DEVELOPMENT OF A NEW ATTRITION INDEX USING SINGLE IMPACT

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Abstract

Alumina breakage is a significant problem for alumina producers. Weak alumina tends to result in difficulties in materials handling, excess loss of product and environmental issues. Alumina strength is currently measured, as it has been for many years reported as Attrition Index using the Forsythe technique and apparatus. However this test suffers from a number of drawbacks. The main one is that since it only considers the change in < 45 fl m , it falsely reports as strong alumina a weak alumina with a coarse size distribution.

A project to examine an alternative method for determining alumina strength based on single particle impact is underway with Central Queensland University's PELM (Process Engineering and Light Metals) Centre, Gladstone. An apparatus similar to that developed by Ghadiri (University of Surrey, UK) has been constructed keeping in mind simplicity of construction and use. The principle of the apparatus is to accelerate alumina particles using the vacuum of a small chamber in which a target is positioned. Each particle impacts the target once, as the method name suggests, and either breaks or survives the impact. After the whole sample has passed through the apparatus, both the initial and impacted sample are analysed to determine the extent of breakage. Results will be presented of a series of aluminas from several locations, corresponding to different morphology types. Breakage will be compared with the current technique according to the ranking of strong or weak product.

Introduction

Alumina breakage is a significant problem for alumina producers. Weak alumina, and consequent fines production can result in difficulties in materials handling, excess loss of product and environmental issues. Alumina strength is currently measured using the Forsythe technique, which involves producing a fluidised column of alumina in a standardised arrangement and measuring the change in the mass of particles < 45 fl m over a set period of time. Although used as a standard test in the alumina industry for a number of years, the test suffers from a number of drawbacks. First, the test requires a large volume of material to be tested and takes an hour or more to complete. This makes it poorly suited to process control. Second, the attrition of the particles is poorly controlled, as there may be dead spaces in the fluidised bed where the particles receive a different level of attrition to particles more directly in the fluidised stream. Thirdly, the method of measuring attrition by only considering the change in <45 fl m particles has been found not to be a satisfactory discriminator. In particular, a weak alumina may be reported as being strong simply because its initial particle size was large. A new method of measuring particle strength would be of advantage to the industry [1-4].

This project is to examine an alternative method for determining alumina strength based on single particle impact. This apparatus involves small number of particles impacting a target and has the potential to provide a more uniform loading of particles while being able to carry out the tests in a short period of time using a minimum of material. The process developed by Bentham et al.[3] used a glass tube to funnel particles towards a target for a single impact event. Once the particles leave the target, they are collected on filter paper and sized. The particles are driven by a vacuum behind the filter. The advantages of this process are that a large proportion of the particles in the sample receive a similar impact event. The breakage behaviour obtained should then be able to be related to relatively uniform treatment of the particles. The testing procedure should also require much less material and be carried out over a shorter period of time than for the Forsythe technique. The technique offers the possibility of providing a simple, rapid testing technique for determining alumina strength that ultimately could replace the Forsythe technique.

The project proposes a modification of the Bentham et al. [3] technique to examine the breakage behaviour of alumina particles. This paper reports on the first two stages of the development of this device. These are:

- Design and commissioning of a modified test apparatus using similar design principles to Bentham et al. [3]
- Testing of three different alumina types to demonstrate the ability of the equipment.

Design of the equipment

Despite the differences in properties between alumina and the materials tested in the paper by Bentham et al. [3] (paracetamol, lactose), calculations have shown that the impact requirements for breakage are similar and so the equipment was designed along similar lines. Although there are few design details given by Bentham et al. [3], the paper indicates that impact velocities vary from 3 m/s to 20 m/s and that the length of the glass tube down which the particles travel is 1 m. In designing the equipment, provision must be made for being able to vary the tube length and diameter in order to allow for a range of particle impact velocities. The apparatus must therefore be in a modular form in order to allow for these variations.

The device manufactured at Central Queensland University (CQU) followed a similar design to that shown in Figure 1. The device was constructed with a 2.8 mm diameter glass tube, 730 mm long. The initial set-up of the device was so that average gas velocities in the tube could be varied from 0.8 m/s to 100 m/s. The impact target was mild steel.

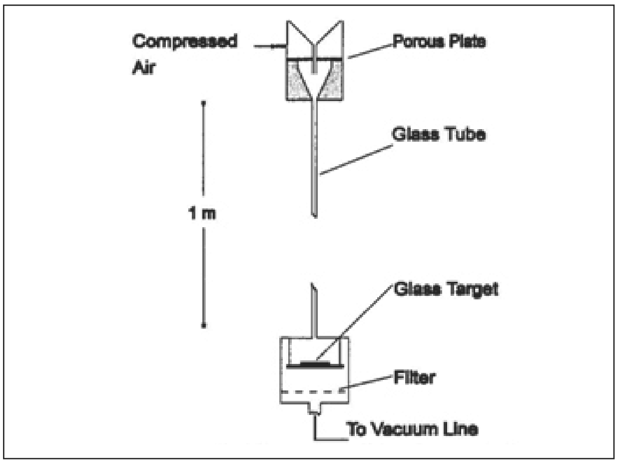

Figure 1. Ghadiri test apparatus (from [3]).

