Effect of Particle Size in Recovering of Coal Fines from Washery Tailings by Oil Agglomeration

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Abstract

Large amounts of fine coals are produced in the word due to increased mechanization in coal mining and performance inability of processing of coals. In coal cleaning plants, these coal fines are reported to tailings causing an environmental pollution and loss of valuable energy source. Therefore, recovery of fine coals from the tailings has significant importance for human health and saving of energy sources. Gravity techniques cannot be applied for cleaning and recovery of coal fines. Although flotation is considered to treat fine coals, satisfied quality of coal cannot be obtained. Oil agglomeration is a promising a candidate for deashing and desulphurization of fine coal and recovery of fine coal from the tailings. In this study, fine coal recovery from the tailings of a Turkish coal washery by oil agglomeration method was investigated. Effect of the particle size on the performance of the process was investigated.

Keywords: fine coal, coal washery tailings, oil agglomeration

Introduction

Coarse particles, >200 μm, can be processed using water-based gravity separation techniques which rely on the large density disparity of the materials to be separated. Fine particles, on the other hand, cannot be effectively processed using these techniques. That is, a separation cannot be achieved on a reasonable time scale due to the small size of the particles and the resulting limited effect of gravity. Therefore, other techniques which discriminate between the different particle types based on their surface chemistry are employed. Although flotation has been applied with great success, difficulties can be countered when the coal to be processed contains a large amount of ultra-fine material or there is a substantial level of clays Selective agglomeration is a technique which has received considerable attention in the past as having the potential to solve the before mentioned problems in fine coal processing (Netten et al., 2016). Oil agglomeration has important benefits, such as, quality of product in terms of pyrite, easy handling and transportation of the product, high recovery, suitability to oxidized coals and coals with clay slimes, simplicity and cheapness of dewatering stage (Şahinoğlu and Uslu, 2013; Şahinoğlu and Uslu, 2015). In the oil agglomeration process, the immiscible bridging liquid such as oil is added to an aqueous suspension. The suspension is agitated to contact the oil droplets and particles. The oil wets hydrophobic particles and brings them together to form agglomerates. The agglomerates are separated from the other particles by screening (Duzyol, 2015).

Excessive usage of coal in industry results in momentous generation of coal waste which is seen as fly ash or coal-water slurry. These coal wastes create environmental pollution. Thus, the reduction in generation of coal waste is essential which can be achieved by reducing the coal-water slurries through extraction of coal fines (Garg et al., 2017) Fine coals disposed to environment should be beneficiated in terms of both prevention of environmental pollution and loss of energy sources (Şahinoğlu and Uslu, 2015). From this perspective, coal-oil agglomeration as an increasingly popular phenomenon is used for recovery of coal fines (Garg et al., 2017.)

In Turkey, fine tailings of these washeries are sent to tailing ponds leading to significant economic loss due to coal-rich character of tailings. These tailings also cause environmental problems (Çicek et al., 2008; Özgen et al., 2011; Özgen and Sezgin, 2014). Total loss of recoverable amount of fine coal is estimated to be over 1 million tons/year (Çicek et al., 2008; Özgen and Sezgin, 2014). Tailings area of GLI (West Lignite Enterprises) after several years contains over 6 million tons of tailings (Erdem et al., 2010).

In the present study, fine coal tailings of Tunçbilek Coal Washery of GLI (InTurkey) was recovered by oil agglomeration. Effect of coal particle size on the performance of oil agglomeration process was investigated.

Material and Methods

Sample of fine washery tailings was taken from Tunçbilek Coal Washery of G.L.I before entering thickener for dewatering. Proximate-calorific value 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

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

Tab. 1. Analiza techniczna węgla

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
LowerCalorific Value(kcal/kg)	2353	2472
UpperCalorific Value(kcal/kg)	2501	2628

Tab. 2. Particle size analysis of the sample

Tab. 2. Analiza składu ziarnowego węgla

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. 3. Proximate analysis of the sample (-0.5+0.025mm)

Tab. 3. Analiza techniczna próbki (-0.5+0.025mm)

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

not subjected to cleaning process. At first, tests were undertaken for cleaning the sample of -0.5+0.025mm whose proximate analysis is given in Table 4. Then, coal sample of -0.5+0.025mm was dry ground to size fractions of -0.3 mm and -0.125 mm and agglomeration test were repeated to determine the effect of particle size. As bridging material, filtrated waste sunflower oil was used. Its viscosity and density are 35.81mm²/s and 0.918 g/cm³, respectively.

