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Estimation of Coal Substance Liberation using X-ray CT Images

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ABSTRACT

The liberation efficiency depends on mineralogical properties of ores and the fracture produced by the high-voltage pulse crushing is extremely complex phenomenon. In this study, coal samples were applied by high-voltage pulses and fragmented particles of the tested samples were non-destructively observed by microfocus X-ray CT scanner. A method for estimating the degree of libration of coal substance from the fragmented particles based on CT images was suggested.

1. INTRODUCTION

It has been reported that the high-voltage pulse crushing was quite efficient to improve liberation of composite elements, and it has already been put to practical use for liberation of diamond.(Andres et al. 2001, Fujita et al.1999) The high-voltage pulse crushing has been applied to Nantun middling coal for coal substance liberation, and the liberation of the coal substance became much higher than that in mechanical comminution methods such as roll crusher.(Ito et al., 2006). Four coal samples from different localities has been tested by the high-voltage pulse crushing, and the liberation behaviors of mineral matters were different from each other depending on the

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kind of minerals and coal substances. Coal is a composite material which contains much kind of minerals having wide size distribution, and property of coal substance vary according to samples. Then the high-voltage pulse crushing results of the coal samples are affected by the properties of both the coal substances and the kind of minerals, and it is difficult to make clear the mechanism of preferential breakage at the grain boundaries from these results.
In this study, coal samples were applied by high-voltage pulses and fragmented particles of the tested samples were non-destructively observed by microfocus X-ray CT scanner. The libration degree of coal substance using CT images of the fragmented particles was estimated.

2. HIGH VOLTAGE PULSE CRUSHING TESTS

To apply the electric pulses to samples, the arrangement schematically drawn in Fig. 1 was used. Output voltage is defined as set voltage at high-voltage generator, and input voltage and input current are defined as measured voltage and current by digital oscilloscope, respectively. The samples were placed between two electrodes (anode electrode and cathode electrode) and immersed in water to decrease the corona discharge. The anode electrode (needle) and the cathode electrode (plate) are made of iron and copper, respectively. The applied voltage to anode electrode, which is placed in the center of upper surface of the sample, was recorded by oscilloscope directly as input voltage. The input current was measured through the current transformer connected to amplifier and the oscilloscope.