To carry out a test, the rig was assembled and the vacuum was applied until steady state was reached. The pressure difference between the upper and lower chambers (ΔP) was then adjusted to provide the desired reading. The pressure in the top chamber was also measured and this was used to calculate the air stream velocity in the tube according to the Hagen-Poiseuille equation. Samples of alumina were prepared into 5g batches and these were gradually fed into the device by hand in such a manner as to minimally impede the flow of air through the device. In later experiments, a microriffler was fitted to the inlet of the device to provide a repeatable delivery rate of particles.

Once the test was complete, the bottom of the device was removed and the alumina was removed from the filter paper. Tests showed that little material remained in the filter paper after the alumina was removed, and the filter paper could be reused without interference. Samples of the attrited alumina were then tested using a Malvern Mastersizer to determine particle size distribution.

Initial particle size distribution

Testing of three types of alumina was carried out. These were supplied anonymously and are labelled B, F and Q. All three samples had been tested using the conventional technique based on attrition index, the samples were graded as Strong, Medium and Weak, respectively.

As can be seen in Figure 2, Series F and Q showed very similar particle size distributions, whereas Series B had a smaller average particle size. It has been suggested that the initial particle size distribution has a significant effect on attrition index by the conventional industry method.

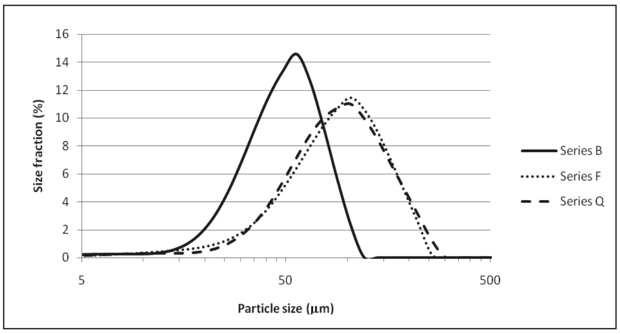

Figure 2. Initial size distribution of alumina test samples.

Repeatability of the tests

The first series of tests was carried out using only Series Q samples. Repeat tests were performed in order to gauge the inter-test variability. In this series, 15 samples were passed through the rig under nominally identical conditions. At this stage the air stream velocity was not measured but was approximately 100 m/s and provided a high degree of breakage. The results of the particle size testing are shown in Figure 3.

As can be seen, the particle size distributions fall into two distinct bands for "as-received" and "after breakage". Significant levels of alumina breakage were observed in these samples, expected as Series Q was known to be a "weak" alumina product. Important to note is that the variability between alumina samples after breakage was small, suggesting that repeatability of the test was good. For the initial material, the cumulative % passing 48 μm was found to be an average of 24.8% with a standard deviation of 2% based on 13 samples. For the samples after breakage as shown in Figure 3, the average cumulative % passing 48 μm was 79.4% with a standard deviation of 1.4% based on 27 samples.

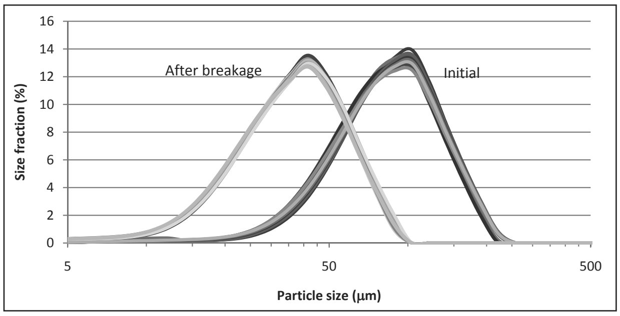

Figure 3. Repeatability of test results for Series Q (13 samples of as-received (initial) and 15 samples attrited under nominally identical conditions)

Effect of distance from tube to target

The distance from the tube to the target was varied from 3 mm to 50 mm. The results indicated that the effect on breakage for this type of alumina was not significant. The results are shown in Figure 4. The results show that a slightly greater breakage was observed as the distance from the target increased, however the effect is very slight and not at this stage statistically proven.

Effect of air stream velocity

The air stream velocity was set by controlling the pressure in the upper chamber of the device. The average velocity in the tube was calculated using the Hagen-Poiseuille equation and was not at this stage measured directly. The calculated average air velocities in the tube varied from 0.8 m/s to 95 m/s. For these tests the distance from the end of the glass tube to the target was set at 50 mm. All three series of alumina were used and the results are shown in Figures 5, 6 and 7.

