Automation of the Sieving Technique for Online Particle Size Analysis within a Milling Circuit

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Abstract. Particle size analysis plays a critical role in the mineral processing industry, especially on the milling circuit, which is an energy intensive process requiring optimal operating conditions. This paper presents a study undertaken to develop an online particle size analyser which is based on the sieving technique. A summary of the stages involved in the development of the instrument are outlined, which include preliminary testwork, conceptualisation and prototype design, assembly, and concept testing. Mechanical design principles were followed during the design process, and preliminary tests proved that the concept is feasible. Preliminary testing of the concept validated the design, demonstrating its capability of being robust. The proposed instrument is expected to be less expensive than currently existing instruments, and can be more reliable because it applies the sieving technique, which is typically used to validate most online particle size measurement instrument in the market. Once the concept was validated in the laboratory, a more advanced prototype was designed which is suitable to be tested in a mineral processing concentrator.

1. Introduction

Particle size analysis plays a critical role in the mineral processing industry as it enables the optimisation of energy intensive processes, especially milling. It is essential for maintaining product quality for downstream processes such as flotation and leaching, whilst ensuring profitable operations are achieved. Sieving is the oldest particle size measurement technique, and it is still utilised to verify modern particle size measurement instruments based on indirect methods such as microscopy, laser diffraction to name a few [1].

This study focuses on the development of a robust online particle size analyser based on the sieving technique. The traditional sieving method, is known for being accurate, but it is a manual and time consuming technique. The primary objective of the study is to design an affordable instrument, with high precision and accuracy, whilst optimising the time it takes to complete the particle size measurement, allowing the instrument to be online.

2. Experimental methods and concept design

2.1. Dry and wet sieving tests

Preliminary testwork was required to determine the feasibility of developing the concept of an online particle size analyser based on the sieving technique. The concept revolved around the automation of the sieving technique, therefore certain stages of manual sieving were required to be eliminated, mostly the drying of the sample. It was therefore critical to conduct dry and wet sieving tests to determine how a PSD generated from dry solids particles differed from the one generated from wet solid particles.

This comparison test was conducted on samples collected from various mines, with the deviations being critically analysed. The analysis of these results determined if it was feasible to proceed with generating a concept design.

2.2. Concept design

Manual sieving method, requires the sample addition on top of the sieve stack, followed by shaking it with a sieve shaker, and emptying the retained particles on each sieve, while simultaneously weighing them. This involved moving the sieves in the X, Y and Z direction.

To automate this procedure, it was critical to simplify it, therefore the X and Y movements were eliminated, and the sieves were required to move in the Z direction (up and down).

Load cells played a critical role in simplifying the automation of the sieving procedure. Components such as the fork lifter, shelf, and sieves, were 3D printed using PLA material. Load cells were attached to a vertically moving shelf, which is actuated up and down. The fork

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lifter is directly attached to the load cell, and it is responsible for lifting the sieve up and down, whilst simultaneously measuring the weight of the sieve. The system automatically tared itself before each cycle begins. The thickness of the components were designed based on Equation 1[2] below:

$$h = \sqrt{\frac{6M}{b \cdot \sigma_{allowable}}} \quad (1)$$

This was also verified by conducting a Finite Element Analysis on all the critical components.

3. Results and Discussion

Figure 1 below illustrates results of the preliminary tests conducted to determine the feasibility of developing the particles size measurement instrument.

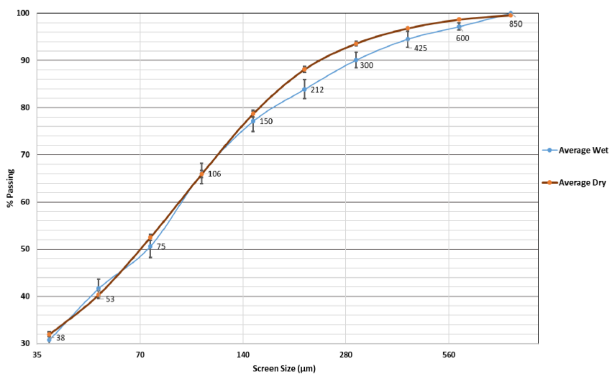

Figure 1. Zn Ore primary cyclone dry and wet averaged PSD curves

Since it was critical to optimise the analysis time, the PSD results were required to be calculated using the wet mass of particles retained on the sieves. Therefore it was critical to compare the PSD curves generated by the dry and wet solids particles. Figure 1 illustrates that the deviation between the two PSD curves was minimal and less than 5% on size classes between 150 to 600 µm.

