



Comparison of Flotation and Screening as Separation Method in Coal Recovery From Tailings by Agglomeration

Özüm YAŞAR¹⁾, Tuncay USLU¹⁾

¹⁾ Karadeniz Technical University, Mining Engineering Department, Trabzon, Turkey

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Abstract

Dependency of Turkey on foreign energy adversely affects the economy of the country and may cause energy shortage in the near future. As a primary domestic energy source, coal is used for energy production in addition to imported oil and gas. However, significant amount of fine coal is lost together with tailings in coal washeries. Recovering of fine coals from these tailings will make an economic contribution to country. In the present study, fine coals were recovered from tailings of a coal washery in Turkey by using oil agglomeration method. Flotation was used in agglomerate separation stage of oil agglomeration. Results were compared with that of previous study in which agglomerates were recovered by screening. The performance of the process increased sharply when flotation was used instead of screening in agglomerate separation stage. A clean coal with 28% ash was recovered from the washery tailings containing 55% ash by 85% combustible recovery.

Keywords: coal, coal processing oil agglomeration, fine coal tailings, waste vegetable oil

Introduction

Turkey has heavy dependence on foreign countries for energy (Düzgün and Kömürgöz, 2014; Elsland et al., 2014; Öztürk and Yüksel, 2016). Since large natural gas and petroleum reserves will not be discovered in the near future, coal, as only domestic energy source, should be produced and used efficiently without being wasted (Yaşar et al., 2018). Although Turkey has considerable amount of coal reserves, their quality is low (Atılğan and Azapacı, 2017). Low quality coals are cleaned in coal washeries to increase the quality. However, considerable amounts of fine coals are disposed together with the mineral matters. Fine coals reported to tailings mean loss of an economically valuable energy source and potential environmental pollution due to accumulation in tailings areas. 1 million ton/year fine coal is estimated to be lost (Çiçek et al., 2008; Özgen et al., 2011; Özgen and Sezgin, 2011). It was stated that over 6 million tons of tailings were accumulated in Tunçbilek tailings area (Erdem et al., 2010).

Fine coal cleaning is difficult as the small size of the particles limits the efficiency of traditional gravity separation techniques. Although different improvements have been made in gravity concentrators and flotation machines, several problems including handling, transportation and dewatering of fine coal product have not been solved yet. In addition, treatment of high clay-slime coals by using existing technologies is difficult (Netten et al., 2015). The oil agglomeration process is very promising for beneficiation of fine coal (Meshram et al., 2015; Netten et al., 2015; Netten et al., 2016). It is more suitable method for oxidized and high clay-slime coals. Its dewatering stage is low cost (Şahinoğlu and Uslu, 2015). Agglomerate- tailings separation stage is simple (Şahinoğlu and Uslu, 2013). In oil agglomeration method, hydrophobic particles are agglomerated by using a bridging oil, while hydrophilic particles remain in suspension. The clean coal can be separated from the suspension by floating, skimming

and screening (Şahinoğlu and Uslu, 2013; Şahinoğlu and Uslu, 2015).

In the previous study (Yaşar et al., 2018) that is the first to use oil agglomeration method for fine coal recovery from the washeries of Turkey, recovery of approximately 50% of economically valuable clean coal from the tailings of Tunçbilek coal washery was achieved and the further detailed studies were recommended for increasing the performance of the process in term of combustible recovery to make additional improvement in the economy of the process. In the present study, fine coals from the same tailings was tried to be recovered by oil agglomeration in which agglomerates were separated from gangue and slurry by using flotation instead of screening. Because it was seen in the previous study (Yaşar et al., 2018) that small agglomerates whose size was not sufficiently large to retain on separation screen could not be recovered and considerable amount of coal was lost despite their agglomeration activity. No study on comparison of screening and flotation for agglomerate separation in oil agglomeration has been meet before.

Materials and methods

Material

Sample of fine washery tailings was taken from Tunçbilek Coal Washery of G.L.I of TKI before entering thickener for dewatering. Proximate-calorific value analysis, petrographic analysis and particle size analysis of the sample including also ash values are illustrated in Table 1-3, respectively. +0.5 mm fraction and slime fraction (-0.025mm) was not subjected to cleaning process. Tests were undertaken for cleaning the sample of -0.5+0.025mm whose proximate analysis is given in Table 4. As bridging material, filtrated waste sunflower oil was used. Its viscosity and density are 35.81mm²/s and 0.918 g/cm³, respectively.

