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MICROWAVE ACTED MICRO GRINDING OF ŞIRNAK ASPHALTITE SLIME, LIGNITE SLIME

MİKRODALGA ETKİLİ ŞIRNAK ASFALTİT ŞLAMI VE LİNYİT ŞLAMININ MİKRO ÖĞÜTÜLMESİ

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ABSTRACT

In terms of the advanced technological developments in energy production the low quality coals need the most feasible technologies. it is possible to produce coal-derived products from low quality coals. On the contrary of environmental concerns of low quality coal burning, coal preparation, grinding and washing of various type of low quality coals need feasible evaluation. The grinding systems are needed in today's modern technology. In this fine grinding study, Hardgrove and Bond grindability tests are practiced over Şırnak shale, Şırnak asphaltites and bottom ash. Grinding tests ere carried out to certain weight samples conditioned in microwave oven at the fine size values in the product. The duration period are changed after grinding for 60 and 90 minutes. Şırnak asphaltite and Şırnak shale were dry milled in two different horizontal and vertical roller mills in different micro-grinders and the fineness values of 20 µm and 45 µm are determined and compared. The unit energy consumption for different types of clinker production in industrial mills has been calculated and presented comparatively. The differences in the grindability of raw materials and the amount of energy consumed in cement production were determined by experimental and industrial tests. The easiest to grind is Şırnak asphaltite and shale, while the most difficult to grind is marl. As a result of the HGI and Bond tests, they are the decisive tests in industrial-scale grinding of cement. Since materials that are easy to grind are evaluated, it has been observed in this study that clinkers with additives produced using claystone are more advantageous. Micronized grinding of soft limestone instead of marly limestone has proven to be easy. The particle size functions in the micro pulp are defined in the vertical ball mill. In the production of additive Portland cement, micronized grinding of oak charcoal and fly ash with microwave requires less energy and can be grinded more easily.

Keywords: Fine grinding, Hardgrove mill, Microwave activation, Coal grinding, Coal breakage, HGI, Şırnak asphaltite

1. INTRODUCTION

For grinding raw materials in a grinding mill plant, the chemical treatment method is becoming much effective in energy consumption of mills (Howard et al.,1976, Howard & Datta 1977). Power needs will decrease with chemically fractured material. In the standards, the tests of mainly Bond and Hardgrove Index are commonly used as an industrial standard providing distinct energy requirements in all industrial applications (Bond, 1952). A chemically activated grinding process can save energy in grinding of hard materials, such as cement clinker, granulated slag, limestone, and quartz (Tosun, a 2015). This process subjects to the aggregate materials to high internal fracturing weakness between the macro and micro fissures and crack faces (Refahi et al., 2007, Tavares & King, 2002, Tavares & King, 2005). Although this comminution technique closely resembles natural alteration, the degree of alteration by chemical breakage in chemical activation achieved within the chemical pots is carried out, even after only a single pass (Howard & Datta,

1977) determined that chemical comminution having many advantages, this method using ammonia, providing ash liberation in coal grinding with chemical breakage.

The Bond Work Index is determined as a standard test method using the 30 cm diameter Ball Mill over a certain weight sample of ore. Bond index of ore provides a scale for grinding energy of grinders as an industrial standard common, resulting satisfactory scaling in all industrial applications. Pussolanic additives such as fly ash, clinker and fly ash are consumed in limited quantities among cheap natural waste sources in cement production (Toroman&Ucurum,2012). By using fly ash, the production cost of cement with additives is reduced and its quality is improved. Adequate grinding of these additives and less energy consumption are required by using fine grinding techniques. With the production of high-efficiency ash and slag, an annual fly ash stock exceeding 600 million tons is formed in the world. Coal power plants with fly ash stockpile can use them in cement production. In addition, during the construction, rubble and other wastes are dumped into forest areas and thrown into the soil, polluting the soil. While electricity is produced in Şırnak Silopi thermal power plant located in the Southeastern Anatolia Region, a high amount of fly ash is produced with approximately 220 thousand tons and this high amount of the ash needs to be evaluated in cement production (Anonymous, 2013). Microwave grinding of coal ash reduces the cost of grinding coal and clinker and additives, and provides high quality cement production (2-3). The use of the microwave effect in the long-term milling plant resulted in more shale breaking and higher desulfurization in the coal preparation plant (Tosun, b 2018).

