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The moisture content effect on coal cleaning performance of dry separator in different feed rates

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ABSTRACT

This research is concerned with the effects of moisture content in different fractions on the coal cleaning performance of dry separator. The lignite samples, coming from Çorum, Muğla and Soma districts, were used in the tests. Whereas the all samples were tested in three different moisture contents and three different feed rates, the other variables, riffle height, table frequency and separator surface slope, have been kept constant at their best values after were tested in three steps. Results were analysed with tromp curves to indicate the parameters' effects in detail. The relationships, between coal mass recoveries, combustion recoveries and moisture contents in different fractions, were presented. Consequently, the results revealed that the moisture content had a remarkable effect on separation efficiency. The separation efficiency was, however, inversely affected as the moisture content increase, and the best results were obtained in minimum moisture content for all samples tested. The best-obtained Ep values were 0.15 for the Soma, 0.165 for Mugla while it was 0.145 for the Corum sample. The Soma sample was the most affected sample by increasing moisture content.

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Dry coal separation; moisture effect; feed rate effect; lignite

Introduction

One of the significant environmental challenges facing the world today is that air pollution and global warming. That's why the most important question should be how efficiently coal is used to generate more energy from each tonne. The answer is in the aim of coal cleaning, which is to remove non-combustible material such as, silicate minerals, carbonate minerals and pyrite from coal for increasing its efficiency. By the coal combustion can be improved in the thermal efficiencies of power stations.

Currently, water-based coal preparation technologies are heavily used around the world in which the techniques depend on density differences. However, wet processing of coal requires a large amount of water and final coal product requires dewatering which adds additional cost to the process. Dry separation technologies, like water-based methods, also separate coal and ash-bearing material according to their different relative densities

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(Arslan 2006; Chen and Wang 2006). There are limitations for dry methods due to particle size, particle shape, moisture and near gravity content (Chen and Yang 2003; Rao et al. 2015; Zhenfu et al. 2002). Although the affecting parameters of separation performance are common in both methods, there is a different parameter, the moisture content of coal, for dry coal cleaning methods. The majority of the lignite has a high moisture content in Turkey (Cicek 2008).

As an economical point of view, burning coal of low water content is necessary. Although the high moisture content of low-rank coal is known, the effect of moisture content of coal in dry coal cleaning methods performances was not investigated in detail before.

There are different types of coal moisture. One of them is surface moisture which makes the coal wet and it can be easily removed by evaporation even at room temperature. The other one is known as inherent moisture that within the coal itself and difficult to remove. Moisture is calculated as the weight loss between the untreated and analysed samples, usually defined as total moisture. It can be determined by different methods including heating coal with toluene or drying in a minimum space oven at 150°C in a nitrogen atmosphere for low-rank coals such as lignite.

In this research, the effect of moisture content of coal samples, coming from different districts of Turkey, on separation performance of dry separator at different feed rates is investigated.

A few dry, density–based separators were developed in the period from 1910 to 1930 (Osborne 1986). The technologies shared the same basic principle mechanisms, that are commonly employed, in wet cleaning separation such as, dense medium separations, pulsated air jigging, riffled table concentration and air fluidized coal launders (Donnelly 1999; Gongmin and Yunsong 2006; Lochart 1984; Sahu, Bıswal, and Parıda 2009; Xuliang et al. 2018). The FGX separator, developed by Tangshan Shengzhou Machinery Co., Ltd. in 1996, is one of the most successful applications of dry cleaning of coal. The separator, used in the tests is called “table type air separator”, shares the same principles and similar design with the FGX separator with some innovative changes (Kademli and Gulsoy 2013).

Material and Methods

In the present study, three different lignite samples, from Mugla, Corum and Soma, were chosen as the test materials to indicate the effect of moisture content on dry coal cleaning performance. The proximity analyses of samples are given in Table 1

The dry separator has a surface with regular openings of 3 mm size and with riffles, placed inclined on the surface, has 15 mm height (See in Fig. 1). The separator has an air blower to supply stratification of the coal and tailings. It provides air that passed holes on

Table 1. Proximity analysis of samples.

