Effects of Microwave Energy on Grinding of Colemanite

M. F. Eskibalcı, S. G. Özkan
Istanbul University, Eng. Faculty, Mining Eng. Dept., Avcılar, Istanbul, Turkey

E. Yiğit
Yıldız Technical University, Faculty of Chemical & Metallurgical Eng., Metallurgical Eng. Dept. Esenler, Istanbul, Turkey

ABSTRACT:
Experiments were carried out on the samples of pure colemanite mineral samples supplied by Eti Mine Inc.'s Bigadic Boron Mines and classified according to particle size fractions of -8+4mm, -4+2mm and -2+1 mm. Grinding tests were performed on the samples using a conventional dry rod mill of which parameters kept constant during all tests. Material characterization tests including complete chemical, mineralogical by XRD and moisture analyses were also done in order to see the effect of microwave energy on colemanite surfaces. A kitchen type microwave oven with 2450 MHz frequency was used for surface modification by microwave pretreatment at five power levels before grinding. The effects of microwave pretreatment on the grindability of colemanite were determined by cumulative particle size distributions of the ground products. Microwave energy certainly affects grindability of colemanite due to loss of moisture near the surface and also some crystal water inside the lattice. Therefore microcracks due to this phenomenon ease the grindability of the mineral.

Keywords: Microwave treatment, colemanite, grindability, characterization

1. INTRODUCTION:

Microwave energy is a form of electromagnetic energy, which travels in high frequency waves. The wavelengths are between 1 mm and 1 m with corresponding frequencies that range from 0.3 to 300 GHz. Within this range, microwaves have extensive use in communication, especially in radar, cellular phones, television and satellite applications (Xia, 1997). The most commonly used frequencies for heating purposes are 915 MHz and 2.45 GHz, which correspond to wavelengths of 33.5 and 12.2 cm, respectively. These frequencies were chosen by international agreement to minimize the interference with communication services (Bathen, 2003; Al-Harahsheh et. al., 2003).

The heat transfer mechanism is different in microwave heating the conventional heating. Microwave energy transmits heat to the center and surface of a material simultaneously i.e. independence of thermal conductivity on heating rate is overcome and the time required to heat the materials can be shortened, (Harahsheh and Kingman, 2004; Pickles, 2004).

Various applications of microwave heating have been proposed for the processing of minerals. One particular area is the reduction of grinding costs through a phenomenon known as thermally assisted comminution. Thermally assisted comminution is the heating and quenching of ores to reduce lattice strength, therefore, reducing grinding costs. Conventional thermally assisted liberation of minerals requires large heat inputs and the overall energy balance is unfavourable. Microwave thermally assisted liberation has several attractions mainly that as only responsive phases within the material are heated, no energy is wasted 'bulk heating' the sample. In addition, there may be no need to heat the material to high temperatures (Sener and Ozbayoglu, 1996; Kingman and Rowson, 1998; Kingman et al. 2000; Pickles, 2004)

2. MATERIALS AND METHODS:

The colemanite samples which used in the experiments were supplied from the Eti Mines Inc.'s Bigadic Boron Mines. Firstly the mineral surfaces were washed by water for removal of clay minerals and dried. Then the minerals were crushed and classified according to particle size ranges of -8+4mm, -4+2mm and -2+1 mm in order to use at the experiments. A kitchen type microwave oven with 2450 MHz frequency was used for surface modifications by microwave energy at five power levels before grinding. The samples of each size range have been under the exposure of microwave energies of 180 W, 360W, 540W and 900 w with durations of 5,10,15 and 30 minutes.

Grinding experiments were carried out with a dry ceramic ball mill of 2.5 l volume. Grinding medium was consisting of 40% of total volume and grinding time was 15 minutes for each experiment. The screening tests of samples were conducted by dry screening. The particle size distribution curves of the products were drawn by conventional methods. The effects of microwave pretreatment on the grindability of colemanite were determined by cumulative particle size distribution curves of the ground products.

2.1. Chemical Analysis

Chemical analysis of the sample were performed at Eti Mines Inc.'s Bigadic Boron Mines. Chemical composition of the samples were given in Table 1. Analysis of B_2O_3 and H_2O were done by volumetric and others were done by X-Ray Fluoressance analyzer equipment.

