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The Effect of Microwave Energy on Grindability of a Turkish High-Ash Coal

M.S.Delibalta[a]; O. Y. Toraman[a],*

[a]Nigde University, Mining Engineering Department , 51245 Nigde, Turkey.
*Corresponding author.

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Abstract

In the present study, the effect of microwave energy on grindability of high-ash (46.39%) and sulphur (3.99%) Turkish coal has been investigated. Coal samples (-9.52+3.18 mm) was treated by microwave at a frequency of 2.45 GHz with different power levels (0.48-0.64-0.80 kW) and residence times (30-150s.). In order to determine the crushing/grinding resistance of low ranked lignite coal samples treated by microwave oven, the Impact Strength Index (ISI) test was applied for each treated and untreated sample and compared with each other. Experimental results have shown that significant increases in grindability were achieved when the coal samples were exposed to microwave radiation. The ISI of samples decreased up to 96%.

Key words: Microwave energy; Low rank coal; Crushability; Grindability; Impact strength ındex (ISI)

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INTRODUCTION

Enormous quantities of coal must be ground as feed to coal fired power stations. The grinding of coal prior to combustion is a highly energy intensive process. A significant increase in coal crushability/grindability would allow the power requirement to the mills to be reduced significantly. Pre-heating of coal in an oven has been shown to reduce grind strength (Harrison and Rowson, 1996), although it is unlikely that this would be an economically viable method, at least not through associated energy requirements. Microwave heating is fundamentally different from conventional heating, because microwaves take the form of electromagnetic energy and can be penetrate deep in the sample, which allows heating to be initiated volumetrically (Jones et al., 2002). Grindability could be increased by preheating the coal with waste heat reducing energy costs. Simulation of locked cycle tests gave a 40% increase in grindability. Approximately 40% grinding energy saving can be expected (Lytle et al., 1997). Microwave pretreatment of coal selectively heats The mineral matter based on differences in dielectric properties, thereby causing the pyrite to decompose tomagnetically susceptible pyrrhotite. Also, it resulted in weakening of the coal-mineral matrix, thereby altering the angularity and surface properties of the ground particles (Meikap et al., 2005). As a result of microwave pre-treatment, the rate of breakage increased with an increase in particle size and the grinding resistance was reduced with microwave pretreatment without altering the fundamental property of the coal (Sahoo et al., 2007).

The effect of MW treatment on coal was also described by Marland et al. (2000). According to author, depending upon the microstructure and geological properties, coals naturally contain water to varying degrees and water is considered to be a good absorber of MW energy. When MW are applied, the molecular dipoles of water align and flip around as the applied field is alternating. Their movements produces frictional heating. The average heating rate of water has been calculated at 0.9^{o}C/s when exposed to MW radiation at a power of 0.65 kW and a frequency of 2.45 GHz, mineral matters within coal differ in their ability to absorb MW radiation. Some minerals readily heat within an applied electric field. Other minerals appear transparent to MW radiation.

Harrison and Rowson (1997) demonstrated that a reduction of 30% in the comparative work index could be achieved using a 0.65 kW 2.45 GHz MW source. The reduction in relative work index occuring because of cracking initiated around pyrite grains and superheating of water in the porous coal structure. Toraman et al. (2010) investigated the effect of high power (5-20 kW) MW energy on the grindability of Turkish lignite coal. MW treatment increased the Hardgrove Grindability Index (HGI) at high power for a short residance time (2 s.). On the other hand, MW energy intensity and the exposure time were found as the most important factors affecting grindability. The increase in HGI was up to 125% at a power of 0.90 kW for 60 seconds exposure time according to the non-treated sample (Ozbayoglu and Depci, 2006). Recently it was found that by the researchers that the MW-assisted grinding produced good results particularly for HGI, WI and specific rate of breakage (Sahoo et al., 2011).

