A new method for characterizing particle crushing of cobalt crust based on fractal theory

Manhong Li, Xiaoyan Li, Hongping Tang, Hao Zheng, Jianpin Peng, Jun Li, Hong Xiao
State Key Laboratory of Exploitation and Utilization of Deep Sea Mineral Resources,
Changsha Research Institute of Mining and Metallurgy Co. Ltd., China

ABSTRACT

Fractal dimension is one of the physical parameters that can reflect ore and rock fragmentation degrees. By summarizing the inherent law of particle breakage, this paper proposed a new method for characterizing the particle crushing of cobalt crust. Linear slope and correlation coefficient for particle size distribution in log-log coordinate are chosen as the key parameters. To verify the applicability of the method, a large amount of laboratory test were conducted. In the tests, cutting depth, rotating frequency, traveling speed were controlled. Test result show that the granularity of crushed cobalt-rich crust has clear fractal property, a quite good linear fitting can be obtained by the proposed model. Thereafter, the relations among fractal dimension and cutting depth, rotating frequency, traveling speed were analyzed. The outcome of this paper may have significant meaning in application.

KEY WORDS: Particle crushing; fractal theory; laboratory test; linear fitting.

INTRODUCTION

Cobalt crust grows on smooth seamount slope from 500 to 3000 meters depth (Yamazaki and Sharma, 2000), is multi-metal ore that is rich in cobalt, nickel, silver, copper, gold, platinum, and rare-earth element. Now the cobalt crust is an emphasis of researching on deep sea mineral resources both in the home and foreign (Manheim, 1986; Glasby, 2003). Because of the complicated environment of deep-sea mining, cobalt crust cut and broken should be lifted to the supporting ship by the collection and lift system (Chung, 1994; Liang et al., 2002). Undersized granularity will pollute seabed environment seriously, yet oversized one will block the collector and lift system, so the granularity should be controlled strictly in a required range. The collective rate, mullock interfusion rate, energy consumption and the rule of granularity distribution are not only related to the structural parameters of spiral mining head, but also related to the different work parameters (penetration depth, walking speed, cutting frequency) in different tiny topography of deep sea bed. So it is necessary to develop an appropriate model of crushing cobalt crust with mining head and to investigate the influence of cutting depth on crushing process.

So far many researches have been concerned on the operation about ore-rock fragmentation, and detailed explanation of the broken mechanism have been discussed, such as maximum tension theory, maximum shear stress, classical fracture mechanics theory, and so on. These studies provided various formulas for classic distribution, such as Godin-Schuhmann distribution, Rosin-Rammller distribution, Weibull distribution to describe the laws on the fragmental degree. Many formulas are too close to distinguish and insufficient to explain in existing theory. However for the fractal theory, it has been made considerable progress on the research about ore rock fragmentation, but it has seldom been studied on cobalt crust.

Fractal is a description to the phenomena of objective world that is not smooth, continuous but not differential, fragmental. Since Mandelbort (1983) introduced fractal theory, it has extended from natural geometry to geosciences, physics, chemistry, material engineering, biology, medicine, and so on. Until now this theory has achieved brilliant application outcomes. Natural characteristics of fractal are self-similarity and scale-invariance. Practical fractal mostly is statistic, self-similarity and lineal relation of double logarithmic coordinate also is in statistic sense.

The cobalt-rich crust possess an irregular surface texture thickness, its average thickness is 4-6cm (Yamazaki et al., 1995;). And its compressive strength of deep-sea cobalt-rich crust is in the range of 3.7MPa and 36.2MPa (Larson et al., 1987). The strength is similar to medium hard coal, so the characteristics of ore body and its mining are similar to coal bed. It also has been indicated that the microstructure of crust and its bedrock typify fractal structure of self-similarity (Qin, 2005;), so we can infer that cutting granularity distribution of cobalt crust also has fractal structure.

THEORY FOR PARTICLE CRUSHING OF COBALT CRUST

As for the proper self-similarity fractal, the dimension can be calculated by definition of similarity dimension. This is to say, it can be directly determined from the fractal model of cobalt crusts crushing. But for some objective phenomenon in nature, such as