Tab. 1. Proximate-calorific value analysis of the sample

Tab. 1. Analiza wartości opalowej próbki

Proximate Analysis	Air Dried	Dried
Moisture (%)	4.83	-
Ash (%)	55.60	58.42
Volatile Matter (%)	21.92	23.03
Fixed Carbon (%)	17.65	18.55
Lower Calorific Value (kcal/kg)	2353	2472
Upper Calorific Value (kcal/kg)	2501	2628

Tab. 2. Petrographic analysis of the sample

Tab. 2. Analiza petrograficzna próbki

Macerals (% Volume)			Minerals (% Volume)	
Huminite	Liptinite	Inertite	Pyrite	Other Minerals
50	5	3	2	40

Tab. 3. Particle size analysis of the sample

Tab. 3. Analiza składu ziarnowego próbki

Particle size (mm)	Amount (%)	Ash (%)
+0.5	37.14	33.45
-0.5+0.25	12.07	53.49
-0.25+0.125	5.62	51.72
-0.125+0.075	2.55	43.51
-0.075+0.038	3.98	52.76
-0.038+ 0.025	2.31	60.95
-0.025	36.33	80.35

Tab. 4. Proximate analysis of the sample (-0,5+0,025 mm)

Tab. 4. Analiza próbki (-0,5+0,025 mm)

Proximate Analysis	Air Dried	Dried
Moisture	3.62	-
Ash	52.6	54.58
Volatile Matter	25.13	26.07
Fixed Carbon	18.65	19.35

Methods

Agglomeration experiments were undertaken in cylindrical glass vessel whose diameter was 11.7 cm. Four portable baffles were inserted to vessel. The stirring process was achieved by means of RZR 2021 type overhead stirrer. Water was distilled before the experiments. Coal samples were mixed with water (solid ratio: 10%). Coal-water mixtures were stirred at 1000 rpm for 5 min. to provide perfect wetting of coal grains. The oil (15wt. % of coal) was then put as agglomerant and mixture of coal-oil-water was stirred at 1400 rpm for 10 min. The experiments were performed at ambient pH of the mixture. After agglomeration, the suspension was transferred to a flotation cell. The suspension was conditioned at 1000 rpm for 3 min. After air addition into system, suspension was agitated at the same rate for different flotation times (0.5–2 min.) In addition, tests were undertaken for determining the effect of agitation rates (800–1400 rpm) at optimum flotation time (1min). Clean coal (float product) was skimmed from the cell.

Then, vacuum filtering and acetone washing for de-oiling were applied for agglomerates. After drying of oil-free agglomerates at 105 ± 5 °C, weighing was carried out and cleaned coal products were stored for analyses. Finally, ash analyses were undertaken. The yield, combustible recovery (CR), ash reduction (AR) and ash separation efficiency (ASE) were calculated by means of following equations:

$$CR (\%) = [(MP / MF) \times ((100 - AP) / (100 - AF))] \times 100 \quad (\text{Eq.1})$$

$$AR (\%) = [1 - ((MP) \times (AP) / (MF) \times (AF))] \times 100 \quad (\text{Eq.2})$$

$$ASE (\%) = CR + AR - 100 \quad (\text{Eq.3})$$

where, MF: Mass of dry feed (g), MP: Mass of dry and oil-free product (g), AF: Ash in dry feed (wt.%), AP: Ash in dry and oil-free product (wt.%).

Results and discussion

As seen from Figure 1, increasing flotation time from 0.5 min to 1 min improved the combustible recovery from 67.8% to 85.2%. Further increase in time had no considerable effect on amount of recovered combustible coal matter that became 86.3% at flotation time of 2 min. Increasing flotation time affected the ash contents of produced clean coals adversely. Ash rejection reduced from 78.6% to 63.2% as a result of increasing time from 0.5 min to 2 min. Clean coal with minimum ash percent was achieved to be 27.5% at 0.5 min. Increasing time reduced the selectivity of the process and led entrainments of mineral matter into voids of agglomerates. Maximum ash separation efficiency that is the indicator of optimum performance was calculated as 57.5% at 1 min flotation time at which a clean coal with 28.1% ash was produced by combustible recovery of 85.2%.

