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Usage of air jigging for multi-component separation of construction and demolition waste

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A B S T R A C T

The use of air jigging for performing multi-component separation in the treatment of mixed construction and demolition waste was studied. Sorting tests were carried out with mixtures of equal bulk volume of concrete and brick in which fixed quantities of unwanted materials - gypsum, wood and paper - were added. Experimental results have demonstrated the possibility to use air jigging to carry out both the removal of low-density contaminants and the concrete concentration in only one process step. In relation to the removal of contaminants only, the overall performance of jigging process can be comparable with that of commercial air classifiers and automatic sorting systems. Also, the initial content of contaminants seems does not have a significant effect on the separation extent. These results are of particular importance for recycling plants processing as they represent an alternative to optimize the use of air jigs. Further investigation is needed in order to evaluate the practical feasibility of such method.

1. Introduction

Construction and demolition wastes (CDW) constitute a major waste generated worldwide. Environmental pressure with regard to waste disposal and the exploitation of non-renewable raw materials have encouraged the search for viable technologies for recycling of CDW. The choice of appropriate recycling techniques depends on to a great extent on its composition. Mixed CDW typically consists of stony fraction (concrete, ceramics, mortar and aggregates), metals (steel, iron, copper and aluminum), non-stony fraction (plastics, wood, paper, organic materials and glass) and, occasionally, hazardous wastes as lubricants, oils and materials containing asbestos and heavy metals (Llatas, 2013).

For each of these groups, a set of techniques has been addressed in order to upgrade the quality of the recycled concrete. For instance, is considered a good practice to separate organic materials such as wood and paper using air blowers, float separators or hand picking (Silva et al., 2014). Ferrous and non-ferrous metals are usually removed from CDW by means of magnetic and eddy current separators, respectively (Xing and Hendriks, 2006; Coelho and de Brito, 2013a). Stony constituents such as clay bricks and gypsum are comparatively harder to separate and have a direct impact on the quality of recycled concrete aggregate (RCA) produced. In particular, special attention should be given to the gypsum waste, since it is a major source of sulfates, having potential to harm the microstructure in secondary concretes and also to increase the generation of hydrogen sulfide (H_2S) in landfills (Montero et al., 2010; Godinho-Castro et al., 2012). In this sense, several techniques have been proposed in order to improve the separation of stony constituents from the concrete fraction, with emphasis on mineral dressing operations (Xing and Hendriks, 2006; Tam and Tam, 2006; Angulo et al., 2010; Ulsen et al., 2013; Cazacliu et al., 2014).

Among these techniques, air jigging has been pointed out as an appropriate technology for use in high-performance recycling plants (Coelho and de Brito, 2013a; Cazacliu et al., 2014; Sampaio et al., 2016). Jigs are gravity concentrators, i.e. they perform separation of particles into classes according to their specific gravity, in which a particle bed is repeatedly submitted to expansion and contraction strokes by means of pulsation of water or air (Burt, 1984; Sampaio and Tavares, 2005). The result is the

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stratification of the bed into layers of increasing density from the top to the bottom. Air jigging is derived from more conventional water jigging, and even though it is not as efficient as this one, it has important economic and environmental advantages by not using process water (Weinstein and Snoby, 2007). Recent studies have shown that air jigging can significantly improve the quality of RCA by removing gypsum and brick, resulting in a product with concrete content higher than 90% in mass (Cazacliu et al., 2014; Sampaio et al., 2016).

However, despite the significant quality improvement of the recycled aggregate, the use of air jigs implies higher processing costs than those of conventional recycling plants. For instance, Coelho and de Brito (2013b, 2013c) showed that costs associated with purchase and maintenance as well as energy consumption of air jigs can be higher than any other equipment in a dry recycling facility. Given the impact of the treatment process on the price of the recycled aggregates, the search for improvements that upgrade product quality while maintain the economic benefits is mandatory in order to become recycled aggregates more competitive in comparison to natural aggregates.