The Hardgrove work index can be used only for determining the grinding power for coal and soft rocks but also to classify the difference in hardness of different coals and coal shale. Every coal material has a characteristic Hardgrove index at standard level. The power required to break the high ash coal fine is higher due to the high content of harder shale material [2].

The Hardgrove index is widely used to estimate the power required to grind microwave act treated fractured coal materials. Because of the short determination of this index, fracturing intensity has investigated the effect of mechanical parameters on grinding, and the relationship between them.

The strength values obtained by the micro-cracks, fractures, tensile stress cracks and pores created by microwave radiated treatment are the common geological design parameters for the materials in concrete structures or the rocks. The parameters regarding rocks give the failure values to the construction engineers. Microwave radiated fracturing and following comminution on the purpose is to break rock to given sizes. It is improved that the assessment of tests were interrelated between the failure energy and the final size reduction and surface area.

It is significantly mentioned that alteration of cement raw materials, such as limestone, marl, tuff or shale rocks, interrelation between compressive strength and propagating fissures. Microwave radiated duration period changed the ground characteristics of coal (Li et al.,2005). These improvements in the acting technique are especially useful for coal grinding in pulverized coal burning industries.

The unaxial compressive failure load I_c of the cement raw materials interrelated with the grinding so that the relationship can be defined among the Bond Work and Hardgrove Index values and compressive strength of chemically fractured coal characteristics will emphasize the great importance (Tosun, 2014). The aim of this study is to investigate the behavior of coal and shale under different microwave conditioning methods using fine size samples and waste slimes to establish a relation among strength and HGI properties and Bond Grindability, Bond Work Index.

1.1. The Standard Bond Grindability Test

In the study in which coal shale and marl were treated with moisture as the sand size in compact texture with microwave oven, it was observed that the internal stresses increased in the porous coal and very selective thermal crack formation was achieved. In addition, sulfur removal from coal below 1 mm in size has been achieved (Tosun, 2018a). In cement production, very fine grinding to a size of 90 microns and below 40 microns includes successive hammer crushing-roll grinding, autogenous or semi-autogenous tube grinding units (Tosun, 2018b). The design of vertical mills to be used in fine grinding and “ultra-fine” micronized grinding plant, selection of grinding media is important in terms of energy saving and grinding costs (Tosun, 2014). The standard Bond grindability test has been described as follows.

In grinding, the product fineness depends on the type of grinder and grinding medium, while the unit energy consumption for the fine product amount varies. The grindability index differences of raw materials have been determined by experimental and industrial tests depending on the amount of energy consumed in cement production (Tosun, 2014). It is observed that the easiest to grind is shale, and the hardest material is blast furnace slag and clinker (Özbayoğlu et al., 2008 Gökçen et al.,2012, Tavares et al,1998). The desired fine grinding conditions is optimized by using maximum amount of limestone and marble residue powder instead of clinker which is difficult to grind, the end of wet grinding tests (Unland & Szczelina, 2005).

1.2. Hardgrove Index Method

The fracture energy and type for each mineral is greatly influenced by the hardness and texture of the material. Hard materials in coal and slag generally remain unground at low weight percent due to metamorphism or as a result of metamorphism, remaining on a certain sieve, which is defined as residue. Fly ash and slag grindability therefore also varies. According to the type of cement to be produced, the raw material homogenization amounts should be determined before starting the grinding process and should be inspected in a controlled manner with cement quality tests. All coal samples are criticized by the ASTM D 409-08 procedure for determination HGI (ASTM,2008).

2. MATERIAL and METHODS

The samples are crushed in a laboratory scale jaw crusher, and then the standard Bond grindability test is performed. The Bond work index values (Wi) are calculated from the equation below.

The standard Bond grindability test is a closed-cycle dry grinding in a standard ball mill (30.5x30.5 cm) and screening process, which is carried out until steady state condition is obtained. This test was described as in the standard. The feed samples had the particle size distribution as illustrated in Figure 1 and 2.