As seen from Figure 2, combustible recovery and ash separation efficiency reduced after 1000 rpm agitation rate. Further increase of rate to 1400 rpm reduced the combustible recovery from 85.2% to 82.1%. Ash separation efficiency

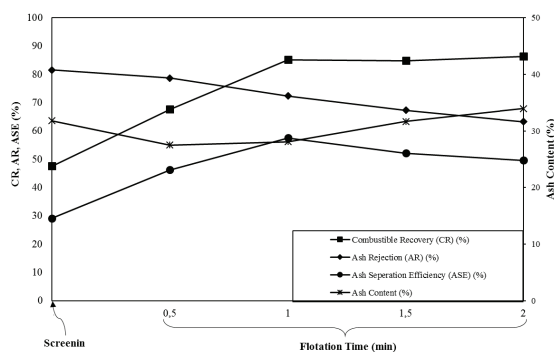


Fig. 1. Effect of flotation time on the performance of the process
Rys. 1. Wpływ czasu flotacji na przebieg procesu

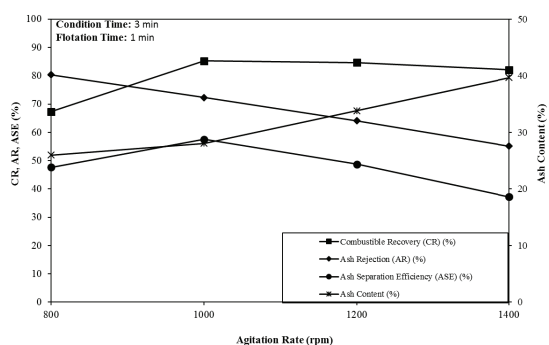


Fig. 2. Effect of the agitation rate on the performance of the process
Rys. 2. Wpływ stopnia agitacji na przebieg procesu

reduced from 57.5% to 37.2%. It can be attributed to destroying of some agglomerates due to increasing turbulence and change of medium from mild to severe resulted from excess agitation rates. High ash coal products and lower ash rejection ratios at higher agitation rates are results of moving of fine clay particles and other mineral matters to the surfaces and voids of agglomerates.

Ash content of coal product obtained as 26.0% at 800 rpm increased sharply to 39.7% at 1400 rpm.

When the performance of the screening applied in previous study and that of flotation used in the present study as agglomerate separation methods was compared (Figure 1), it was seen that flotation caused recovery of cleaner and higher amount coal from washery tailings. Although screening produced a clean coal with 31.8% ash by combustible recovery of 47.6%, flotation ensured the production of clean coal with 28.1% ash by recovering the 85.2% of combustible matter. It was concluded that small agglomerates lost as undersize of -0.5mm separation screen could be recovered by flotation. In

addition, difficulty in removing some of mineral matter from screen during water washing was eliminated by using flotation instead of screening. Therefore, cleaner coal product was produced.

Conclusion

By using oil agglomeration method in which flotation is applied for agglomerate separation, a clean coal with 28.1% ash was recovered from the washery tailings with 54.6% ash by combustible recovery of 85.2%. Optimum combination of flotation time-agitation rate giving the maximum ash separation efficiency was found to be 1min-1000 rpm. Performance of the flotation in agglomerate separation was proved to be greater than that of screening. It was seen that small sized agglomerates lost during screening was reported to clean coal product in case of usage of flotation instead of screening. By using flotation, combustible recovery and ash separation efficiency was improved sharply.

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Porównanie flotacji i przesiewania jako metod separacji w odzysku węgla z odpadów w procesie aglomeracji

Zależność Turcji od energii z zagranicy wpływa negatywnie na gospodarkę państwa i może powodować niedostatek ilości energii w niedalekiej przyszłości. Jako główne rodzime źródło energii traktowany jest węgiel, który stosowany jest do produkcji energii jako dodatek do importowanych ropy naftowej i gazu. Jednakże, znacząca ilość drobnego węgla jest tracona wraz z odpadami w płuczkach węgla. Odzysk drobnego węgla z tych odpadów spowoduje poprawę sytuacji ekonomicznej kraju. W prezentowanym badaniu, drobny węgiel został odzyskany z odpadów z płuczki węglowej w Turcji za pomocą metody aglomeracji olejowej. Flotacja została zastosowana na etapie rozdziału podczas tego procesu. Wyniki zostały porównane z tymi z poprzednich badań, gdzie aglomeraty były odzyskiwane poprzez przesiewanie. Wydajność procesu wzrosła znacząco kiedy zastosowano flotację w miejsce przesiewania na etapie rozdziału aglomeratów. Czysty węgiel o zawartości popiołu 28% został odzyskany z odpadów płuczki, zawierających 55% popiołu przy odzysku 85% części palnych.

Słowa kluczowe: węgiel, przeróbka węgla, aglomeracja olejowa, odpady drobnego węgla, odpadowy olej roślinny