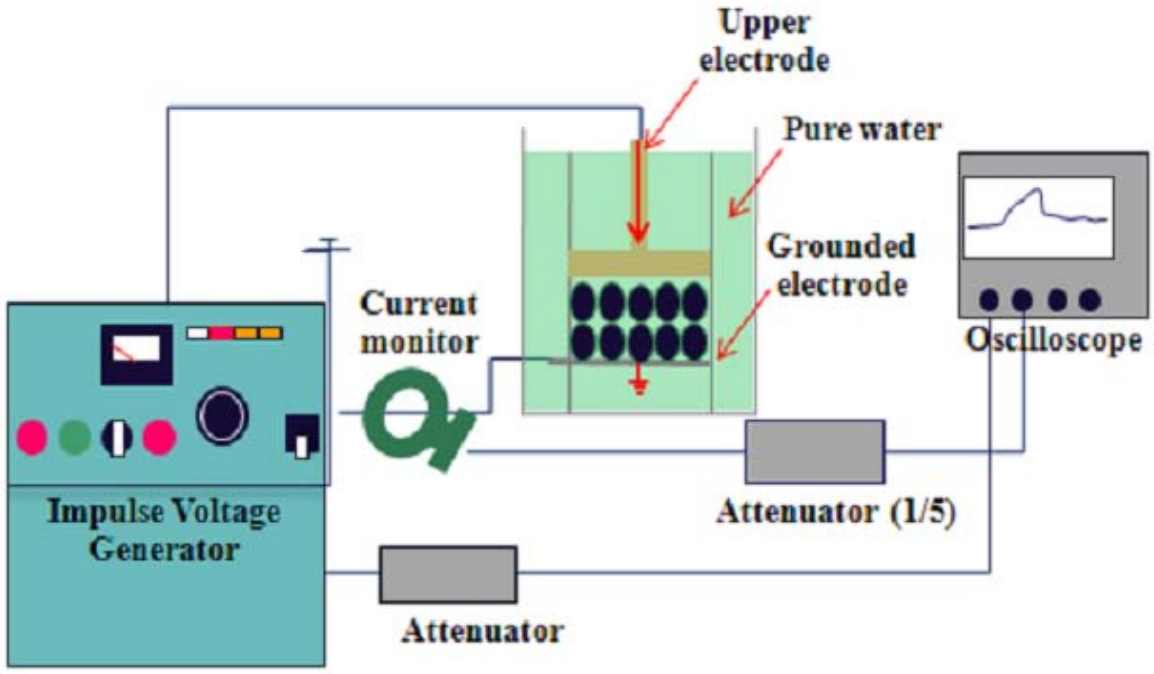

Fig. 1 Schematic diagram of high voltage pulse crush system

Coarse particles of the 4mm to 9mm fraction was used for the high voltage crush tests and high voltage discharge was applied to 3 particle layers to get a sufficient volume of product for the analysis. The three particle layer sample was set on the cathode electrode and before the test the distance between the anode and cathode electrodes was measured and 1.2L of pure water, enough to soak the sample, was filled in the disintegration container. In the tests, the applied voltages started at 10 kV and increased in steps of 5 kV until dielectric breakdown occurred. Dielectric breakdown start to occur around 25kV for the coal samples. Input voltage was set between 30-40kV and discharges repeated for 20 times.

3. ESTIMATION OF DEGREE OF COAL MINERAL MATTER LIBERATION USING MICROFOCUS X-RAY CT IMAGES

3.1 Microfocus X-ray CT scanner and non-destructive observations

Microfocus X-ray CT scanner which is installed at KIST in Korea was used to observe three-dimensional microstructure of fractured coal samples. The micro X-ray source in the CT scanner is of the ‘sealed-type’ with radiation power of up to 90kV. Its resolution is 250μA, and the minimum focal spot size is 5 microns (0.005 mm). The scanning chamber can accommodate objects of size up to 300 mm in diameter and 500 mm high. The high voltage pulse crushed samples were placed on the sample table and scanned by cone beam geometry. Figure 3 show three dimension CT images of sieved products with nine meshes which have different mesh sizes.