Simultaneously, there has been a growing interest in improving the performance of pneumatic classifiers used to separate low-density wastes such as paper and wood. This category includes the drum density separator, the zigzag air classifier and vertical or diagonal windshifter (Peirce and Wittenberg, 1984; Sampaio and Tavares, 2005; Nihot, 2015). Typical pneumatic classifiers use a continuous air flow to separate constituents with different terminal velocities (Peirce and Wittenberg, 1984). However, the density separation efficiency is considered relatively low due to the significant effect of the size and shape of the granules. In this sense, previous studies have been proposed the development of pulsed flow air classifiers (Everett and Peirce, 1990; Duan and He, 2005; Cheng-long et al., 2009) in order to diminish such influences. These separators use a pulsed air stream in such way that particles are submitted to successive cycles of acceleration-deceleration. The aim of the method is to prevent particles to reaching the terminal velocity since the initial acceleration of falling particles depends only on the densities of the solid and the fluid and is independent of the particle size (Wills and Napier-Munn, 2006; Riazi and Gupta, 2015). Thus, the distance traveled by the particles is mainly affected by the differential initial acceleration, and therefore by particles densities. It is interesting to note that the differential initial acceleration constitutes one of the three mechanisms involving in the jigging phenomena according to the classical theory of stratification in jigs proposed by Gaudin (1939) (the other mechanisms are hindered-settling and consolidation trickling). Indeed, the separation method of pulsing air classifiers has striking similarities with air jigging in such a way that even its original development has been pointed as derived from the concept of jigging (Stessel and Peirce, 1986).

On the basis of the foregoing, it is very reasonable to suppose that air jigs can be able to separate low-density wastes from a particle bed in a similar way as pulsed air classifiers do. Moreover, given that air jigs are able to sort coarse aggregates with nearly equal densities (as concrete and brick), the separation of organic impurities is expected to be an easier task. In this case, an air jigging system could perform the removal of light contaminants from the stony fraction and the concentration of heavy aggregates in a single stage. In terms of processing, this could enable air jigs to work directly with mixed CDW, reducing the number of process steps necessary to recover the recycled aggregate and thus decreasing the cost per ton of CDW processed.

In order to investigate the technical applicability of the aforementioned approach, this study aims to examine the usage of an air jigging device to simultaneously carry out the separation of organic impurities, gypsum and brick from the concrete fraction in only one single stage. The sorting process and the composition of jig products for a batch scale operation were examined in detail. Experimental results show the potential of the multifunctional use of air jigging to combine processing steps and also provide the framework for future studies to assess the feasibility of practical implementation.

2. Experimental setup

2.1. Equipment

The experiments were performed in a batch pilot-scale air jig model AllAir® S-500 from AllMineral, which is able to reproduce the sorting process experienced in an industrial jig. The jig has a capacity of approximately 50 kg per batch and a grain size range of 1–25 mm. The complete jigging system includes a blower, separating chamber, control panel and dust collect unit, as displayed in Fig. 1. The separation in the jig occurs as a result of the passage of a pulsating air flow through the bed of particles that are supported on a perforated plate (Ø = 1 mm) inside the separating chamber. During the process, two distinct upward air flows pass simultaneously through the bed. While a continuous flow keeps the bed in a pre-expanded state, a pulsating flow promotes successive strokes of dilation and compaction of the bed. This creates conditions to segregate particles of different densities due the relative vertical motion of the grains in response to the combined action of the air drag force (upward motion) and the gravity force (downward motion). The net result is the concentration of denser materials in the lower zones of the bed and lighter materials in the upper ones.

In the control panel is possible to set the fluidizing air rate and the pulse frequency of the air flow. The first is adjusted in terms of the percentage of the blower power (Combimac 49631/B1Y1), ranging from 0% to 100%. The blower power is 15 kW and it delivers air flow up to 73 m^3/min. The pulse frequency is adjusted in function of the rotation of a pneumatic flutter valve (from 0 to 300 rpm) that controls the air intake into the separating chamber. This consists of several overlying layers of PlexiGlass (500 × 500 × 25 mm) which can be removed separately so that different vertical strata of the bed can be sampled after the stratification.

2.2. Materials

The tests were conducted with binary mixtures of concrete and brick wherein limited amounts of gypsum, wood and paper were added. The presence of such constituents, including the brick, is highly undesirable since they compromising the quality of the RCA produced (Martín-Morales et al., 2013). Concrete and brick particles in the size range of 12–20 mm were prepared from the separate crushing of concrete laboratory compressive cylinders (type 30 MPa at 28 days) and solid clay bricks, respectively. In this mixture, the bulk volumes of each component were those necessary to completely fill two layers of the separating chamber, corresponding to 18,245 g of concrete and 13,239 g of brick. Gypsum particles in the same size range were obtained from solid gypsum blocks. Wood and paper scraps were collected directly on a building site and consisted of wastes of transport pallets and drywall panels, respectively. All materials were virtually dry so that the effect of moisture content on separation efficiency was considered negligible. The particle density of concrete, brick and gypsum were measured by means of water displacement after waterproofing, with values being of 2.39 g/cm^3, 2.26 g/cm^3 and 1.86 g/cm^3, respectively.

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