Proximity Analysis of Samples	Soma	Mugla	Corum
Original Base			
Total Moisture (%)	14.53	17.40	17.80
Ash (%)	31.57	36.24	50.81
Volatile Material (%)	34.45	32.76	27.15
Total Sulphur (%)	2.04	2.21	2.4
Calorific Value (Kcal/kg)	2622	1447	1464

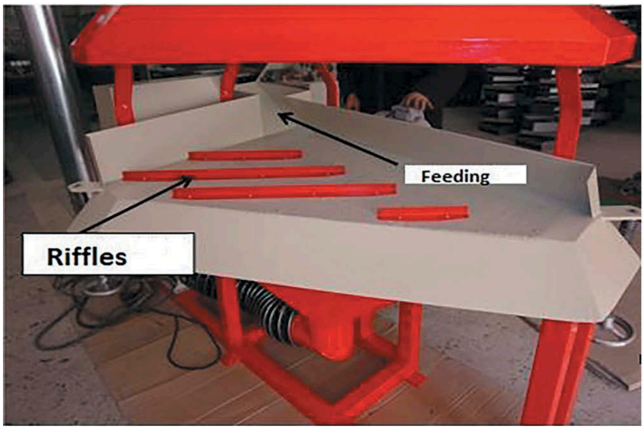

Figure 1. Surface of Separator.

the table surface to fluidize all the material and transport the light (lignite) particles over the riffles. The rate of vibration and air blowing were controlled by frequency controllers, while the feed rate was controlled by an electromagnetic controller. It also has a vibrator to shake the surface.

The high-density particles (rock) move towards along riffles which direct the particles to the back of the table for discharging. The riffles cause the high-density particles to move towards the discharge side of the table whereas the light ones rise on it and to move towards concentrate. In dry coal cleaning operations, there are some affecting operational parameters such as the riffle height, table slope, table frequency. There are some other affecting parameters come from a material such as feed rate, the particle size of the feed and moisture content of the feed. All the operational parameters and particle size distributions were fixed their best values in accordance with the results of chemical analyses and industrial operation limits (see in Table 2).

The particle size of test samples was determined as – 38 + 6 mm in accordance with industrial experiences of dry coal cleaning. The samples were tested in three different feed rates such as 2 t/(h·m^2), 1.68 t/(h·m^2) and 1.32 t/(h·m^2) and three different moisture contents (see in Table 3).

The moisture contents of the test samples were analysed and each sample was divided into three groups by splitter. Whereas one group were left to dry for a long time, the other group were taken a water bath and were left to drain extra water on them and the last group were used with original moisture that already has it. By this way, three different moisture contents were obtained for each sample.

There were two determined discharge units in the system in order to obtain products as a lump of clean coal and tailing. Firstly, the test samples were fed to the surface directly by

Table 2. Fixed Operational Parameters accordance with their optimum values.

Parameters	Step 1	Step 2	Step 3	Fixed Value
Riffle Height (mm)	15	20	25	15
Table Frequency (Hz)	39	42	45	45
Table Slope	0.15	0.21	0.26	0.15

Table 3. Test Parameters.

	Moisture (%)		
Feed Rate (t/h.m2)	Soma	Mugla	Corum
1.32	7.5	6.7	7.1
1.32	14.5	17.4	17.8
1.32	26.2	24.7	25.4
1.68	7.5	7.1	7.1
1.68	14.5	17.4	17.8
1.68	26.2	24.7	25.4
2	7.5	7.1	7.1
2	14.5	17.4	17.8
2	26.2	24.7	25.4

an electromagnetic feeder. Secondly, it was taken in the form of clean coal and tailings respectively. Then finally, the concentrator was cleaned, controlled and then operated in a manner appropriate to the new test conditions for each test. All tests were conducted in a batch mode. The products, clean coal and tailings, were ground to 250 μm by milling and then were analysed to find their calorific values and ash content. All tests were repeated twice, and no meaningful differences in results were evident.