Table 1: Chemical assays of the colemanite samples

B_2O_3 %	CaO %	Na_2O %	MgO %	SiO_2 %	SO_4 %	SrO %	Al_2O_3 %	Fe_2O_3 %	As ppm	LOI %
49.17	26.71	0.25	1.27	2.95	0.26	0.09	0.08	0.012	3.030	19.01

2.2. Mineralogical Analysis

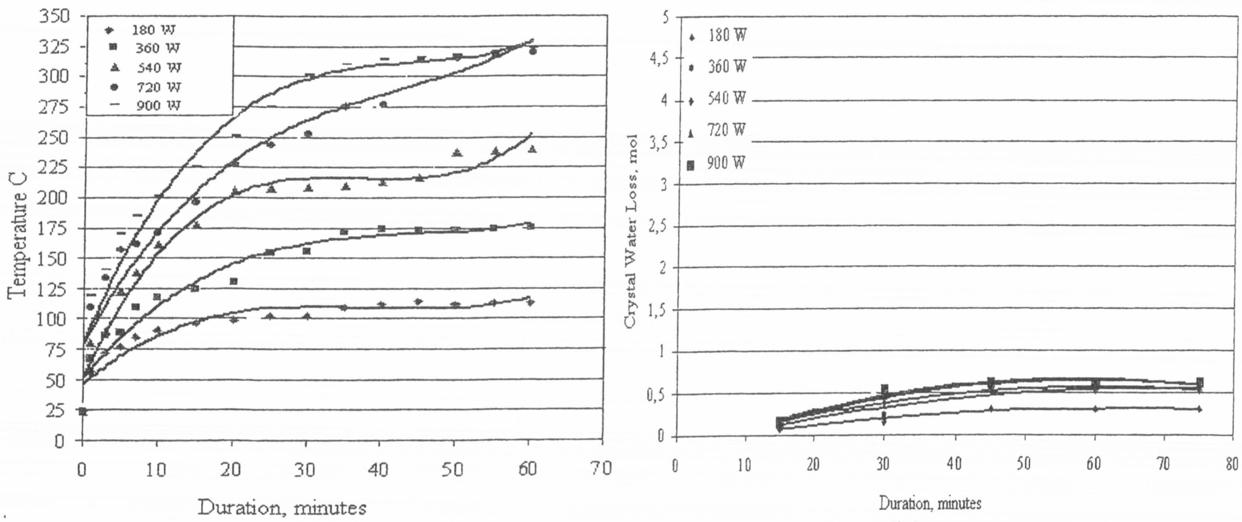
XRD analyses were also performed to determine the mineralogical structure of original sample and microwave exposed samples. The peak of the XRD assays confirms the purity of the samples. Determination was done by Rigaku D. Max. 2200 PC XRD 200 Vac 3g 20 A/50 Hz apparatus.

It was shown that mineralogical structure was stable at all of five different power levels.

2.3. Heat and moisture analysis of samples

After the exposure to microwave energy the samples were analyzed for the loss of crystal water content and the temperature levels obtained. At the systematic tests the energy levels of microwave oven were adjusted as 180, 360, 540, 720 and 900 Watts.

The temperatures obtained and the losses of crystal water content were shown in Figure 1 after the exposure to microwave energy at various levels.



(a) (b)

Figure 1: (a)The temperatures obtained after the exposure of microwave at various levels and (b) the losses of crystal water content after the exposure of microwave at various levels.

According to Figure 1 it seems that the temperatures reach to high levels in shorter time at high microwave energy levels.

Crystal water content of colemanite is 21.91% the loss of weight of colemanite after the exposure to microwave energy at 900 W level is 2.67%. This corresponds to 12.18% loss of crystal water also to 0.61 mol crystal water weight (5x0.1218=0.61).

2.4. Grindability Tests

The flowsheet of grindability tests is shown in Figure 2. In these tests three size range samples of colemanite of 100 grams were chosen. Firstly, grindabilty tests were conducted with original tests samples, then the tests were conducted with the samples after the exposure to microwave energy at 5 different energy levels with 5, 10, 15 and 30 minute durations.

