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EVALUATION OF ÇORUM ALPAGUT WASTE LIGNITE FINES

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The fine fraction having 71.2 % -0.1mm particles in the Çorum Alpagut Lignite Mine of Turkish Coal Enterprises not only causes economical losses, but also is an important environmental hazard source since this fraction is pumped and accumulated in the slime ponds around the region. The amount collected in those ponds can be neither marketed nor removed away. Consequently, the fine fraction problem in Çorum Alpagut Dodurga Lignite Mine appears to be the most important disadvantage for the plant. To overcome this problem, this fine fraction coal which comprises of approximately 20 % of the total washed coal, should be concentrated to obtain a marketable product with acceptable calorific and ash values. For this purpose concentration experiments including Humphrey Spiral and Shaking Table have been carried out with these fine fractions taken from the cyclones and thickener that are currently in operation in the coal washery of the plant. As a result of those studies, all the concentration methods have proved to be effective, producing a concentrate with a considerable calorific value increase and an acceptable ash percentage. The combustion kinetics and properties of those fractions have also been determined by thermogravimetric methods and the results of the concentration studies have been supported with the combustion kinetic values of fractions and their products.

INTRODUCTION

The tailing ponds of coal washeries is one of the major sources of environmental pollution for the surroundings. In addition to this, large areas that can be utilized for agricultural or similar activities, become useless. All these facts make those ponds one of the most critical problems for the coal washing industry all around the world (Kirnarsky et al. 1998).

One of the plants which faces such a problem is TKİ Alpagut-Dodurga Coal Washery located in Dodurga-Çorum which meets the industrial and domestic demands of the region. This plant is run by Park Company and works on the basis of Drewboy Bath and Heavy Medium Cyclones cleaning with a capacity of 100 tons/hour (Figure 1). The plant produces four different products with sizes of 50-150mm, 18-50mm, 10-

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18 mm and 0-10mm. In addition to the Heavy Medium Cyclone, two more cyclones, namely Coarse and Fine Circuit Cyclones are also in operation in the flowsheet. These cyclones are not used for cleaning but to assist the dewatering operation by decreasing the amounts that will go to the thickener.

