Minerals Engineering 23 (2010) 321–325

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Controlled wash water injection to the hydrocyclone underflow

M.G. Farghaly [a,*], V. Golyk [b], G.A. Ibrahim [c], M.M. Ahmed [c], Th. Neesse [a]

[a] University Erlangen-Nuremberg, LUR, Paul-Gordan Str.3, 91052 Erlangen, Germany
[b] AKW, Equipment and Process Design GmbH, Hirschau, Germany
[c] Mining and Metallurgical Engineering Department, Faculty of Engineering, Assiut University, Assiut 71516, Egypt

ARTICLE INFO

Article history:
Received 6 August 2009
Accepted 26 September 2009
Available online 27 October 2009

Keywords:
Hydrocyclone
Fines
Controlled water injection

ABSTRACT

In hydrocyclones, the classification efficiency is limited by the fines, which are discharged together with the water in the underflow. It is well known that the injection of water in the conical portion of the cyclone reduces the fines in the underflow. This paper presents an improved technique, which is done via an injection at the upper end of the apex or the conical end. This results in a greater washing effect and reduced consumption of wash water. The process is stabilized by controlled water injection specific to the underflow shape. This controlled wash water injection is applied to kaolin processing for the reduction of kaolin losses in the cyclone underflow.

A series of tests using 50-mm cyclones was conducted in this work, which demonstrates the marked improvement of the partition curves using controlled water injection.

1. Introduction

There have been several attempts focused on improving the washing of the sediment in the conical section of the hydrocyclone (Honaker et al., 2001; Udaya et al., 2004, 2005). Tangential water injection into the cyclone cone has been applied to displace feed pulp water in the underflow stream and increase the sharpness of the separation (Dahlstrom, 1954). The process was first used in the paper industry (Bradley, 1965). Dahlstrom (1954) successfully adopted this technique for desliming mined products. Kelsall and Holmes (1960) developed and demonstrated the first unit for the classification of sand, in which 48% of the <10 micron material in the feed transferred to underflow was reduced to 11.5% after water injection. Experiments with coal were performed by Firth et al. (1955) on a modified hydrocyclone with water injection.

Patil and Rao (1999) studied the performance of a hydrocyclone with a truncated cone and water injection apparatus. Experiments were conducted using water and ground silica. Mohanty et al. (2002) investigated a cyclone with a cone water injection (Cyclowash) in the cleaning process of coal fine particles <45 μm, and compared the results with the conventional cyclones. A classification study was performed by Udaya et al. (2005) to recover free minerals from a ground lead–zinc ore. These investigations were carried out using a 100-mm water injection cyclone. The effects of different variables on the performance of the cyclone were measured. The results indicated that the entrapment of free heavy minerals of lead and zinc in the underflow product could be minimized via the water injection cyclone. The authors found that the cut size (d_{50}) gradually increases with the water injection rate until a value of 100% of the underflow water is reached, and then increases sharply with further increases in the water injection rate. The results also indicated that the imperfection values for the sharpness of the separation decrease gently with increased water injection rates. They concluded that the optimum water injection rate is approximately 100% of the underflow water rate.

In summary, the application of water injection in cyclones has been restricted up to now to special cases and separations in the coarse range. The addition of water disrupts the cyclone flow and can easily deteriorate the separation. A further disadvantage is its sensitivity to changing feed conditions.

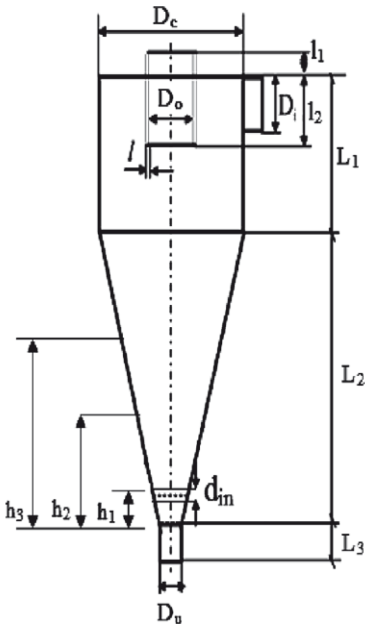
2. Experimental

2.1. Hydrocyclones

The test rig consisted of a 50-mm hydrocyclone that was fed with a centrifugal pump and operated in a closed circuit. The hydrocyclone parameters are listed in Fig. 1. The cone end of the hydrocyclone was modified to have a circular ring with 3 and 5 openings at equal distances on the perimeter, which were used for the wash water injections. A control valve was installed in the duct of the water injector, through which the water rate (l pm) could be adjusted to the desired value.

* Corresponding author. Address: University Erlangen-Nuremberg, LUR, Paul-Gordan Str.3, 91052 Erlangen, Germany. Tel.: +20 198989426.
E-mail address: m_galaly@yahoo.com (M.G. Farghaly).

0892-6875/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mineng.2009.09.021



Parameter	Dimension
D_c	50 mm
D_i	8x18 mm
D_o	varied
D_u	varied
L_1	130 mm
L_2	350 mm
L_3	135 mm
$l_1 + l_2$	79 mm
l_2	40 mm
l	8 mm
d_{in}	1.5 ; 2.5 mm
h_{in}	h_1= 40 mm h_2= 80 mm h_3= 120 mm

Fig. 1. Geometry of the 50-mm hydrocyclone with water injection.