Fig. 2 Micro X-ray CT equipments of KICT

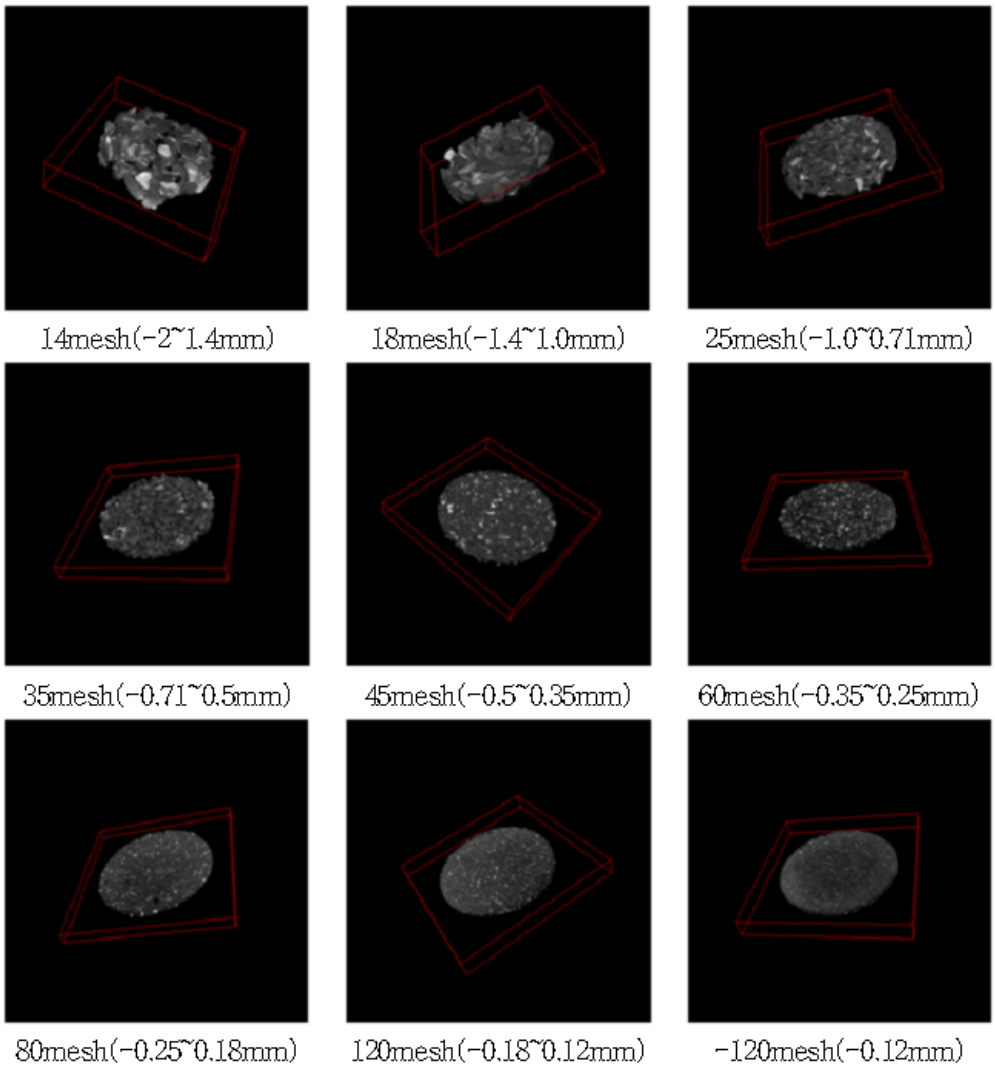

Fig. 3 Three dimension CT images of high-voltage crushing products of -9mm~+4mm coals

3.2 Estimation of the degree of coal mineral liberation

Coal substance and mineral matter have their own characteristic ash content, and exist as three kinds of particles, that is, as liberated coal substance, liberated mineral matter(MM), and locked particles of both components (Fig. 4). Here, the degree of mineral matter liberation (DML) can be obtained by the following equation:

$$DML = \frac{Area\_of\_Liberated\_MM}{Total\_Area\_of\_MM} \times 100 \qquad (1)$$

Fig. 5 show variation of the degree of mineral matter liberation(DML) with decreasing the particle size. Particles produced from high voltage crushing increased with particle size reduction and reached 90% liberation under size of 0.25mm. Particles produced by hammer mill showed lower DML throughout overall fraction.

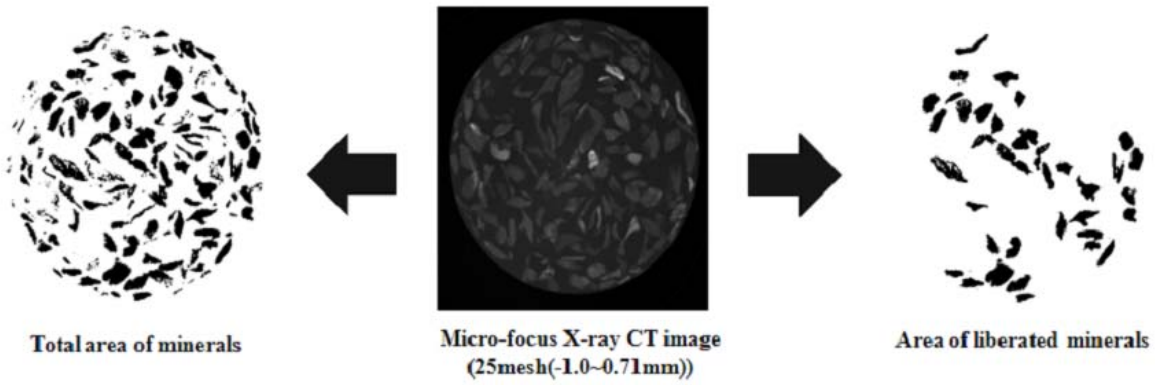

Fig. 4 Extraction of total area of minerals and area of liberation minerals from CT image