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 (15 wt. % 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 sieve with aperture of 0.5 mm to separate the agglomerates from water and tailings. Agglomeration tests using the recovery sieve of 0.3 mm and 0.125 mm were also undertaken for coal particle size of -0.3 mm and -0.125 mm, respectively. Agglomerates were washed with 1.5 L water to remove the entrained mineral matter. 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 rejection (AR) and ash separation efficiency (ASE) were calculated by means of following equations:

$$\text{Yield (\%)} = (M_P/M_F) \times 100 \qquad \text{(Eq.1)}$$

$$\text{CR (\%)} = [(M_P/M_F) \times ((100–A_P)/(100–A_F))] \times 100 \qquad \text{(Eq.2)}$$

$$\text{AR (\%)} = [1– ((M_P)\times(A_P)/(M_F)\times(A_F))] \times 100 \qquad \text{(Eq.3)}$$

$$\text{ASE (\%)} = \text{CR}+\text{AR}–100 \qquad \text{(Eq.4)}$$

where, M_P: Mass of dry and oil-free product(g) M_F: Mass of dry feed (g), A_F: Ash in dry feed (wt.%), A_P: Ash in dry and oil-free product (wt.%).

Results and Discussion

When the 0.5 mm recovery sieve was used, combustible recovery decreased with decreasing coal particle size (Figure 1). This can be attributed to the formation of larger agglomerates with increasing size of coal. Maximum combustible recovery was obtained to be 47.6% for the coal feed size of -0.5 mm. It seems

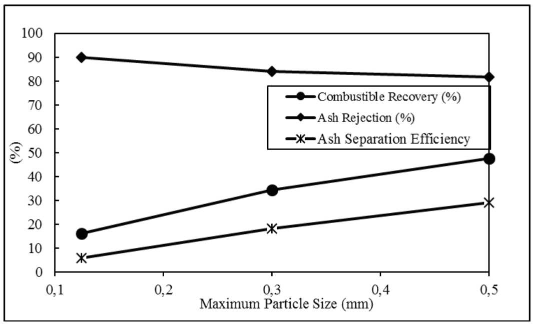

Fig. 1. Effect of particle size on the performance of the process (Recovery sieve size:0.5mm)

Rys. 1. Wpływ wielkości ziaren na efektywność procesu (uziarninie poniżej 0,5 mm)

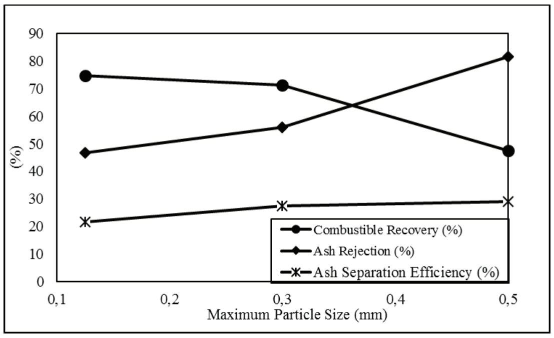

Fig. 2. Effect of particle size on the performance of the process (Recovery sieve size equals to maximum particle size)

Rys. 2. Wpływ wielkości ziaren na efektywność procesu (próbka bez odsiewania)

that fine size coal particles could not produce a high amount of agglomerates whose size is sufficiently large to retain on separation sieve with an aperture size of 0.5 mm. Another reason of reduction in combustible recovery in response to reduction in particle size may be liberation of mineral matter. Because, liberated mineral matters prevent hydrophobic coal particles from getting agglomerated. Contrary to combustible recovery, reduction of particle size enhanced ash rejections. Maximum ash rejection was obtained to be 90% for the coal feed size of -0.125 mm. Increase in ash rejections due to reduction in coal particle size was consistent with the expected improvement in the liberation of mineral matter. Locked mineral matter liberated from the coal structure by size reduction could not be agglomerated by oil due to their hydrophilic structures. Ash separation efficiencies of 29.1%, 18.4% and 5.9% were calculated for the coal feed size of -0.5mm, -0.3m and -0.125 mm respectively.