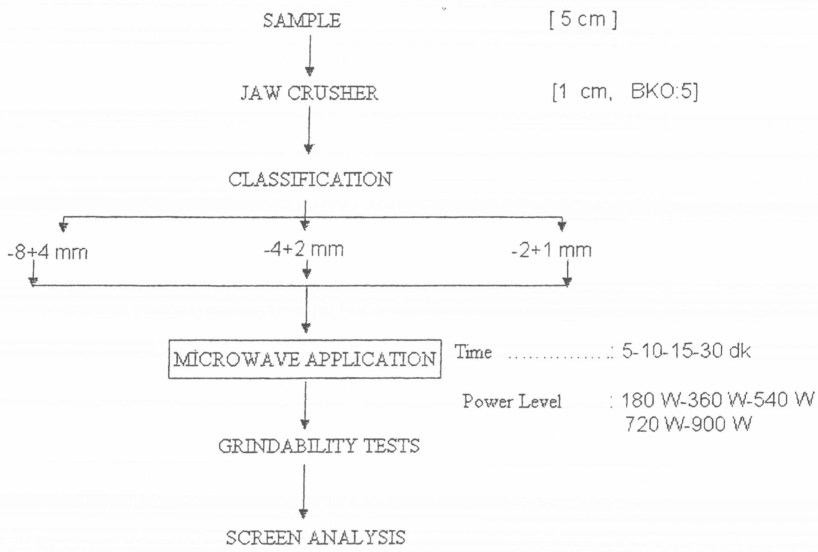
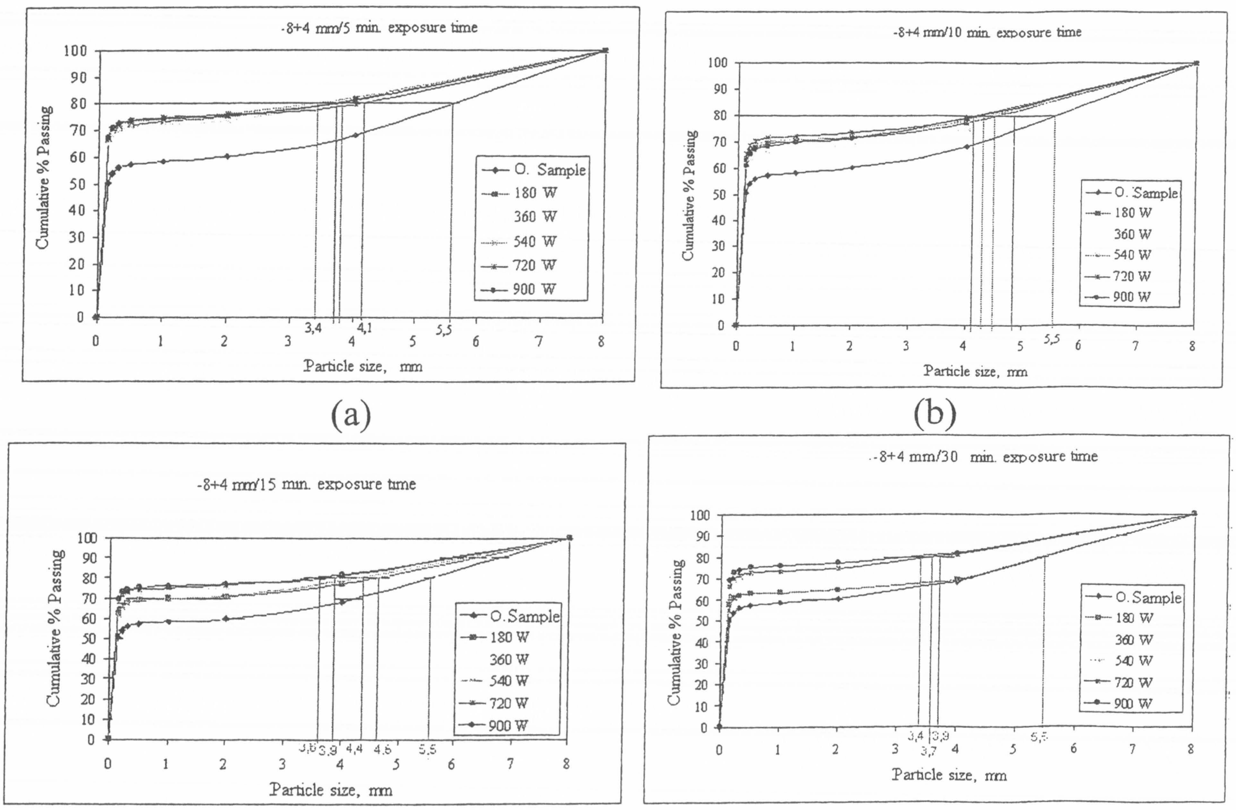


Figure 2: The flowsheet of grindability test (Eskibalci, 2007)

Grindability tests results of the samples of -8+4 mm size range after the exposure to microwave energies as % cumulative passing curves are shown in Figure 3a with five minute duration, Figure 3b with 10 minute duration, Figure 3c with 15 minutes duration, Figure 3d with 30 minutes duration.