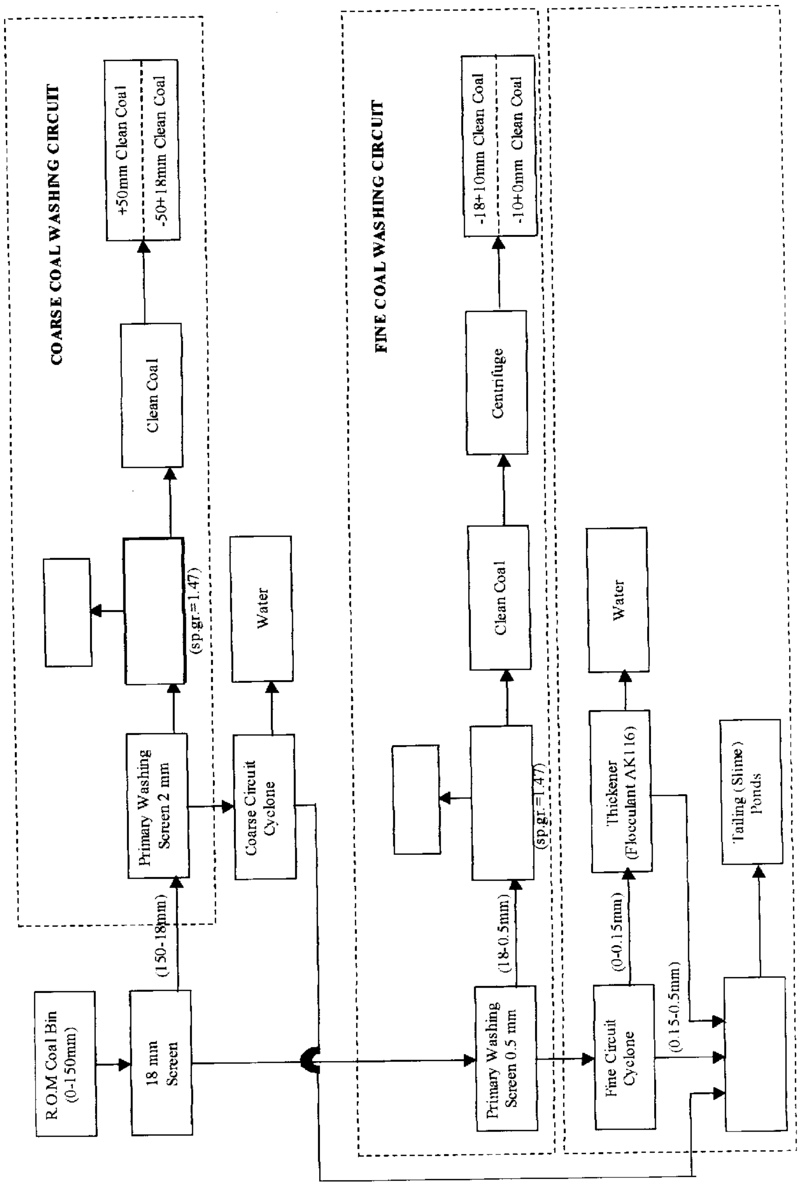

Fig. 1. Simplified flowsheet of TKI Alpagut Dodurga Lignites Coal Washery

The underflows of those cyclones are separated as the tailing fraction and pumped to the tailing ponds around the region. The amount lost as tailing fraction is dramatically high and reaches about 20 % of the total production. The existing ponds will be full and out of use soon due to this great amount removed, so new available areas are required immediately. Also the amount of 20% is an important amount that accounts as a defficiency for the plant. Consequently, the fine fraction of TKİ Alpagut-Dodurga Lignites is not only an environmental hazard source, but also an economically lost potential.

Decreasing the amount of tailings will solve both the tailing pond and economic problems. Therefore, in this study the possibility of obtaining a concentrate from the tailings fraction of the Alpagut Washery by gravitational concentration methods and the characteristics and kinetics of the products are searched.

MATERIAL AND METHODS

For the concentration applications, the fine fraction having 71.2 % -0.1mm slime, separately taken from the fine circuit cyclone, coarse circuit cyclone and thickener of TKİ Alpagut-Dodurga Lignites coal washery, have been used.

These separately taken fractions were first dewatared and dried completely both to take samples for thermogravimetric analysis and calorimetry measurements and to obtain uniform amounts for each experiment. The concentration experiments were carried out using a laboratory Wilfley type shaking table with dimensions of 123-64cm and 5 turn Humphrey Spiral 24 AM CC with feeds whose pulp densities were about 30 %. For the combustion characteristics and kinetics of the samples, the thermogravimetric analysis were performed by placing approximately 26 mg samples in a Polymer Laboratories 1500 PL/TG analyser. During the thermogravimetric analysis, the samples were combusted at a range of 20-900^{O}C at a heating rate of 10^{O}C/min by supplying a constant airflow of 15ml/min. The calorific values of each sample and the products were determined by using a Parr Oxygen Bomb Calorimeter. Prior to the experiments, the TG analyser was calibrated for the qualitative estimation of the weight changes during combustions.

RESULTS AND DISCUSSION

HUMPHREYS SPIRAL EXPERIMENTS

Humphreys Spiral experiments have been carried out individually by using feeds taken from the underflows of fine circuit and coarse circuit cyclones and thickener. Since the pulp density of about 30 % has proved to be effective for coal washing operations with Humphreys Spiral, this value is preserved for all feeds. The ash percentages and calorific values of the feeds before the concentration are given in Table 1.

