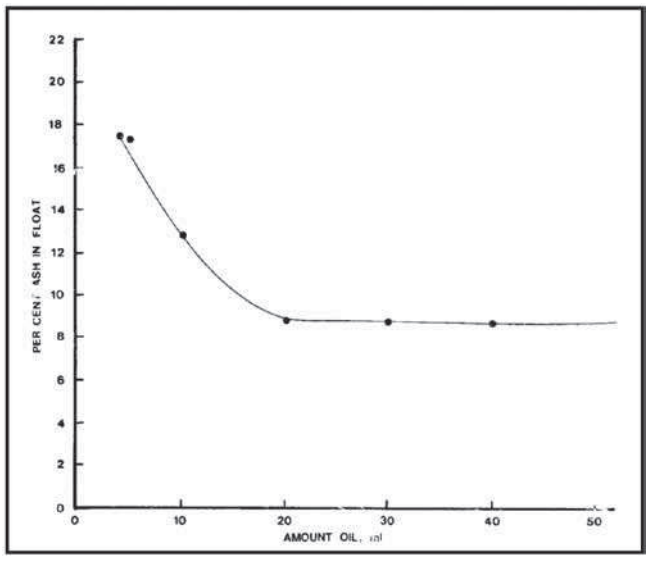

Fig. 2. Effect of the amount of paraffin oil on the ash percent in float
Rys. 2. Wpływ ilości oleju lekkiego (parafinowego) na procentową zawartość popiołu w odzyskanych zaglomerowanych cząstkach węgla

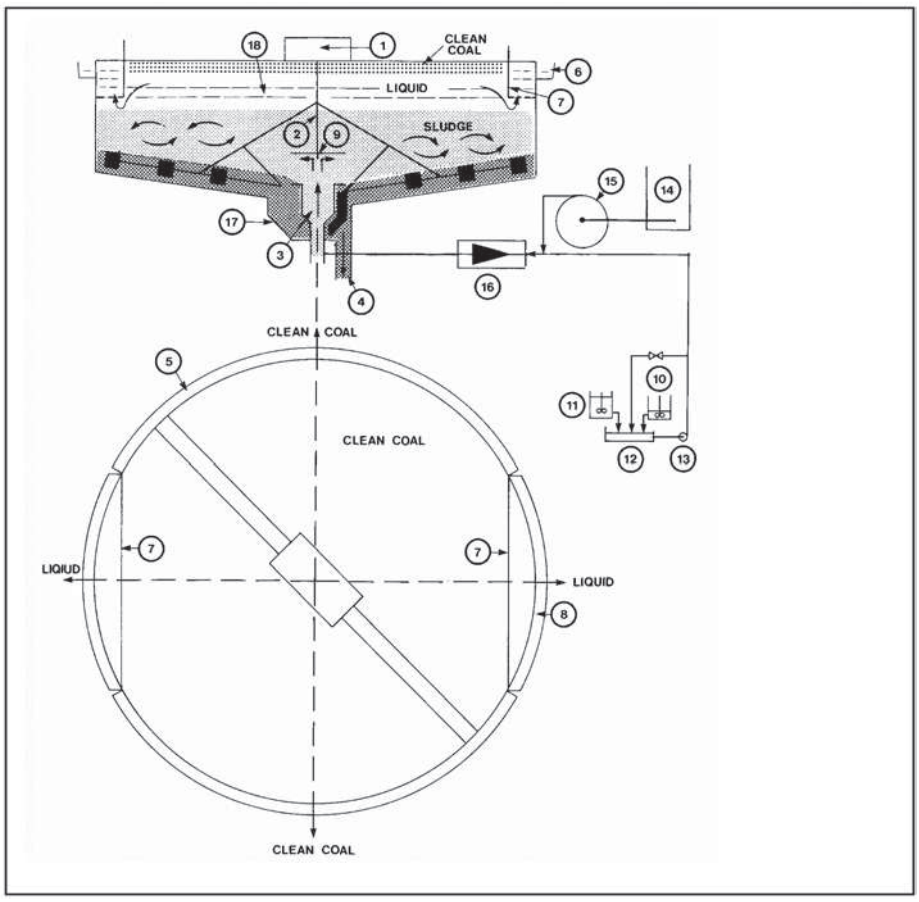

Fig. 3. Concept of apparatus for fine coal recovering, water clarifying and refuse thickening from coal washing waters

Rys. 3. Koncepcja urządzenia do odzysku drobnych cząstek węgla i czystej wody oraz zagęszczania zawiesin odpadów z wód popłóczkowych węgla

bottom of the tank (18), and are raked into the centre where they are removed for dewatering.

A motorized rake (2) with drive unit (1), and incorporating rotating scrapers, sweeps the sediment into the conical section (17) for underflow off-take. The sludge is continuously removed through the conical shaped central outlet (17) in the bottom where it is pumped to the dewatering unit. The clarified water overflows continuously from the tank (18) through the baffle plates (7) (weirs) into launders (6) which surround part of tank's (18) circumference.

5. Conclusions

In conclusion, using light oil as an agglomeration liquid and flocculant as a clarification and densification reagent, clean coal and water are recovered, and the amount of solid tailings material to be disposed in tailings pond is reduced. The results in this work show that up to 60% of fine coal can be removed from the tailings. This indicates that the proposed method is effective in separating coal from dilute tailings. This process is effectively achieved by simultaneous coal agglomeration, water clarifying, and refuse thickening in one step. In recovering the clean coal from the tailings, valuable water is recovered, and problems associated with the tailings lagoon are drastically reduced. In, all the experiments conducted, the ash content of the coal slimes were drastically reduced, which shows the effectiveness of the method.

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