In this study, Point load index I_c and unaxial strength were initially measured for the the coal and shale samples. Standard Bond grindability tests were carried out and work indices (Wi) were calculated (Austin, 2004, Bergstrom, 1985). The proximate analysis of coal samples is given in

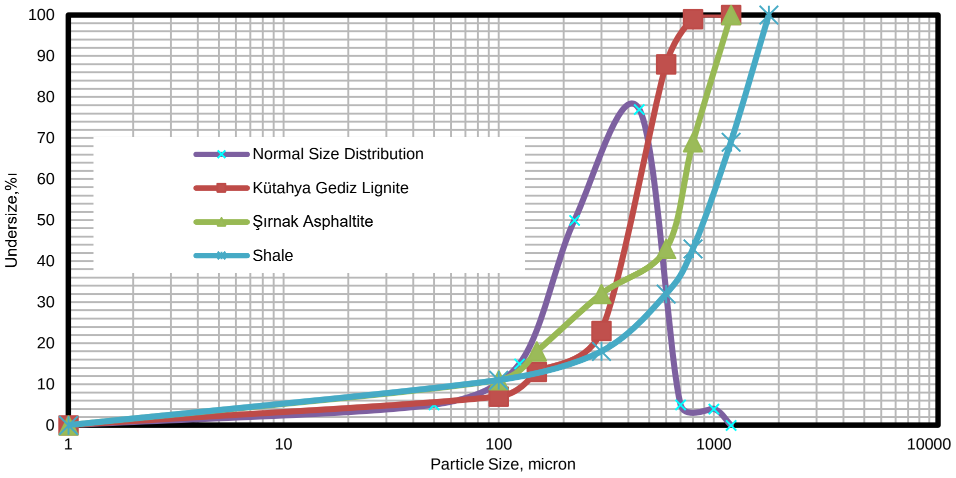

Figure 1. Particle Size Distribution and Normal Size Distribution of HGI Coal and Shale samples.

Table 1. The chemical composition of the shale sample is also presented in Table 1.

Representative milled samples with the feed size of 0,6 mm are brought to a thickness of 100 micron with a 2 kg ball grinder and loaded into the microwave oven to increase the microwave radiation effect on the dry samples at a duration time of 10 minutes. Sample bags packed form are kept under microwave radiation for sufficient heating effect for 100 gr sample bags at 10 minutes. The microwave acted samples are subjected to the following grinding tests for fine grinding and ultra-fine grinding. The microwave improved the vibration of the inner atomic plane, resulting in high heat and interfacial cracks. In these grinding experiments, microwave irradiated samples such as limestone feed below 106 microns, Şırnak asphaltite and shale samples are ground below 45 micron to 20 micron and the effect of microwave radiation on ultra-grinding ability is determined by passing through the weight ratio.

Microwave radiated samples were tested for HGI and Bond grindability.

Table 1. Proximate Analysis of Coal and Chemical composition of shale samples used in experiments.

Samples	Fixed Carbon,%	Volatile Matter,%	Ash,%	Moisture,%	Total S,%	Calorific Value, kcal/kg
Kütahya Gediz Lignite	40.55	60.96	36.1	16	6.1	3207
Şırnak Asphaltite	40.28	62.5	39.4	0,2	6.6	4820
	CaO	SiO_2	Na_2O	MgO	K_2O	LOI
Coal Shale	5.42	54.8	2.1	4.1	2.1	2.15

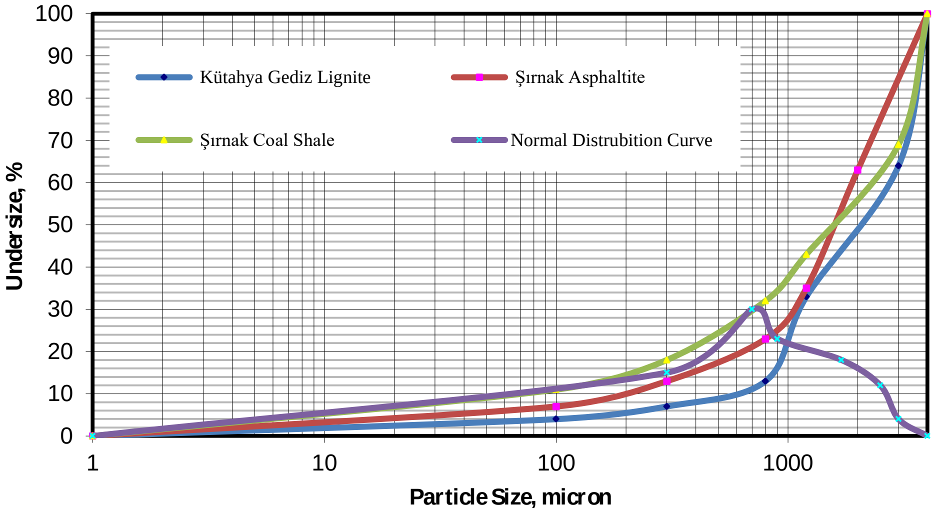

Figure 2. Particle Size Distribution and Normal Size Distribution of Bond Test Coal and Shale Samples.