The Bond's grindability test (WI) can be used to determine the work index of any type of ore or material. But the process is tedious and long time consumption. The laboratory determination of Hardgrove grindability index (HGI) is less time consuming than that of the selection-for-breakage function. On the other hand, impact strength test as a criterion of comminution was first developed by Protodyakanov (1950), and then it was used by Evans and Pomeroy (1966) for the classification of coal seams in the UK. The test was then, modified by Paone et al. (1969), Tandanand and Unger (1975), and Rabia and Brook (1980). Various authors (Kahraman, 2001; Toraman, 2010; Su et al., 2010) also used this index value for determination of grindability/crushability of coal and rock samples. This test is simple and very practical. In addition, the apparatus is portable and can be used in the field. As a result, it has been proven that ISI values can be assessed as a criterion of grindability.

The objective of this research is to investigate the influence of microwave energy on the grindability of coal in -9.52+3.18 mm size. For this, the Impact Strength Index (ISI) test was applied for each treated and untreated sample and compared with each other.

1. EXPERIMENTAL

1.1 Material

A low ranked lignite coal from Park Termik AS. (Cayirhan-Ankara, Turkey) was used in the study. The proximate analysis of the coal sample as on received basis is shown in Table 1.

Table 1
Proximate Analysis of Coal Sample

Analysis	As receivedwt%
Moisture	11.34
Ash	46.39
Volatile matter (VM)	29.96
Fixed carbon (FC)	12.31
Total sulphur	3.99
Lower calorific value	2,405 Kcal/kg

1.2 Methods

1.2.1 Microwave Test

Microwave treatment was carried out with a 800W experimental prototype 290 mm(W)×270 mm(D)×190 mm(H) microwave oven with variable power at 2.45 GHz. The microwave oven has five microwave power settings (i.e., 480 W, 640 W and 800 W). The original coal samples of 10 kg were crushed with a jaw crusher and then screened into -9.52+3.18 mm (−3/8″+1/8″) fraction for test studies. Then, samples were exposed to MW radiation at a power of 0.48-0.80 kW and a frequency of 2.45 GHz for 30, 60, 90, 120 and 150 seconds (Table 2). Index tests were determined immediately after the heat treatment to prevent relative humidity affecting the grinding performance.

Table 2
Microwave Heating of Coal Samples

Sample	Microwave power (kW)	Exposure time (second)
Coal x non-treated	0	0
Coal x treated	0.48	30 60 90 120 150
Coal x treated	0.64	30 60 90 120 150
Coal x treated	0.80	30 60 90 120 150

1.2.2 Impact Strength Test

Impact strength (ISI) test apparatus consists of a vertical stanless steel cylinder with a diameter of 4.23 cm. Inside this hollow cylinder, there is a 1.8 kg steel plunger poisioned vertically (Figure 1). During the test, the coal samples with a wight of 100±0.5 g and

-9.52+3.18 mm range are introduced into the cylinder, and the plunger is dropped freely on the samples 20 times consecutively from 30.48 cm. The Impact Strength Index (ISI) value is equal to the amount of coal retaining in the initial size range after the test. The test was repeated three times for each sample and the average value was recorded as the ISI. In accordance with the impact strength index values obtained, coal samples are classified as in Table 3.