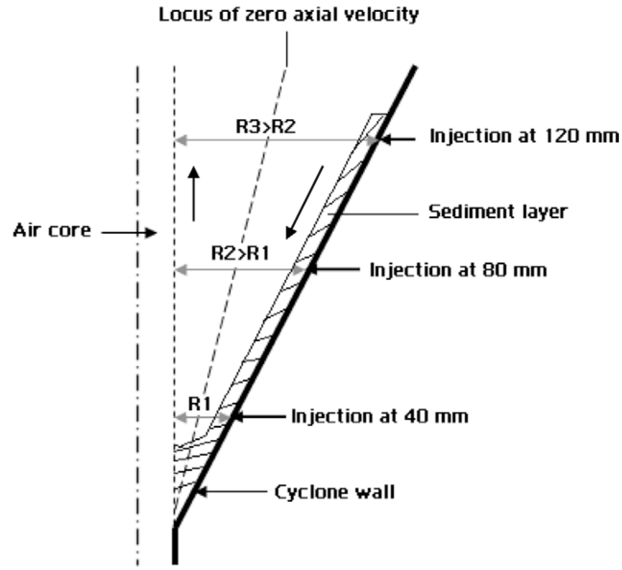


Fig. 3. Locus of zero axial velocity (Kelsall, 1952) for the different injection heights.

2.2. Materials

The feed consisted of 30% feldspar (coarse) and 70% kaolin (fine). Fig. 2 presents the typical bimodal particle size distribution of a feldspar/kaolin mixture. The goal of the classification in hydrocyclones is to separate the valuable kaolin in the overflow. The application of water injection to the hydrocyclone should reduce the kaolin loss from misplaced fine particles in the underflow.

2.3. Test series

2.3.1. Injection height

The concept of the water injection is shown in Fig. 3. The inner and outer vortices are responsible for the separation of the particles. A line called the locus of zero axial velocity divides both vortices (Kelsall, 1952). The downward directed outer vortex transports the coarse sediment to the underflow. Simultaneously, the fine particles move in the inner vortex upward to the overflow. The goal of the water injection to the cone is: to produce a radial flow that is directed to the cyclone center. This flow should wash the sediment and transport the extracted fine particles to the inner vortex. Thus, the radial injection flow must overcome the zero point of the axial velocity. Of course, the distance from the injection point to the inner vortex becomes shorter as the injection approaches the cone end. This was the concept which has been used to develop and install the injection point at the cone end. This should result in a maximum washing effect with low consumption of injection water.

To fully understand this influence, the injection was installed at different distances from the cyclone end: 40 mm (end of the apex), 80 mm, and 120 mm. In Fig. 4 the partition curves are presented for the tested positions of the injection for a moderate injection rate of 3 L/min.

As expected, the best result is obtained when the injection point is positioned at the cone end (40 mm). This is especially exhibited in the washing effect, which is characterized by a decrease of the T_0 and T_{min} values of the partition curve (see Fig. 5).

Fig. 6 indicates that at low injection rates the cut size is decreased. The dilution of the sediment leads to better settling conditions of the coarse particles. Therefore, a moderate decrease of the cut size d_{50} is understandable. These positive tendencies are most prominent at the 40 mm injection distance.

2.3.2. Injection velocity and injection rate

For fine particle displacement to the inner vortex, it is necessary to overcome a minimum tangential injection velocity V_{in}. The injection velocity is determined by the water injection rate Q_{in}, the diameter d_{in} of the injection channel, and the number n of

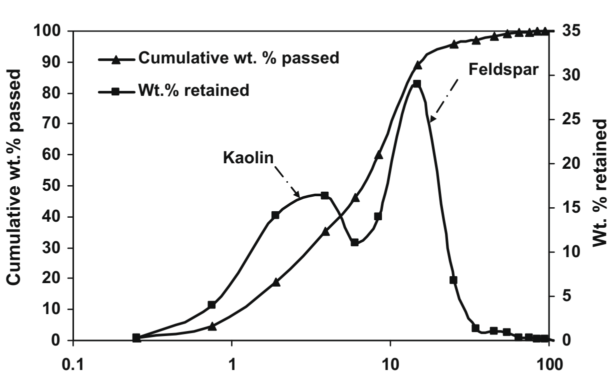


Fig. 2. Particle size distribution of feldspar/kaolin feed material used in a 50-mm water injection cyclone.

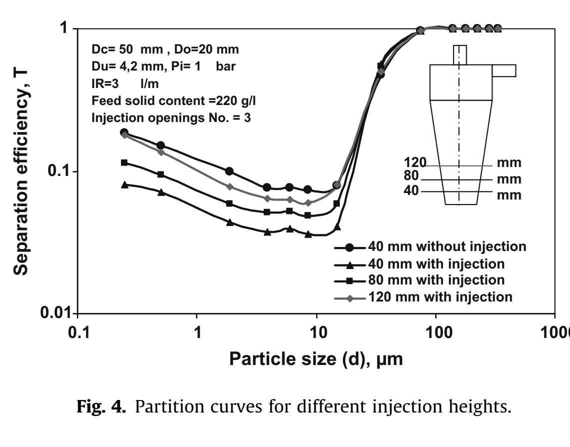


Fig. 4. Partition curves for different injection heights.