Table 1. The Ash and Calorific Values of Feeds

Feed Source	Ash (%)	Calorific Value (kcal/kg)
Fine Circuit Cyclone	36.36	3358
Coarse Circuit Cyclone	32.62	3932
Thickener	53.77	2209

After the experiments, two products namely, concentrate and tailing have been obtained for the thermogravimetric analysis and calorific value determination. It has been observed that the ash percentage of the concentrates obtained from the underflow of fine and coarse circuit have decreased from 36.36 % to 28.26 % and 32.62 % to 25.14 % respectively (Table 1&2, Figure 2&3). Furthermore, the calorific values of those feeds have also increased. On the other hand, the ash percentage of the concentrate of the thickener feed decreased slightly (Table 1&2, Figure 4). In addition to this, the changes in the calorific value of the thickener feed was not as great as the differences obtained in the underflows of the cyclones neither (Table 1&2).

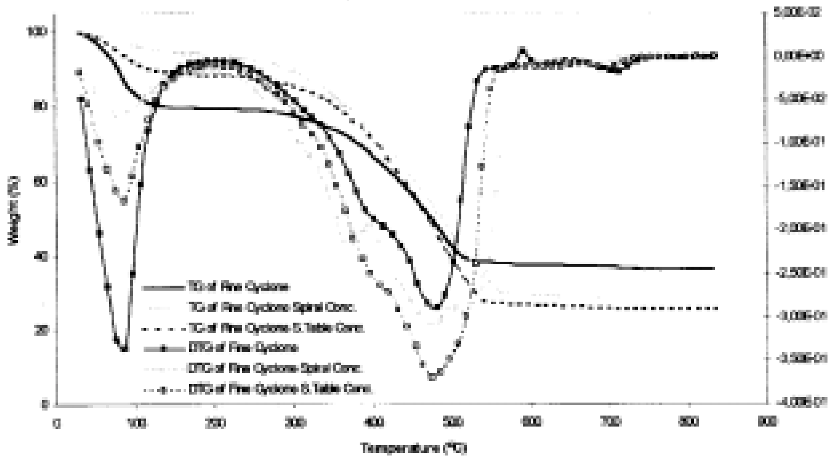

Fig. 2. TG and DTG curves of fine cyclone circuit underflow and fine cyclone circuit underflow concentrate by humphreys spiral and shaking table

Table 2. The Ash and Calorific Values of the Concentrates of Humphreys Spiral

Concentrate Type	Ash (%)	Calorific Value (kcal/kg)
Fine Circuit Cyclone Conc.	28.26	4081
Coarse Circuit Cyclone Conc.	25.14	4137
Thickener Conc.	49.12	2301

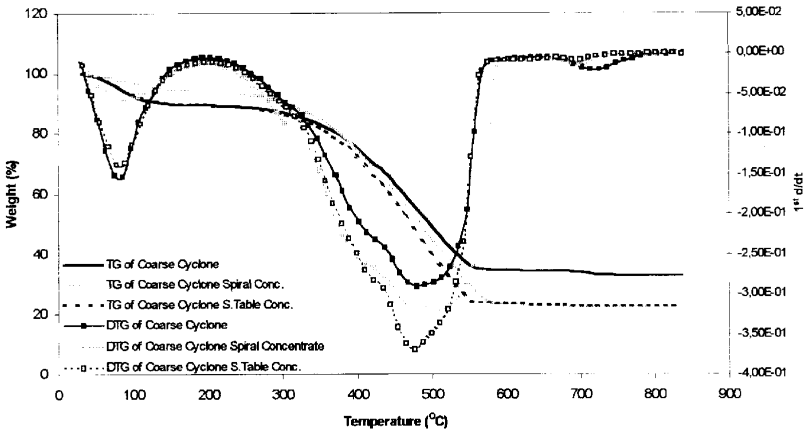

Fig. 3. TG and DTG curves of coarse cyclone circuit underflow and coarse cyclone circuit underflow concentrate by humphreys spiral and shaking table

Similar to the concentrate, in the tailings portion there has been not only an important increase in the ash values of the fine and coarse circuit cyclones, but also a noticable decrease in their calorific values (Table 1&3). However, the ash percentage of the tailing of the thickener feed has slightly increased. Also important decreases in the calorific values was not achieved in the thickener tailing (Table 1&3).