Firstly grindability tests were conducted with original test sample -8+4 mm size range. In the cumulative percent passing curve obtained the d_{80} size is found 5.5 mm. according to the Figures 3a,b,c,d the d_{80} size decreases to 3.4 mm depending on the duration of the microwave energy. This corresponds to the decrease of 38.20% at d_{80} size. It seems that the samples were ground easier after the exposure to microwave energy.

According to grindability tests results of -4+2 size range and samples after the exposure to microwave energy there are no significant differences between original and microwave exposed samples. Corresponding figures of -0.150 mm size range are 89.19% for original samples, 89.10% for the sample after exposure to 180 W, 90.57% for the sample after exposure 360 W, 89.08% after to exposure to 720 W and 90.17% after the exposure to 900 W with 30 minutes duration.



(a) (b) (c) (d)

Figure 3: Grindability tests results of the samples of -8+4mm size range after the exposure to microwave energy.

3. CONCLUSIONS:

The temperatures of minerals having different dielectric constants reach higher levels after the exposures to microwave energies according to literature data. The grindability tests indicate better grinding after the exposure to microwave energy. Microwave energy probably creates thermal shocks producing microcracks within the material at the boundaries of crystals so that better grinding conditions are obtained.

The other fact is that the material loses some crystal water with the exposure to microwave energy and this also produces better grinding conditions. The d_{80} size

5.5 mm of the original samples reduced to 3.5 mm at the samples after exposure to microwave energies indicating better grinding.

REFERENCES:

Al-Harahsheh M.; Kingman S.W.; 2004, *Microwave assisted leaching-a reviev*, Hydrometallurgy, Volume 73, Issues 3-4, June 2004, 189-203.

Bathen D., 2003, *Physical waves in adsorption technology-an overview,* Separation and Purification, Technology, 33, 163-177.

Eskibalci, M.F., 2007, *Cevher hazirlama ve zenginlestirmede mikrodalga enerjisinin kullanilabilirliginin arastirilmasi*, Ph.D. Thesis, Istanbul University (in Turkish).

Jones D.A.; Lelyveld T.P.; Mavrofidis, S.D.; Kingman SW.; Miles N.J, 2002, *Microwave heating applications in environmental engineering- A Review,* Resources, Conservation and Recycling, vol. 34, 75-90.

Kingman S.W.; Rowson N. A.; 1998, *Microwave treatment of minerals- a review,* Minerals Engineering, vol. 11, No 11, 1081-1087.

Kingman S.W.; Vorster W.; Rowson NA, 2000, *The influence of mineralogy on microwave assisted grinding*, Minerals Engineering, Vol13, No.3, 313-327.

Pickles C.A., 2004, *Microwave heating behaviour of nickeliferous limonitic laterite ores*, Minerals Engineering, 17, 775-784.

Sener S.; Ozbayoglu G., 1996, *Effect of heat treatment on grindability of ulexite,* Innovations in Mineral and Coal Processing, The 7th International Mineral Processing Symposium Istanbul/Turkey, Atak, Önal& Çelik (eds), 29-31, Balkema, Rotterdam.

Thostenson E.T.; Chu T.W., 1999 , *Microwave processing: fundementals and aplications*, Composites: Part A 30, 1055-1071.

Vorster, W.; Rowson N.A.; Kingman S.W., 2001, *The effect of microwave radiation upon the processing of Neves Corvo copper ore,* International Journal of Mineral Processing vol. 63, 1, 29-44.

3. Physical Separation Processes

Proceedings of

THE 11th INTERNATIONAL MINERAL PROCESSING SYMPOSIUM

21-23 October 2008 Belek-Antalya, TURKEY

Edited by

G. Özbayoğlu, A. İ. Arol, Ç. Hoşten, Ü. Atalay