The effects of moisture on separation efficiency were investigated by indicating the relationship between moisture contents and process recoveries and the productivities of the process in different moisture contents for different samples are indicated by tromp curves. Ep and d_{50} values were calculated for different moisture contents of different samples.

Results and Discussions

Analyses results of all samples are given in Tables 4, 5 and 6. The combustible recoveries of concentrate, a total amount of removal ash contents and concentrate mass recoveries were calculated by using Equations from 1 to 3 respectively.

$$\text{Combustible recovery} = [(M_C \cdot (1 - A_C))/(Mf\,(1 - Af))].100 \tag{1}$$

$$\text{Total amount of removal ash} = [(Mt \cdot At)/(Mf \cdot Af)].100 \tag{2}$$

Table 4. Soma Sample Analysis Results.

Feed rate	Moisture Content (%)	Combustible Recovery (%)	Total Removal Ash Content (%)	Concentrate Mass Recovery (%)
1.32 t/h.m2	7.5	68.9	55.2	64.6
	14.5	64.8	49.5	58.5
	26.2	55.1	47.8	63.9
1.68 t/h.m2	7.5	73.7	48.7	69.8
	14.5	69.7	41.9	64.4
	26.2	58.8	39.5	69.1
2 t/h.m2	7.5	78.4	42.4	73.5
	14.5	76.4	35.81	70.9
	26.2	61.6	32.9	72.8

Table 5. Mugla Sample Analysis Results.

Feed rate	Moisture Content (%)	Combustible Recovery (%)	Total Removal Ash Content (%)	Concentrate Mass Recovery (%)
1.32 t/h.m2	6.7	61.3	52.1	55.4
	17.4	53.6	51.4	51.4
	24.7	56.5	46.4	55.2
1.68 t/h.m2	6.7	67.6	46.7	60.5
	17.4	55.9	48.2	54.1
	24.7	60.5	41.8	59.5
2 t/h.m2	6.7	72.0	42.1	65.1
	17.4	63.0	40.7	61.4
	24.7	66.6	34.0	66.3

Table 6. Corum Sample Analysis Results.

Feed rate	Moisture Content (%)	Combustible Recovery (%)	Total Removal Ash Content (%)	Concetrate Mass Recovery (%)
1.32 t/h.m2	7.1	69.8	55.8	56.9
	17.8	64.2	52.4	52.4
	25.4	63.1	51.7	52.1
1.68 t/h.m2	7.1	72.3	53.3	61.4
	17.8	64.1	51.4	53.1
	25.4	62.7	50.7	51.9
2 t/h.m2	7.1	73.6	48.1	66.9
	17.8	70.8	40.0	61.5
	25.4	69.9	39.4	57.6

$$\text{Concentrate mass recovery} = (Mc/Mf).100 \tag{3}$$

where;

Mc is mass of clean coal (kg), *Mf* is mass of feed (kg), *Mt* is mass of tailing (kg),

Ac is ash content of clean coal (%), *Af* is ash content of feed (%), *At* is ash content of tailing (%).

The effects of moisture contents and feed rate on the process were shown in Figures from 2 to 4. These figures indicate that the relationship between moisture content, feed rate and calorific values, the total amount of removal ash content, mass recovery of concentrate and combustible recovery.

Figure 2 shows that increasing moisture content and feed rate caused a decreasing in calorific values and the total amount of removal ash content while mass recovery of concentrate, combustible recovery values nearly unchanged.

Figure 3 shows that increasing moisture content and feed rate caused a decreasing in calorific values and the total amount of removal ash content while mass recovery of concentrate, combustible recovery values nearly unchanged.

Figure 4 shows that increasing moisture content and feed rate caused a decreasing in calorific values and the total amount of removal ash content while mass recovery of concentrate, combustible recovery values also slightly decreased.