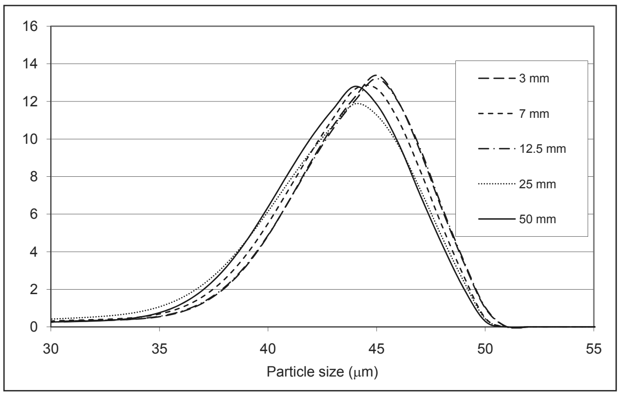

Figure 4. Effect of distance of the end of the glass tube to the target on the final particle distribution for Series Q.

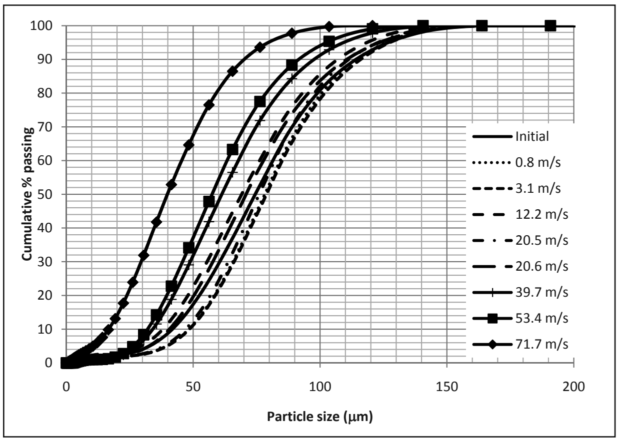

Figure 5. Effect of air stream velocity on particle breakage for Series B.

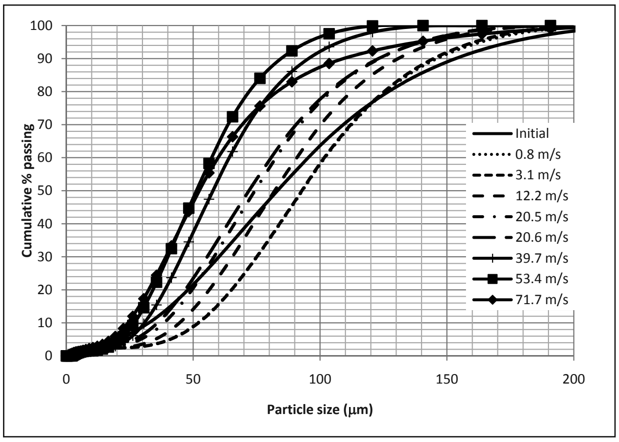

Figure 6. Effect of air stream velocity on particle breakage for Series F.

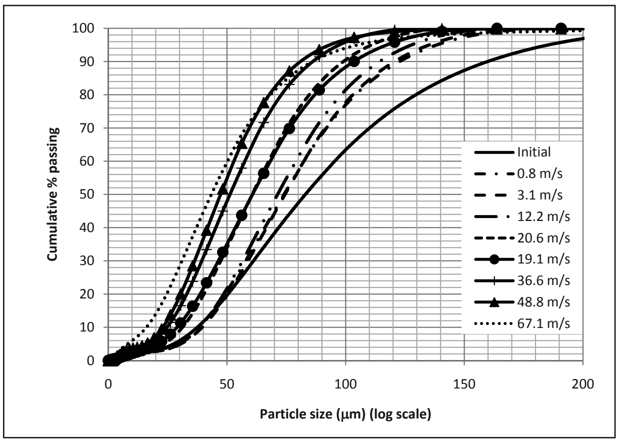

Figure 7. Effect of air stream velocity on particle breakage for Series Q.

It is obvious particle breakage was dependent on air stream velocity and the breakage profiles with respect to the air stream velocity for each of the series were different. Series Q showed a greater degree of breakage than Series B and Series F. This is particularly notable when comparing the results for Series F and Series Q, which had more or less the same initial particle size distributions.

In order to simplify the analysis, the breakage characteristics were also assessed on the basis of the cumulative % passing 48 μm. The results of this testing are shown in Figure 8.

As can be seen, there is a reasonable amount of scatter in these tests. However, the breakage trend for the Q Series was greater than for the other two samples.