When the agglomerate recover sieve size that is equal to maximum size of feed coal (sieve size of 0.5mm, 0.3mm and 0.125 mm for the coal particle size of -0.5mm, -0.3mm and -0.125 mm, respectively) combustible recovery increased with decreasing coal particle size (Figure 2). Because, increased liberation enhanced and increased oil-coal contact due to increasing number of free coal particles Maximum combustible recovery became 74.8% at coal particle size of 0.125 mm. Rise in total surface area of coal particles caused easy and stable adherence of oil on the coal surface. However, reduction in particle size had adverse effect on ash reductions. Ash rejection was achieved as 81.51% maximally at coal particle size of 0.5 mm. Despite increased combustible recovery, amount of mineral matter reporting to agglomerates also increased. Liberation reduced the particle size of mineral matter. Entrainment of fine size gangues into space between agglomerates and on the surface of the agglomerates occurred. Another reason is that reducing size of sieve aperture from 0.5 mm to 0.125 mm affected the screening performance adversely. Agglomerate cleaning by water on the surface of the sieve failed to satisfy the removal of remaining gangues from the surface due to small apertures. Ash separation efficiency decreased with reduction in particle size and became 29.14%, 27.35% and 21.58% for the coal feed size of -0.5mm, -0.3m and -0.125 mm, respectively.

Conclusion

Fine coal tailings from Tunçbilek Coal Washery of GLI (InTurkey) was subjected to oil agglomeration process for recovering fine coal from the tailings. Effect of particle size on the performance of the process was investigated. Reduction of feed particle size has adverse effect on combustible recovery due to insufficient agglomerate growth to retain on the sieve size of 0.5 mm.

Use of recovery sieve aperture having the same size with maximum feed coal size provided increased combustible recovery at finer particle sizes. In contrary to expectations, ash rejections decreased with decreased particle size due to poor performance of agglomerate washing on the sieves with small apertures.

Maximum combustible recovery was obtained as 74.81% at particle size of -0.125 mm and recovery sieve size of 0.125 mm. Maximum ash rejection was achieved to be 89.87% at particle size of -0.125 mm and recovery sieve size of 0.5 mm. Maximum ash separation efficiency occurred as 29.14% at particle size of -0.5 mm and recovery sieve size of 0.5 mm. At maximum separation efficiency, a clean coal with 31.8% ash was recovered from the tailings with 54.58% ash.

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Wpływ wielkości ziaren na odzyskiwanie drobnego węgla z odpadów w procesie aglomeracji olejowej

Na świecie powstają duże ilości drobnych węgli głównie z powodu rosnącej mechanizacji wydobycia węgla. W zakładach wzbogacania węgla drobne ziarna są kieowane do odpadów co powoduje starty węgla oraz zanieczyszczenie środowiska. Dlatego też odzyskiwanie drobnych ziaren węgla z odpadów ma istotne znaczenie z uwagi na ochronę środowiska jak również oszczędzania źródeł energii. Wzboga-cania grawitacyjnego nie można stosować do odzyskiwania bardzo drobnych frakcji węgla. Również w procesie flotacji nie uzyskuje się zadawalających wyników. Obiecujące wyniki uzyskano przez zastoso-wanie do wzbogacania bardzo drobnych klas ziarnowych węgla aglomeracjii olejowej.

Aglomeracja aolejowa znajduje również zastosowanie do odsiarczania węgla. W artykule przedstawio-no wyniki wzbogacania tureckiego węgla metodą aglomeracji olejowej oraz wpływ uziarninia nadawy na efekt wzbogacania.

Słowa kluczowe: miał węglowy, odpady z wzbogacania węgla kamiennego, aglomeracja olejowa