3. RESULTS and DISCUSSIONS

This equilibrium condition may be reached in 6 to 12 grinding cycles. After reaching equilibrium, the grindabilities for the last three cycles are being averaged. The average value was taken as the standard Bond grindability (G_{bg}).

The products of the total final three cycles are combined to form the equilibrium rest product. Sieve analysis is carried out on the material and the results are plotted in order to find the 80% passing size of the product (P_i).

$$W_i = 1.1 * \frac{44.5}{P_i^{0.23} * G_B^{0.82} * \left[\left(10/\sqrt{P_{80}}\right) - \left(10/\sqrt{F_{80}}\right)\right]} \qquad (1)$$

where W_i is the work index (kwh/t); P_i, screen size at which the test is performed (106 μm); G_B, Bond standard ball mill grindability, net weight of ball mill product passing sieve size P_i produced per mill revolution (g/rev); P_{80}, sieve opening which 80% of the product passes (lm); F_{80}, sieve opening which 80% of the feed passes (μm).

The Grindability of samples was determined from HGI and Bond test and the average values with minimum and maximum values for each sample type are given in Table 2.

Table 2. Grindability properties of using rocks

Rock Name	G (g/rv)	Wi (Kwh/t)	HGI	Density
Shale A	3.23	7.2	56	2.62
Shale B	3.73	7.6	52	2.61
Kütahya Gediz	2.52	6.7	72	1.71
Şırnak Asphaltite	3.39	7.7	57	1.81

In experimental studies, The Bond grindability of Şırnak coal shale is the most difficult than other samples. The biggest reasons of low Bond grindability, the porosity of sample was low is based on the solid rock texture.

Although the rocks of Şırnak asphaltite and coal shale were the same type, there are no differences comminution characteristics. The reason of this condition, their porosity has similar as the structure of coal.

The strength of samples was determined from compressive load test and the average values with minimum and maximum values for each sample type are given in Table 3.

Table 3. Compressive strength of Coal and Shale Samples

	I_s Point load Strength, kg/cm^2	σ,Uniaxial Compressive Strength, kg/ cm^2
Shale A	18.90-25.00	78.00
Shale B	19.80-26.00	86.00
Kütahya Gediz	25.00-45.00	54.00
Şırnak Asphaltite	28.00-46.00	61.00

The effect of period of chemical activation on grinding was tested. The graphs were observed as illustrated in Figure 3. Two days treatment was sufficient for developing grindability manner of the coal samples. HGI values increased at about 24% at two days period.

3.1. Microwave Action on Coal

Microwave radiation changed the body temperature of ore minerals and also coal regarding the density (Veasey and Fitzgibbon, 1990), crystal structure and permittivity rate of the material (Lu et al., 2007, Ma and Pickles, 2003). Heating mater under microwave radiation increased by the dielectical surface and body character mentioned given below Table 4 (Walkiewics et al., 1988). The microwave duration time dependence changed with texture, the anisotropic ceramic materials properties arising from the orientation with radiation wave field.

The less permittivity of coal is due to the presence of both sulphide and pyrites in coal matter. The shale, silicate clay matrix is called transparent and reflects through under the microwaves. The carbonaceous matter in the ore is cooling heat. The most amorphous matter are in the organic ring of coal carbon. The heat rises by the constituents of the inorganic impurities in amorphous carbon ring because of high heating.

Table 4. Microwave Temperature Effect on Minerals (Walkiewics et al., 1988).

Mineral Type	Maximum Temperature, oC	Time,min
Chalcopyrite	925	1,1
Cinabarite	145	8,6
Galenite	955	7
Hematite	1085	7
Magnetite	1258	2,75
Marble	74	4,25
Pyrite	1019	6,75
Pyhrotite	586	1,75
Quartz	79	7
Sphalerite	88	7

Some researchers may improve heat it was indirectly heated by microwaves, therefore using magnetite or hematite powders as a susceptor which are improving overheat conduction.

3.1. Effect of Coal porosity

The effect of period of microwave activation on grinding was tested. The graphs were observed as illustrated in Figure 3. Two days treatment was sufficient for developing grindability manner of the coal samples. HGI values increased at about 24 % at two days period. The relationship among Bond Grindability and HGI values were similar in microwave treated coal samples. The most important reason of the relationship was the same as in the breakage under chemical shattered samples and porous structure is more effective rather than solution in the grinding mill. The modified HGI indice values are determined by 20 micron weight of 500 micron feed at 30 gram dry sample as ilustrated in Figure 4.