Although different calorific values and ash contents were obtained from all samples with different efficiencies, the effects of parameters on the separation process were similar. After completed all the experiments, the sink-float tests were carried out with concentrate

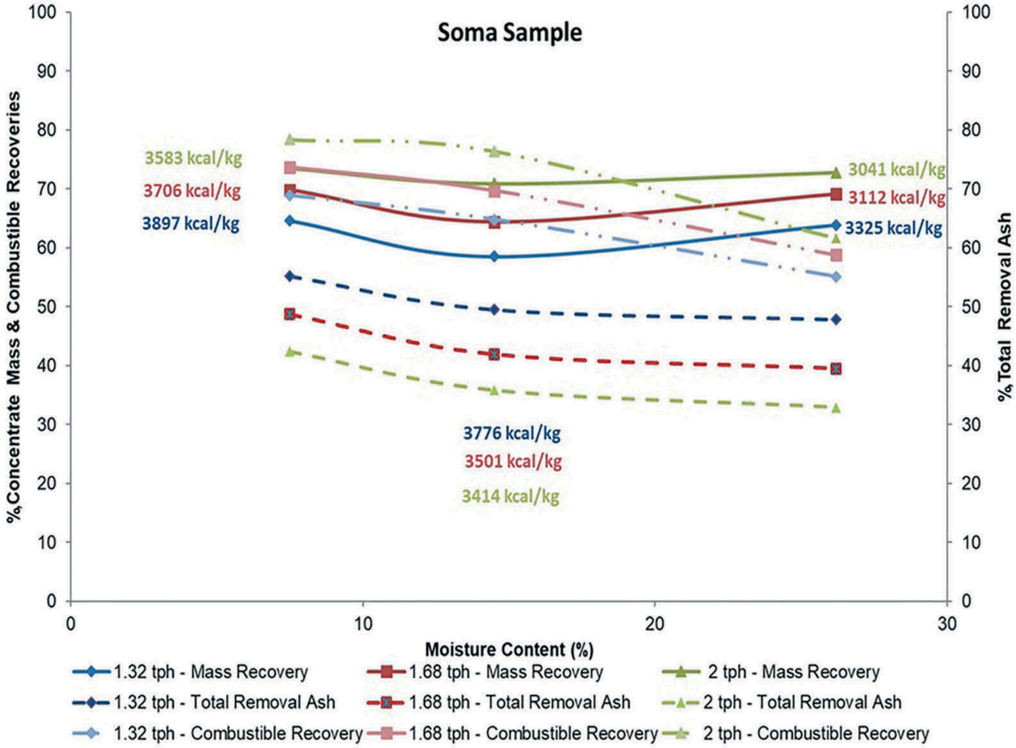

Figure 2. Effects of Moisture contents in different feed rates of Soma sample.