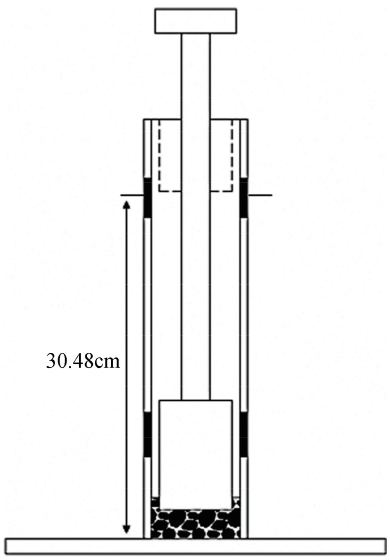

Figure 1
Impact Strength Index Test Apparatus

Table 3
Classification of Coals in Terms of Impact Strength Index Test

ISI	Classification
>75	Extremely hard
75-60	Very hard
60-40	Hard
<40	Soft

2. RESULTS AND DISCUSSION

Turkish coals generally have a high ash – moisture content and low calorific value. Lower ranked coals are more sensitive to microwave radiation possibly due to increased inherent moisture content. There is evidence to suggest that gaseous evolution (water and volatile matter), as well as gangue mineral expansion, causes cracks and fissure formations that are responsible for the improvement in grindability (Marland et al., 2000). In the present study, the exposure time of MW heating has been varied from 30 to 150 seconds. The results which were indicated in Table 4 showed that the increase in exposure time affected the grindability positively, e.g. the change of 0.64 kW (150 seconds exposure time) caused a 96% decrease in the ISI. Generally, coal samples showed large changes in grindability, with ISI decreases of 2-96%.

Table 4
ISI Test Results of Coal Samples

Sample	Exposure time (second)	ISI	Classification
Coal x non-treated	0	56.2	Hard
Coal x MW treated (0.48 kW)	30	55,7	Hard
	60	55,3	Hard
	90	48,0	Hard
	120	33,7	Soft
	150	32,8	Soft
Coal x MW treated (0.64 kW)	30	54,3	Hard
	60	48,2	Hard
	90	36,5	Soft
	120	32,6	Soft
	150	28,7	Soft
Coal x MW treated (0.80 kW)	30	48,8	Hard
	60	46,7	Hard
	90	36,2	Soft
	120	31,5	Soft
	150	30,1	Soft

The release of the moisture content (11.34%) of the coal tested might be the cause of the thermally induced stresses and reduction in resistance to grindability. Most of the mineral matters appear transparent to MW radiation except pyrite (iron sulfide). Some mineral components within coal such as FeS_2 have relatively higher dielectric constants to others which means that their temperature increases relatively faster. In particular, the microwave energy excites pyrite at higher rates (1.0^{o}C/s) than other coal components (for quartz 0.08^{o}C/s). As the total sulphur centent of coal tested was very high (3.99%), pyritic sulphur effect would also be appreciable. Therefore, the differential expansion of minerals within the coal might be significant during heat treatment. Figure 2 shows ISI index vs exposure time for coal samples. Figure 3 also shows fractures occured on coal before (a) and after (b) microwave irradiation (90 sec., 0.80 kW).

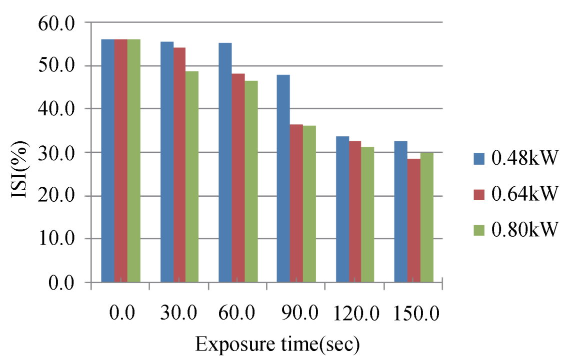

Figure 2
ISI Index vs Exposure Time for Coal Samples

(a)

(b)

Figure 3
Fractures Occured on Coal Before (a) and After (b) Microwave Irradiation (90 sec, 0.80 kW)

CONCLUSIONS

In this study we studied the effect of microwave treatment on grindability of low rank high-ash Turkish coal by using impact strength index. The results obtained are summarized as follows:

(1) Experimental results have shown that reductions of up to 96% ISI index can be achieved by MW exposure of high-ash coal samples at a power of 0.64 kW for 150 seconds exposure time according to the non-treated sample.

(2) The results were indicated that low ranked coals are very sensitive to MW radiation due to increased inherent and surface moistures. Rapid expansion of moisture within the coal causes some physical changes, such as craks and fissures formations which are responsible for the improvement in grindability.

(3) Expansions in gangue mineral (such as pyrite) are also the probable causes for the improvement in coal grindability.

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