Table 3. The Ash and Calorific Values of the Tailings of Humphreys Spiral

Tailing Type	Ash (%)	Calorific Value (kcal/kg)
Fine Circuit Cyclone Tailing	53.18	1929
Coarse Circuit Cyclone Tailing	43.03	3002
Thickener Tailing	56.11	1822

It can be concluded that Humphreys Spiral proved to be effective and efficient for the concentration of the fine and coarse cyclone circuit underflows, whereas the same success could not be obtained for the thickener feed. The reason for those two different concentration results is the occurrence of AK116 flocculant in the thickener, which is used in great amounts to increase the settling rate of coal particles before pumping to the ponds. Under the effect of AK116, the coal particles in the thickener feed are tightly agglomerated and this is the major reason of the unsuccessful results obtained.

SHAKING TABLE EXPERIMENTS

Shaking Table experiments have also been carried out by the same principle; individually by using feeds taken from the underflows of fine and coarse circuit cyclones and thickener with approximately the same pulp density of 30 %. Like the Humphreys Spiral experiments, high decreases in the ash values of concentrates of the underflows of the fine and coarse circuit cyclones occurred. The ash percentage of the concentrates obtained from the feeds of fine and coarse circuit tailings have decreased from 36.36 % to 25.41 % and 32.62 % to 22.44 % respectively (Table 1&4, Figure 2&3). Furthermore, the calorific values of those feeds have also increased parallel to the decreases in the ash percentages (Table 1&4). On the other hand, the ash percentage of the feed of the thickener decreased slightly (Table 1&4, Figure 4) and the increase in the calorific value was not so high either.

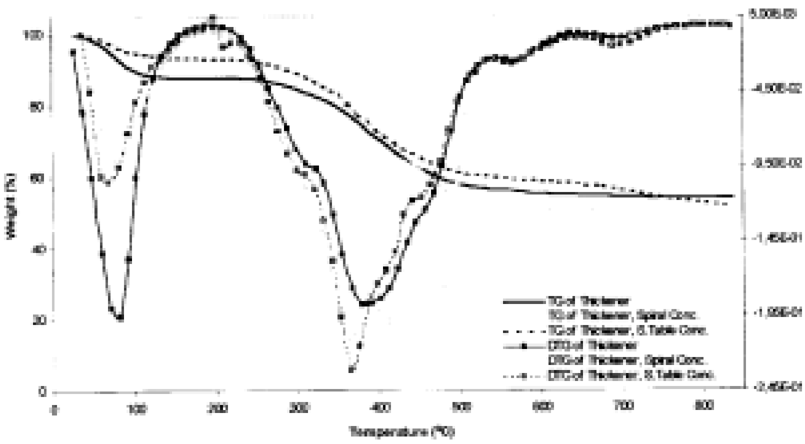

Fig. 4. TG and DTG curves of thickener feed and thickener concentrate by humphreys spiral and shaking table

Table 4. The Ash and Calorific Values of the Concentrates of Shaking Table

Concentrate Type	Ash (%)	Calorific Value (kcal/kg)
Fine Circuit Cyclone Conc.	25.41	4364
Coarse Circuit Cyclone Conc.	22.44	4480
Thickener Conc.	51.22	2242

The trend was similar for the ash percentages and the calorific values of the tailing portions of the fine and coarse circuit cyclones feeds. The ash values increased from 36.36 % to 68.32 % and 32.62 % to 64.59 %, respectively and important decreases occurred in the calorific values (Table1&5). However, the ash percentage of the tailing of the thickener feed has increased slightly again (Table 1&5).

Table 5. The Ash and Calorific Values of the Tailings of Shaking table

Concentrate Type	Ash (%)	Calorific Value (kcal/kg)
Fine Circuit Cyclone Tailing	68.32	1504
Coarse Circuit Cyclone Tailing	64.59	2059
Thickener Tailing	54.18	1907

As well as Humphreys Spiral concentration, experiments with Shaking Table showed that the concentration of the fine and coarse cyclone circuit underflows is possible whereas the flocculant effect in the thickener is the major obstacle against the concentration process due to the particle agglomeration.