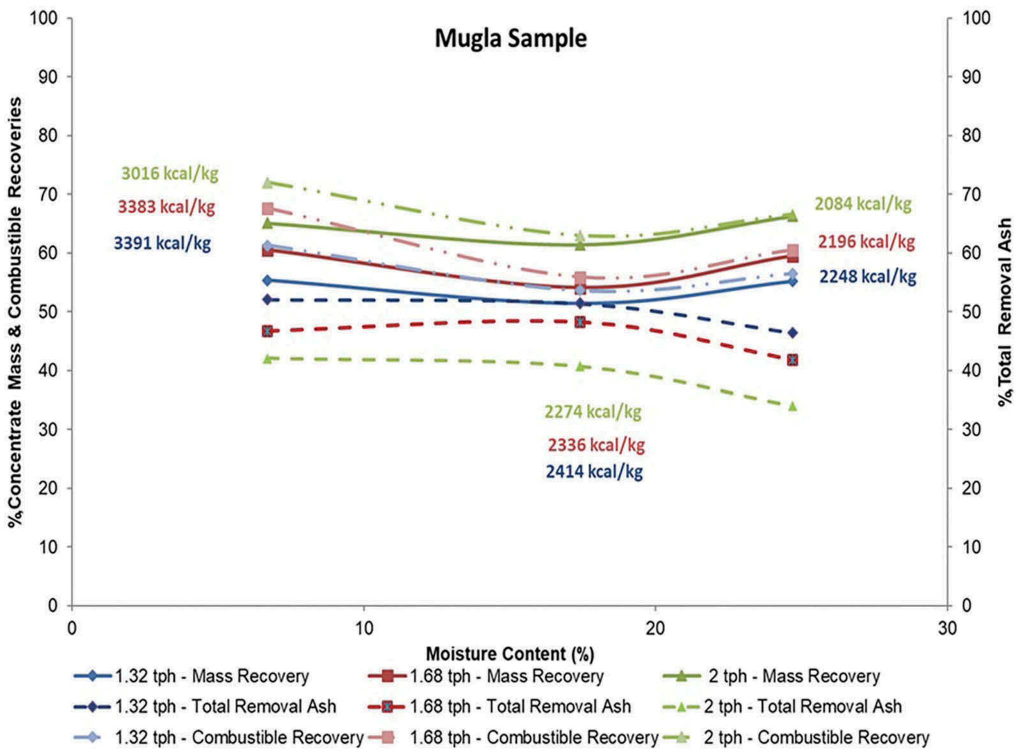

Figure 3. Effects of Moisture contents in different feed rates of Mugla sample.

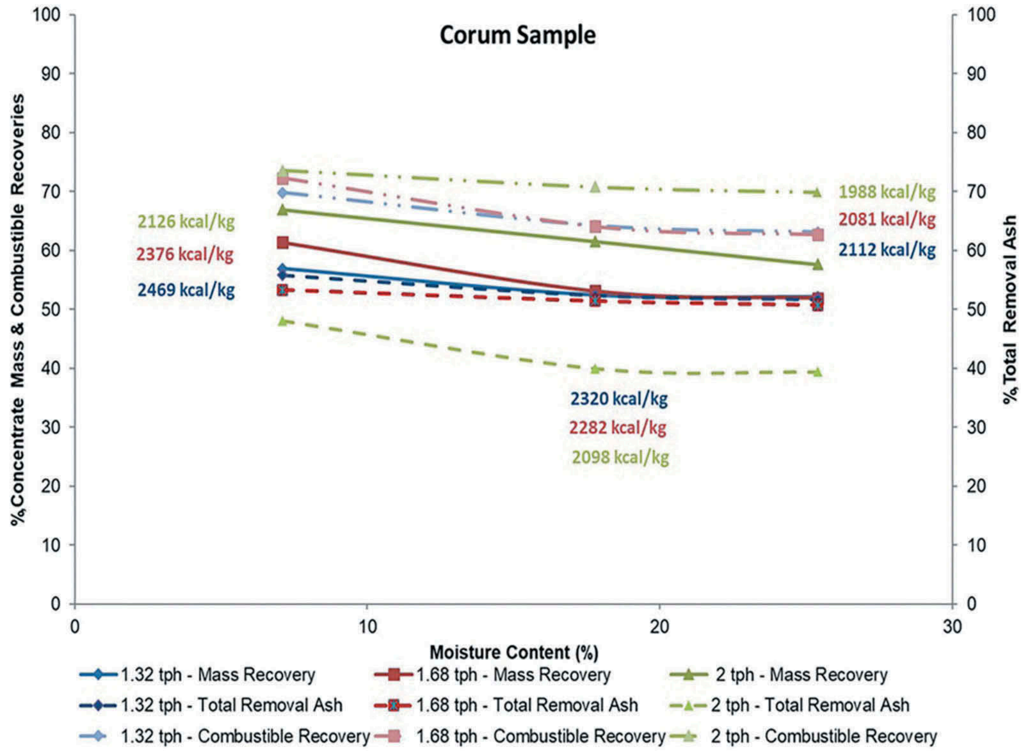

Figure 4. Effects of Moisture contents in different feed rates of Corum sample.

and tailings to calculate the process efficiency of separation. The Ep values, used as a measure of the misplacement of particles in the product streams, and d50, separation densities, were calculated. The Tromp curves for different feed rates were used to analyse the relationship between the feed rate and separation efficiency. The best results were obtained at 1.32 t/(h-m 2) feed rates. Hence the test conditions which have 1.32 t/(h-m2) feed rates were chosen for analysing the relationship between moisture content and separation efficiency. The best Ep values and d50 (cut points) of all samples are given in Table 7.

