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Definition of random and non-random breakage in mineral liberation - A review

R.A. Mariano *, C.L. Evans, E. Manlapig

The University of Queensland, Sustainable Minerals Institute, Julius Kruttschnitt Research Centre, Indooroopilly, QLD 4068, Australia

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ABSTRACT

Mineral liberation is a key step in many mineral processing flow sheets and is achieved by breaking large pieces of ore into smaller particles which are suitable for the subsequent separation process. The ore being broken consists of mineral grains which may exhibit a range of properties affecting how they break. In the literature on mineral liberation the breakage of ore is frequently described as random or non-random, with several types of non-random breakage identified. With numerous researchers investigating this topic over the years, a variety of definitions of random and non-random breakage in mineral liberation have been presented in the literature. This paper examines the published work in this area and provides a comprehensive review of random and non-random breakage published in the literature on mineral liberation. It does not aim to revise the definition of these terms but to review the wide range of descriptors used by researchers in this field and identify common approaches to defining random breakage. The definition could be summarised as random liberation being the independence of breakage from both ore properties and mechanical properties during comminution.

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1. Introduction

Mineral liberation is the main purpose of undertaking comminution on ores prior to separation in a mineral processing circuit. The valuable mineral is liberated to some degree through size reduction processes by breaking large pieces of ore into smaller particles which are suitable for the subsequent separation process.

The ore being broken consists of mineral grains which may exhibit a range of properties including grain shape, grain size, Young's modulus, and these mineral properties together with other characteristics such as intergranular bond strength can affect the way in which the ore breaks. Ore texture encompasses the following properties: size and shape of the mineral grains, grain

* Corresponding author.
E-mail address: r.mariano@uq.edu.au (R.A. Mariano).

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bonding and the nature of the grain interfaces, orientation, and recrystallization and formation of secondary minerals (Malvik, 1988). According to Bérubé and Marchand (1984), Malvik (1988), Petruk (2000) and Vizcarra (2010), the grain size distribution, bonding between grains and mechanical properties of the minerals present are the main characteristics that influence ore breakage and liberation of minerals.

In the literature on mineral liberation the breakage of ore is frequently described as being random or non-random, with several types of non-random breakage having been identified (King and Schneider, 1998). Knowledge about whether an ore is undergoing random or non-random breakage during comminution is useful as non-random breakage may enhance the liberation properties that influence the behaviour of particles in the subsequent separation process. Whether the type of non-random breakage occurring in an ore is beneficial depends on the type of separation process being used. For example, non-random breakage along the surface of a mineral grain that exposes more of the mineral at the particle surface may result in a significant improvement in flotation recovery but would not increase recovery by magnetic separation. On the other hand non-random breakage of comparatively loosely bonded valuable mineral grains out of the ore matrix will result in fully liberated valuable minerals that provide the opportunity for more efficient separation in processes which exploit surface properties, particle density or leaching for recovery.

In mineral liberation modelling, random breakage is frequently assumed for simplification, although it has been recognised that there is some degree of non-random breakage in ores according to earlier research by a number of researchers including Gaudin (1939), King and Schneider (1998) and Evans et al. (2013). It is important to understand how much of the liberation in the ore being analysed is occurring due to random and non-random breakage and consequently whether liberation models based on random breakage are applicable to the ore type. If the amount of non-random breakage in ores is significant the validity of using a random breakage model must be assessed.

With numerous researchers investigating this topic over the years, a range of definitions of random and non-random breakage in mineral liberation have been presented in the literature. The definition of the word "random" in the dictionary is "without pattern or lacking regularity" (Microsoft Encarta Dictionary, 2007). Thus in reference to breakage, it is simply fracture without pattern or lacking regularity. Non-random breakage is used to signify its counterpart.

However, in the published works on mineral liberation, researchers have defined random breakage in a number of different ways. This paper provides a comprehensive review of the definitions of random and non-random breakage published in the literature on mineral liberation.

As this review of the literature demonstrates, some researchers have defined random breakage in an explicit manner; some have relied on its contrary and others have used examples and methods to illustrate the concept. The aim of this paper is to bring together the literature which ranges across the spectrum of time and researchers, and from theoretical to applied approaches and to elucidate the similarities and differences in the definitions of random and non-random breakage in mineral liberation. The scope of this paper is limited to review of the published work of the definition of random and non-random breakage in mineral liberation during comminution.

2. Definition of random and non-random breakage

Analysis of the literature on liberation modelling literature shows that the definitions of random and non-random breakage in mineral liberation presented in the literature can be categorised into five groups as follows:

1. Explicit definition of random breakage: These are the definitions where researchers have stated explicitly how they define random breakage.
2. Definition of random breakage through its contrary: Instead of defining random breakage directly, researchers have defined its opposite, the non-random breakage, in an explicit manner.
3. Random breakage defined using examples and methods: Examples and methods are cited to describe random breakage.
4. Context clue definition without directly mentioning random breakage: The word random breakage is not explicitly mentioned by the researcher, but the context may refer to a description of random breakage.
5. Other definitions: These are definitions of random and non-random breakage which do not fall under the four categories mentioned above.

The papers which have been classified in each group are summarised in the following sections.

2.1. Explicit definitions of random breakage

Author	Statements on random breakage
Meloy et al. (1987)	Used the Intergranular Area Conservation model by Meloy (1984) to derive the lockedness frequency distribution in their study. The principle of this model is that the fragment forming in a rock is a random process and independent of the position of the inclusions.
Lin et al. (1988)	Developed a model which generates progeny particles by simulating a random breakage pattern. The following assumptions about random breakage are made: cracks are randomly distributed throughout the particle; new fracture surface will contain cracks at which new fractures may originate and the progeny are result of interconnected randomly-distributed cracks.
Laslett et al. (1990)	Defined random breakage as independence of the fracturing mechanism and ore texture. They proposed a method to assess random breakage for mineral liberation using line scan-data. Fig. 1 shows the schematic diagram of the particle and breakage mechanism used for modelling. It demonstrates the isotropic uniform random (IUR) line probe crossing a particle creating an intercept (0, l). Using this theoretical viewpoint for the breakage of a homogeneous ore, the effects of random breakage assumption was assessed. They

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