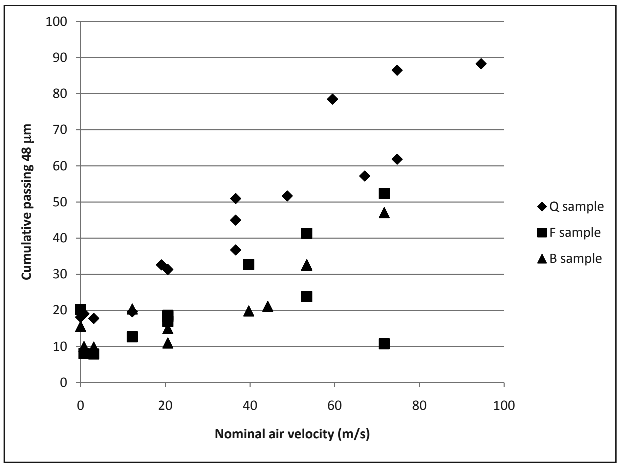

Figure 8. Effect of air stream velocity on fraction of particles passing 48 μm.

Effect of Sample Feed Rate

The rate at which the alumina sample was fed into the device was controlled by an electronic microriffler. This equipment fed the sample into the tube at a reasonably controlled rate. As a preliminary examination of the effect of feed rate, three feed rates were trialled using sample sizes of 3 gms. The slowest rate delivered the sample to the tube in about 40 minutes. As can be seen in Figure 9, feed rate does have an effect on the breakage behaviour as measured using the cumulative % less than 48 μm. Longer feed rate times tend to lead to slightly more breakage as measured using this criterion.

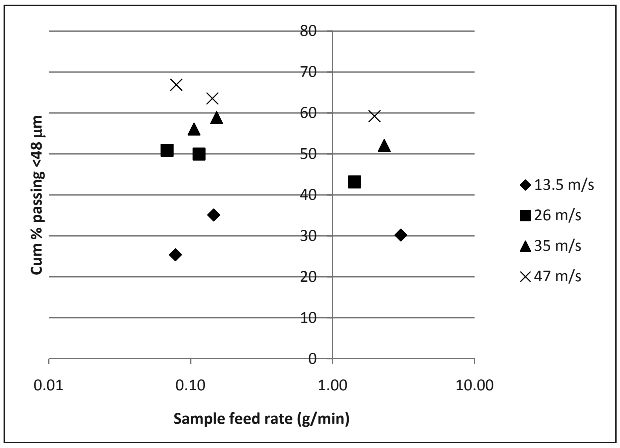

Figure 9. Effect of sample feed rate on the breakage of Q series.

Discussion

A new method of evaluating the strength of alumina particles has been developed based on the work of Bentham et al. [3]. The aim of this device has been to cause attrition of alumina by producing single particle impact on a target. The device has the advantage over the Forsythe method of determining attrition index in that the test does not take long to carry out and uses only a small amount of material. The results described in this paper are a preliminary snapshot of the effect of some of the key experimental parameters on breakage.

The initial studies on the inherent variability of the tests suggested that the tests were able to show a good discrimination between attrited and original alumina. The initial repeat trials suggested that there would be relatively low inter-test variability. A small number of tests were then carried out to determine the effect of the distance from the end of the delivery tube to the target. At this stage, the effect appears to be small. It was decided to standardise this distance at 50 mm for future work. The experimental parameter with the biggest effect on alumina breakage was undoubtedly the air stream velocity. This is unsurprising, as it governs the kinetic energy of the particles as they hit the target.

In order to clarify the data, the cumulative % passing 48 μm was used as a measure of the degree to which the particles had degraded. This parameter was chosen partly because it was relatively easy to measure and it also had some similarity to the "sub 45 μm" parameter used in the existing attrition tests. This parameter changes with air stream velocity as per Figure 8 to indicate a reasonable difference between the three types of alumina. However, there is still considerable scatter in data. It may be better to choose a different set of parameters for evaluating breakage and a range of other parameters are currently being explored, including "diameter at 50% cumulative passing".

The studies into the effects of delivery mode suggest that the rate at which the alumina is fed into the machine is important to the final breakage pattern, suggesting that less breakage occurs as the feed rate is increased. This is probably because as the feed rate increases, the particles begin to interact with each other and the test conditions deviate from the single particle impact mode initially desired.

These are preliminary results that have explored some of the experimental parameters that affect alumina breakage in the single particle impact rig. Although the results are promising, further work is required to validate the test method and show that the method is reliable for evaluating alumina strength. In particular, control of the air stream velocity is critical. Nevertheless, the method does provide a useful alternative to the Forsythe method for evaluating alumina strength, and has the potential to provide more relevant information on the breakage characteristics of the alumina than is currently available.

Acknowledgements

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