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Impact crushing of particle–particle compounds—experiment and simulation

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Abstract

Particle–particle compound consists of various sized particles with non-uniform properties, whose properties vary in large range depending upon applications, methods of manufacturing and ratio of its compositions. The different types of engineering agglomerates and building materials, like concrete, are some of the examples of particle compounds. Recycling of value material from building waste such as aggregates from concrete ball provides impetus to investigate particle–particle compounds.

The liberation of aggregates is carried out by impact crushing in a large scale pneumatic cannon. Both experiments and Finite and Discrete Element simulations are adopted to study the cracking phenomena of aggregates. Also, the different aspects of crushing of particle–particle compounds at different velocities are discussed.
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Keywords: discrete element method; finite element method; crushing; impact; concrete

1. Introduction

The different types of engineering agglomerates and building materials like concrete are some of the examples of particle–particle compounds. Similarly, the proper recycling of particle compounds is very important in order to utilize value materials. The liberation of value material from building waste, such as, aggregate from concrete provides the impetus to investigate particle–particle compounds for recycling. The properties of these compounds vary widely depending upon applications, methods of manufacturing and ratio of their components. Even if the manufacturing conditions are kept constant their properties may be different due to the random positioning of their ingredients.

The aggregate material as the value component is fixedly embedded in concrete so that liberation can only occur by forced crushing. During this process, the bonds between aggregate and hardened cement paste, which is the second but valueless component, have to be burst. Both experiments carried out in a large-scale pneumatic cannon and simulations in forms of Finite Element Analysis (FEM) and Discrete Element Method (DEM) help to find out about conditions for aggregate liberation.

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The beginning analysis of the liberation of aggregate from hardened cement paste was carried out by Kiss (1979) and Kiss and Schönert (1980). Single particle crushing experiments were performed to investigate whether impact, double impact or compression stressing is more suitable for liberation. Spheres of 10 mm in diameter consisting of sand particles embedded in hardened cement paste were used as mineral model material. Arbiter et al. (1969) produced spheres between 74 and 124 mm in diameter from a mixture of flint-shot sand particles and high early strength cement and water to test the free fall at stressing velocities up to 7.6 m/s. It is shown by Schubert (1993) that impact stressing conditions increase the fracture probability of brittle feed material. Herbst et al. (1973) applied mass balances to describe the liberation process more in general. Tomas et al. (1999) analyzed the liberation of aggregate particles during impaction of comparatively large 150-mm concrete spheres at velocities up to 75 m/s. Tavares and King (1998) studied the single particle breakage under impact loading. The liberation and comminution of minerals is presented by King (1994). The goals of all investigations are to observe the crack formation, fracture patterns and particle size distribution.

Kienzler and Baudendistel (1985) investigated elasto-viscoplastic conditions for spheres using FEM simulations. DEM simulations of impact breakage of spherical agglomerates were carried out by Kafui and Thornton (2000) and Thornton et al. (1999). Mishra et al. (2001) found different parameters, which influence the breakage of agglomerates through impaction. Similarly, the solid particle failure under normal and oblique impact was studied by Salman et al. (1995), Salman and Gorham (2000), who used aluminum oxide particles of 5.15 mm in diameter as material and soda lime glass spheres, which diameters ranged between 0.4 and 12.7 mm.

The two-dimensional Finite Element Analysis is carried out with central impact loading condition to understand the stress pattern distributions before cracking rather than to stick in numerical play. In reality, the classical continuum approach is not suitable for the analysis of the particle compound as continuum theory assumes the material as contin-

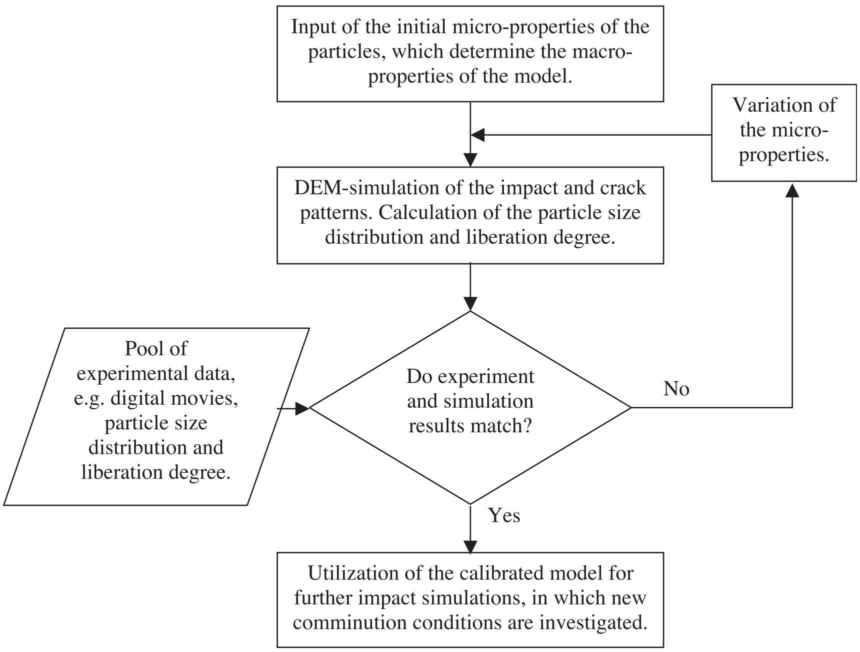

Fig. 1. Calibration procedure of the DEM model of a concrete ball, in which crack patterns, particle size distributions and liberation degrees obtained from experiments are chosen as references.

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