The Ep values were calculated by using Equation 4.

$$\mathrm{Ep} = \frac{\rho 25 - \rho 75}{2} \tag{4}$$

Where, $\rho 25$ and $\rho 75$ are densities of the particles with 25% and 75% of the dispersion factor, which is the probability of elutriation.

Table 7. The Best obtained Ecart Probable and Cut Points values.

Samples	Ep	d50
Soma	0,15	1,62
Mugla	0,165	1,66
Corum	0,145	1,68

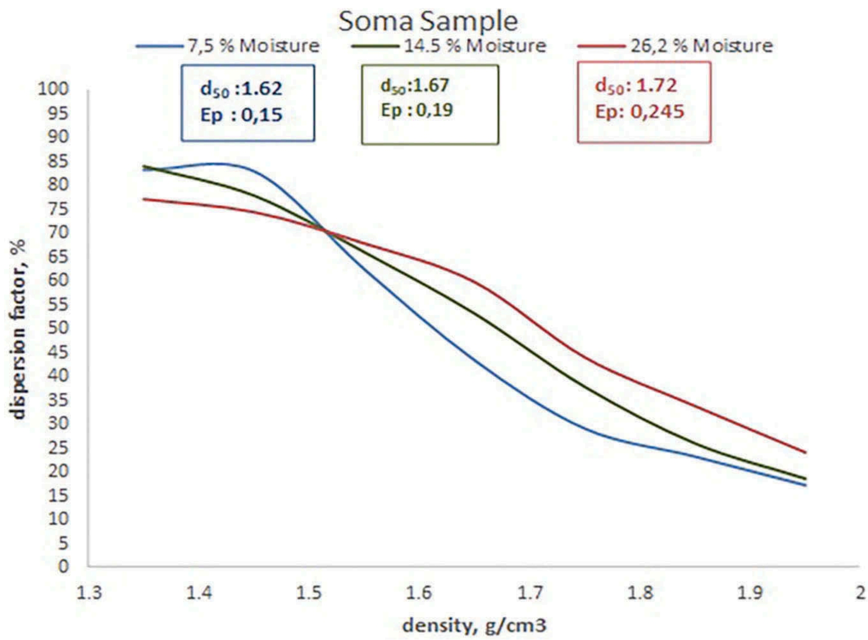

Figure 5. The Tromp Curves of Soma sample in different Moisture Contents.

All samples were analysed in three different moisture contents and Tromp curves were given as figures from 5 to 7 below.

The results of Tromp curve analyses indicated that the performances of dry separation were badly affected by increasing the moisture content of coal. This phenomenon is valid for all samples which are taken from different parts of the country. The moisture contents of coal are playing a more important role in dry coal cleaning than wet methods. It is directly related to separation efficiency and it is an important problem especially low-rank coal such as lignite which has a high moisture content in general.

Figure 8 shows that the relationship Ep values and moisture contents of samples. The Soma sample was the most affected sample by increasing moisture content. Ep values of Soma sample were increased sharply with increasing moisture contents.

Conclusion

Results of this investigation put forward that the drying and separation performance is significantly affected by lignite properties, such as lignite particle size, feed rate and surface moisture content. In this research, three different lignite samples, from Mugla, Corum and Soma, were chosen as the test materials to investigate the effect of moisture content on dry coal cleaning performance.