The HGI of 56 and 66 of Şırnak asphaltite and shale as indice values reduced to values of 38 and 43 Modified Hardgrove indices, respectively. The fine grinding size affected by grinding weight loose in the bowl grinder.

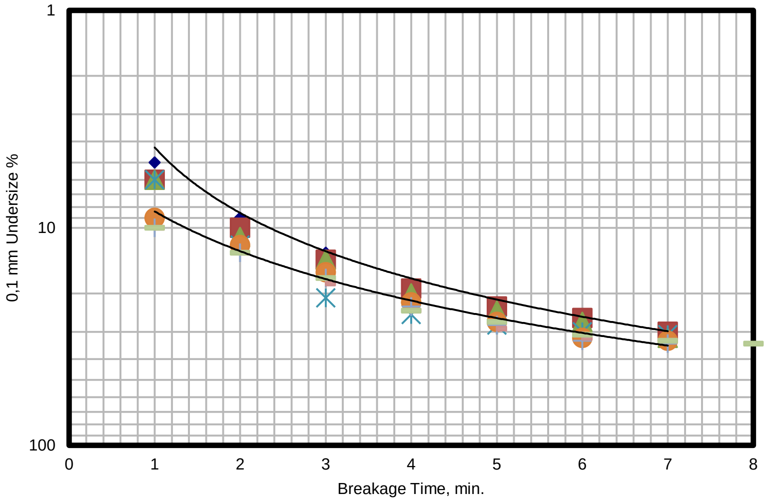

Figure 3. Bond breakage at 0,1 mm with microwave treated coal samples in 10 minutes.

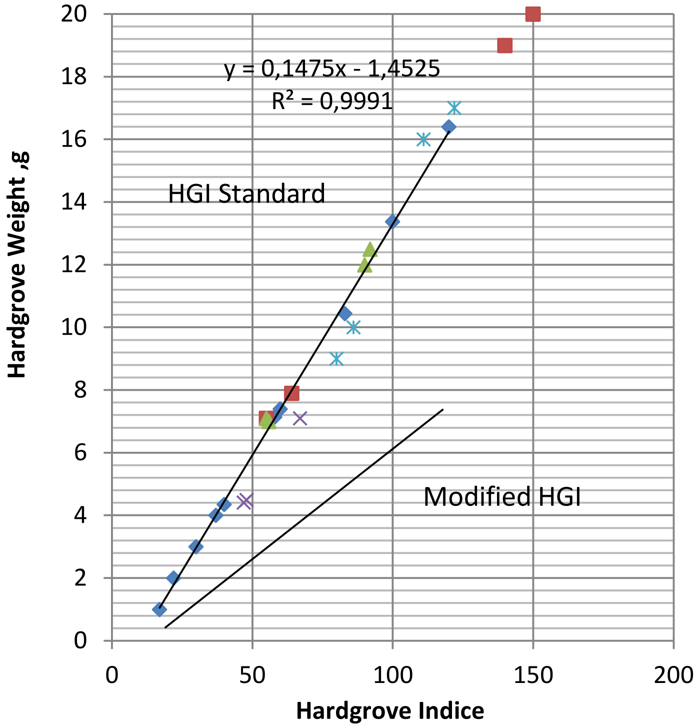

Figure 4. HGI standard and Modified HGI at 0,02 mm with microwave treated coal samples in 10 minutes.

4. CONCLUSIONS

In this study, a method which reduces and eliminates inefficiency and problems during the determination of work index and Bond's grindability is described. The effect of physico-mechanical parameters of the materials on grindability and its relation with grindability are investigated. It is possible to determine physico-mechanical parameters. Statical methods contain difficult test procedures and problems as encountered at Bond's grindability process. However, tests are simple, easy and show minor problems in dynamic methods. A good correlation is obtained between Bond grindability and work index with the values determined from the Hardgrove Index method as a result of the tests done.

The best correlation was found between Bond (grindability and work index) and HGI. Moreover, HGI give better results than static methods because coal grinding is also a compression process. The HGI grinding method was modified for finer and softer materials by using less weight and smaller steel ball using in the bowl grinder. The modified indice values passed under 20 micron had many advantages, because of its simplicity and the relatively different porous texture as compared to Bond Test. The dense particle bed is needed for precision in determining breakage in coal and shale with small steel ball impact. This can be the critical for porous soft rocks breakage under static loading.

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