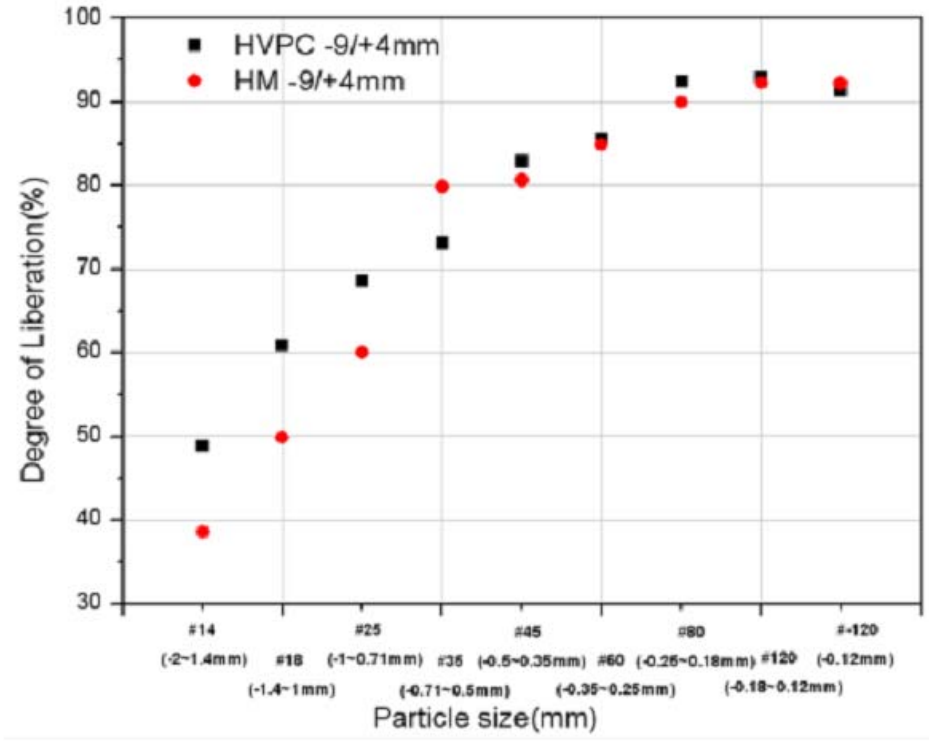

Fig. 5 Degree of mineral matter liberation

4. DISCUSSION

The comminution efficiency of artificial coal samples which includes mineral matter of coals was examined. The artificial samples were fractured by high-voltage pulse crusher. Generally, the high efficient comminution of quartz and calcite samples in large size fraction is considered to result from preferential breakage at interface between mineral particles and cement paste. Examples of CT images of fractures on interface between cement paste and mineral particles are shown in Fig. 6. The fractures at the interface between mineral particles and cement paste were mostly observed in calcite and quartz samples. Therefore, it is concluded from X-ray CT observation results that fracture on the interface between cement paste and mineral particles led quartz and calcite samples to high efficient liberation degrees in large particle size. In addition that, if high-voltage pulses were applied repeatedly, the number of the fractures on the interface between mineral particles and cement paste would increase and liberation degree of the sample in large size fraction would become higher.