The results revealed that the moisture content had a remarkable effect on separation efficiency. The separation efficiency was, however, inversely affected as the moisture content increase, and the best results were obtained in minimum moisture content for all samples tested. The best-obtained Ep value was 0.145 for the Corum sample while they were 0.165 for Mugla and 0.15 for the Soma sample. Meanwhile, using hot gas in both

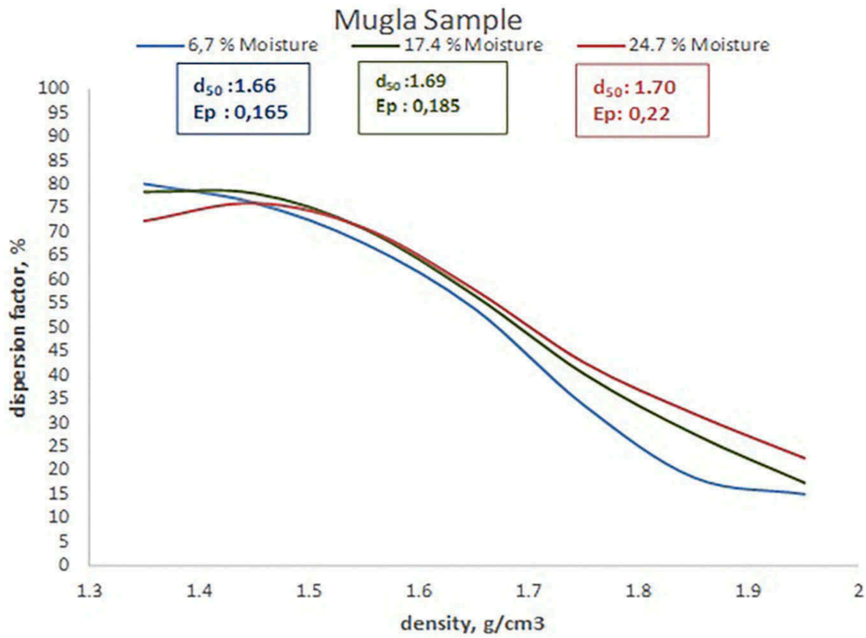

Figure 6. The Tromp Curves of Mugla sample in different Moisture Contents.

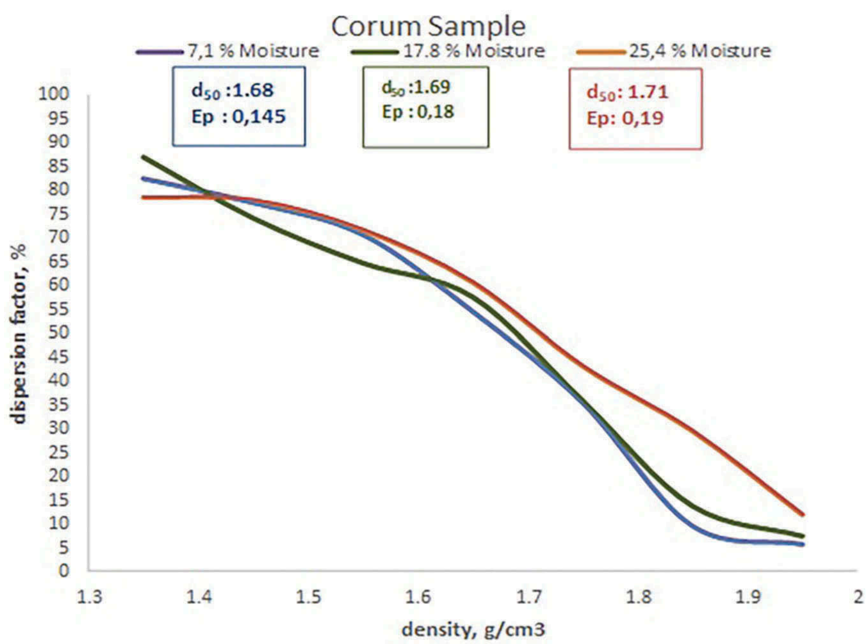

Figure 7. The Tromp Curves of Corum sample in different Moisture Contents.