KINETIC ANALYSIS

Not only the combustion process of a lignite but also its modelling is extremely complicated since several components are simultaneously oxidized during the reaction (Hiçyılmaz et al. 2000). For the kinetic modelling of the combustion of TKİ Alpagut Dodurga Lignite slime fraction samples, Arrhenius Type kinetic model is utilized for analyzing the thermogravimetric data obtained at the end of TG experiments. According to this model:

$$\frac{dw}{dt} = Ar \exp\left(\frac{-E}{RT}\right) w^n \tag{1}$$

where $\frac{\mathrm{dw}}{\mathrm{dt}}$ is the rate of weight change of the reacting material, Ar is the Arrhenius Constant, E is the activation energy, T is the temperature, R is the gas constant, and n is the reaction order.

For analysing the TG/DTG data, the model assumes that the rate of weight loss of the total sample is dependent only on the rate constant, the weight of the sample remaining and the temperature with assumed unity reaction order. So, the equation takes the following form;

$$\frac{1}{w}\left(\frac{dw}{dt}\right) = Ar \exp\left(\frac{-E}{RT}\right) \tag{2}$$

and when the logarithm of both sides is taken, the equation becomes;

$$\log\left[\frac{1}{w}\left(\frac{dw}{dt}\right)\right] = \log Ar - \frac{E}{2.303\, RT} \tag{3}$$

When $\log\left[\frac{1}{w}\left(\frac{dw}{dt}\right)\right]$ is plotted against $\frac{1}{T}$, the straight line will be obtained having a slope of $\frac{-E}{2.303\,R}$ and an intercept of Arrhenius Constant (Kök et al. 1997).

The individual activation energies for each reaction region can be notionally attributed to different reaction mechanisms, but they do not give any indication of the contribution of each region to the overall reactivity of the coal. Therefore, the concept of weighted mean activation energy, E_{wm}, was applied to determine the overall reactivity of coal (Cumming 1984);

$$E_{wm} = F_1E_1 + F_2E_2 + F_3E_3 + \ldots\ldots + F_nE_n \tag{4}$$

where F_1, F_2, …….,F_n are the mass fractions of the combustible content of the sample burned during each region of Arrhenius linearity, and E_1, E_2,……E_n are the individual apparent activation energies obtained over each region of Arrhenius linearity. Figure 5 shows the log (1/w)(dw/dt) vs 1000(1/T) curve for the fine circuit cyclone underflow and the application of weighted mean activation energy concept with respect to the reaction regions.

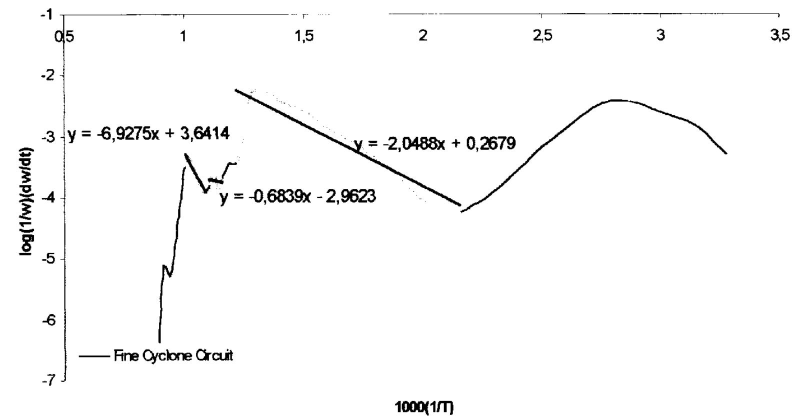

Fig. 5. log(1/w)(dw/dt) vs 1000(1/T) curve of fine circuit cyclone undreflow and the combustion regions

The Activation Energy concept is a measure of the degree of easiness of a coal to begin the reaction and combust completely. In Table 7, the activation energies of the feeds and concentrates and therefore the effect of concentration processes on the activation energies of the samples are seen.