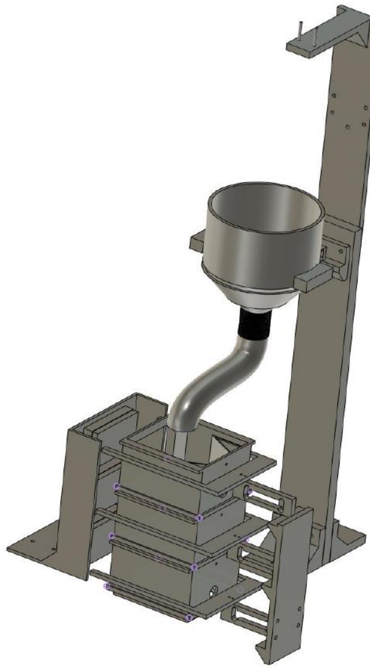

Figure 2. Preliminary design of the concept

Figure 2 illustrates a Fusion 360 design output of the final concept, with all the components assembled together.

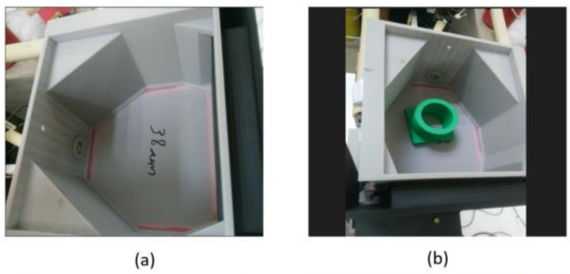

Figure 3. (a) Empty 3D printed sieve, (b) 3D printed sieve with a known mass object placed on it.

Figure 3 illustrates the sieve when it is empty and when a known mass object was placed on it. This experiment was conducted to test concept of the sieve lifting and mass measurement of retained solid particles.

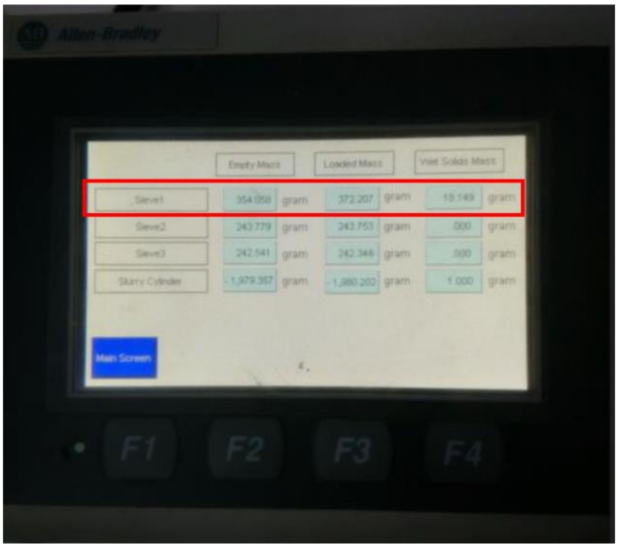

Figure 4. HMI results output from the PLC of the weight of the empty 3D sieve, sieve with known mass object positioned on it, and the difference between the two.

During the preliminary testing, the sieve lifting system tares the load cells by first weighing the empty sieve. This is followed by weighing the mass of the sieve with retained solids particles, in this case a known mass object positioned on top of the sieve. Figure 4 illustrates the captured masses of the sieves and the calculated mass of the object positioned on the sieve

Figure 5. The mass of the object measured with a calibrated scale

Figure 5 illustrates the measured mass of the object placed on the sieve, and the difference between the measured and the calculated mass of the object is less than 0.2 grams.

Figure 6. Assembled concept design of the density meter.

Figure 6 illustrates the assembled density meter which was used to measure the density of the slurry sample to be analysed by the system. The density measurement is required to complete the particle size distribution calculations for the sample, where the initial mass of the sample was automatically calculated.

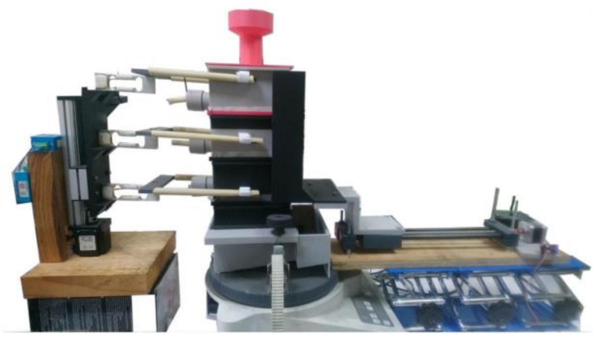

Figure 7. Assembled concept design of the sieve lifting and measurement system

Figure 7 illustrates the assembled sieve lifting and mass measurement system which was used to conduct preliminary testing of the concept.

4. Conclusion

The findings from this study demonstrated that the PSD calculated from dry and wet particle mass has minimal difference. This paved way to conclude that it is feasible to proceed with generating a concept for automating the sieving technique. The developed concept also demonstrated capability of accurately measuring the particle size distribution using the automated sieving technique.

Acknowledgement

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