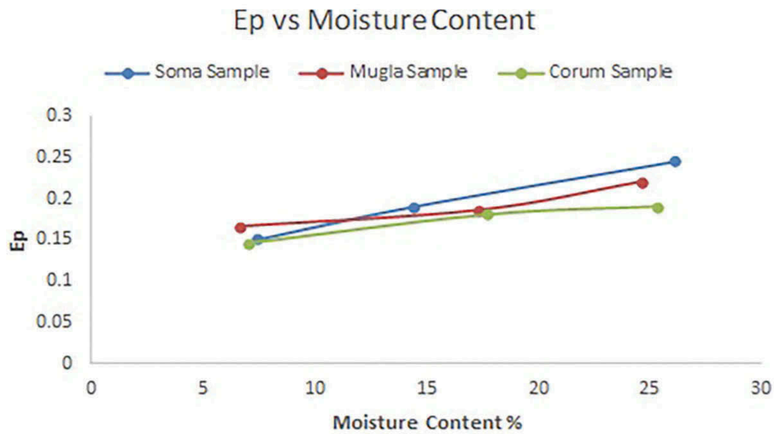

Figure 8. Relationship Ep and Moisture Content for all Samples.

drying and beneficiation processes was studied (Xia, Xie, and Peng 2015). It revealed that a combination of drying and separation has a potential application for low-rank coal beneficiation. Of course, this combination can be also useful for other rank coals. It must be considered about decreasing coal moisture before applying dry separation methods for preventing efficiency loss of processes.

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References

Arslan, V. 2006. Dry coal cleaning methods. *The Journal of the Chamber of Mining Engineers of Turkey* 45 (3):9–18.
Chen, Q., and H. Wang. 2006. Clean processing and utilization of clean energy. *The Chinese Journal of Process Engineering* 6:507–11.
Chen, Q., and Y. Yang. 2003. Development of dry beneficiation of coal in China. *Coal Preparation* 23:3–12. doi:10.1080/07349340302266.
Cicek, T. 2008. Dry cleaning of Turkish coal. *Energy Sources Part A* 30:593–605. doi:10.1080/15459620600826449.
Donnelly, J. 1999. Potential revival of dry cleaning of coal. *The Australian Coal Review* 8:26–30.
Gongmin, L., and Y. Yunsong. 2006. Development and application of FGX series compound dry cleaning system. *China Coal* 1:17–28.

Kademli, M., and O. Y. Gulsoy. 2013. Investigation of using table type air separators for coal cleaning. *International Journal of Coal Preparation and Utilization* 33 (1):1–11. doi:10.1080/19392699.2012.717566.

Lochart, N. C. 1984. Dry beneficiation of coal. *Powder Technology* 40:17–42. doi:10.1016/0032-5910(84)85053-6.

Osborne, D. G. 1986. Fine coal cleaning by gravity methods: A review of current practice. *Coal Preparation* 2:207–41. doi:10.1080/07349348508905166.

Rao, Z., Y. Zhao, C. Huang, C. Duan, and J. He. 2015. Recent developments in drying and dewatering for low rank coals. *Progress and Energy Combustion Science* 46:1–11. doi:10.1016/j.pecs.2014.09.001.

Sahu, A. K., S. K. Bıswal, and A. Parıda. 2009. Development of air dense medium fluidized bed technology for dry beneficiation of coal – A review. *International Journal of Coal Preparation and Utilization* 29 (4):216–41. doi:10.1080/19392690903113847.

Xia, W., G. Xie, and Y. Peng. 2015. Recent advances in beneficiation for low rank coals. *Powder Technology* 277:206–21. doi:10.1016/j.powtec.2015.03.003.

Xuliang, Y., W. Song, Z. Yadong, Z. Yuemin, and L. Zhenfu. 2018. Dry beneficiation of fine coal using planar air jets. *Powder Technology* 323:518–24. doi:10.1016/j.powtec.2017.10.042.

Zhenfu, L., Z. Yaomın, C. Qıngru, F. Maomıng, and T. Xıuxıang. 2002. Separation characteristics for fine coal of magnetically fluidized bed. *Powder Technology* 79:63–69.