The declines in the activation energies of the concentrates of fine and coarse circuit feeds show that, the concentration processes carried out with those samples are effective due to the removal of the mineral constiuents and the results obtained in the kinetic analysis is parallel to those of thermogravimetric analysis. However the decrease in the activation energy of the concentrate of thickener feed is not so high. This is again due to the defficiency of the concentration processes which is caused by the existence of high amounts of AK116 flocculant. The results of the thermogravimetric and kinetic analysis have the same trend, in other words, the activation energies obtained support the success of the concentration processes with the fine and coarse cyclone circuit feeds whereas, the negative effect of flocculant on the concentration of the thickener sample is again seen.

Table 7. Activation energies of the samples

Type of Sample	Concentration Method	Act.Energy (kj/mol)
Fine Cyclone Circuit	-	17.4
Fine Cyclone Circuit Concentrate	Humphreys Spiral	15.2
Fine Cyclone Circuit Concentrate	Shaking Table	14.9
Coarse Cyclone Circuit	-	17.0
Coarse Cyclone Circuit Concentrate	Humphreys Spiral	14.8
Coarse Cyclone Circuit Concentrate	Shaking Table	14.6
Thickener	-	21.9
Thickener Concentrate	Humphreys Spiral	20.8
Thickener Concentrate	Shaking Table	21.2

CONCLUSION AND RECCOMENDATIONS

According to this study, aiming the utilization of the fine fraction as well as a reduction in the amount of tailings of Alpagut Dodurga Coal Washery, the following conclusions and reccomendations are derived:

1. The Humphreys Spiral and Shaking Table concentration processes are observed to be effective on the concentration of fine and coarse cyclone circuit underflows and resulted in high decreases in ash percentage and activation energies whereas important increases in the calorific values are obtained in the concentrates of those.
2. The same processes were not able to produce concentrates with efficient ash and activation energy decrease and calorific value increase in the sample taken from the thickener. This is due to the agglomeration of fine coal particles related to the existence of AK116 flocculant in high amounts.
3. The fine fraction of the TKİ Dodurga Alpagut Lignites Coal Washery can be concentrated with gravitational concentration methods and at the end of the experiments, it has been determined that approximately 60 % of this fine fraction

can be recovered as concentrate. This means that the amount sent to tailing ponds can be decreased down to 8 % which will solve the tailing ponds problem with a great extent. The efficiency of the concentration processes can also be increased by systematic trials and variations in the operating variables of the concentration equipment. However, the absence of AK116 is a must for a successful operation.

4. The slime problem in the region will be decreased greatly in case the required modifications are performed in the flowsheet of the washery and concentration is realized. Therefore, the tailing (slime) pond problem and the usage of AK116 and its cost will be reduced.
5. If concentration is realized in the region, the fraction obtained as concentrate may be too fine for household heating or industrial purposes, but briquetting of this portion can be performed after finding out the optimum briquetting conditions, and the market problem may be overcome by this way.

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Drobna klasa ziarnowa odpadowych pyłów węgla brunatnego z kopalni Corum Alpagut w Turcji, zawiera 71,2% ziaren o wymiarze mniejszym niż 0,1 mm. Materiał ten powoduje określone straty ekonomiczne oraz stwarza potencjalne niebezpieczeństwo dla środowiska naturalnego. Materiał gromadzony jest w stawach osadowych w rejonie kopalni. Materiał zgromadzony w stawach osadowych nie może być sprzedany ani ponownie zawrócony do przeróbki. Drobna klasa ziarnowa odpadowych pyłów węglowych stanowi poważny problem dla zakładu. W celu rozwiązania tego problemu, należy przerobić drobną klasę ziarnową o zawartości około 20% węgla, na produkt handlowy o odpowiedniej zawartości węgla i popiołu. Dla realizacji tego celu zastosowano spiralę Humphrey'a i stół koncentracyjny. Materiał użyty do badań pochodził z cyklonu i osadnika z obiegu wodno-mułowego kopalni., Zastosowane metody koncentracji pozwoliły uzyskać produkt o odpowiedniej kaloryczności i niskiej zawartości popiołu. Kinetyki spalania otrzymanych produktów były określane metodami termograwitacyjnych.