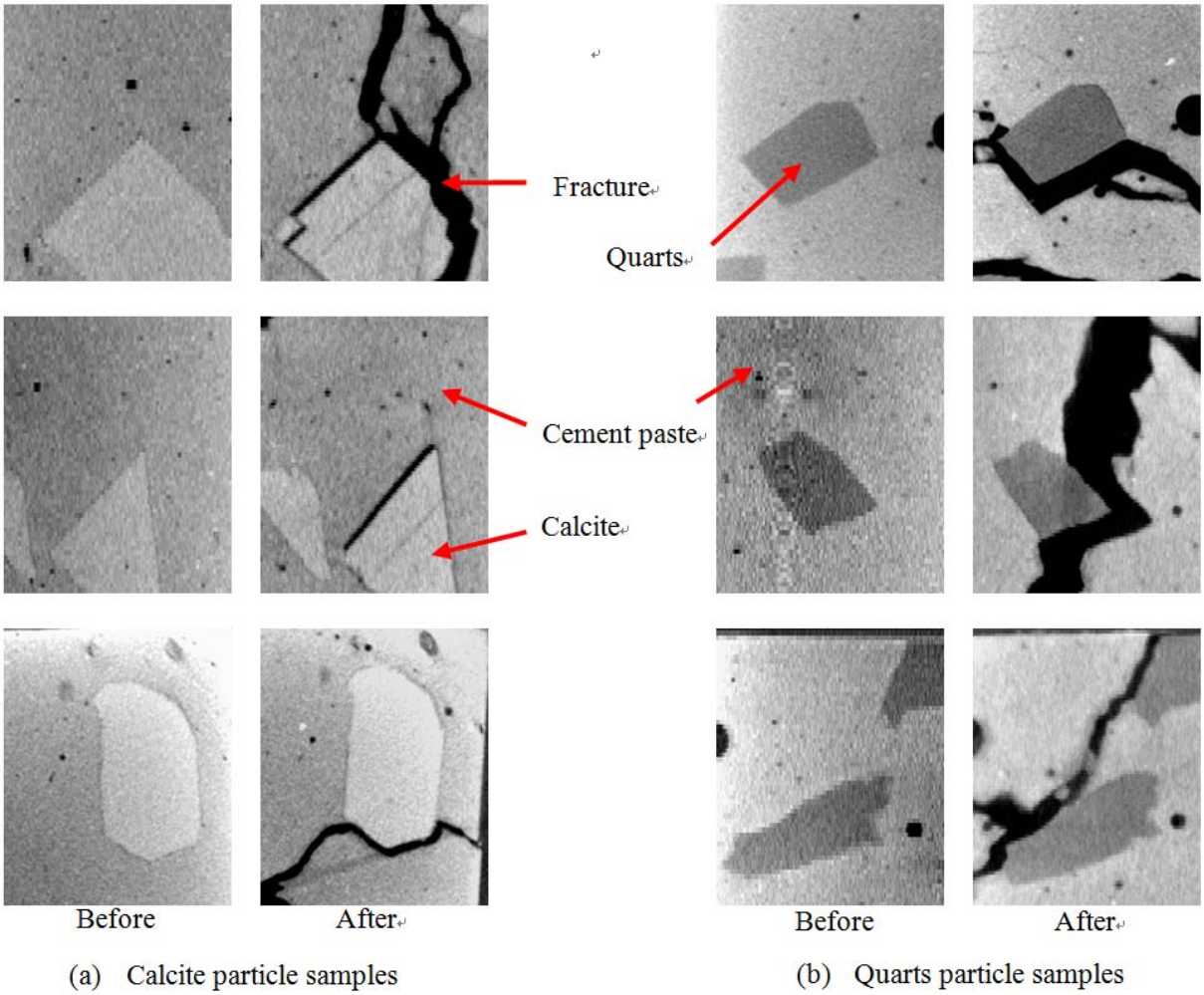

Fig. 6 Cross-sectional CT images of artificial coal samples before and after high voltage pulse crushing

4. CONCLUSION

Coal samples were applied by high-voltage pulses and fragmented particles of the tested samples were non-destructively observed by microfocus X-ray CT scanner. The libration degree of coal substance was estimated using CT images of the fragmented particles. Particles produced from high voltage crushing increased with particle size reduction and reached 90% liberation under size of 0.25mm. Particles produced by hammer mill showed lower DML throughout overall fraction. It is also concluded from X-ray CT observation results that fracture on the interface between cement paste and mineral particles led quartz and calcite samples to high efficient liberation degrees in large particle size.

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