In-Line Density-Compensated Moisture Measurement in Free-Flowing Bulk Solids with an Off-the-Shelf Capacitance Level Probe

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Introduction

This paper describes investigation of a method for in-line measurement of the moisture content of free flowing bulk solids. Earlier work [1] has demonstrated that the output from a capacitance probe gives a measure of moisture content, but is also dependent on the bulk density of the powder sample. This current work investigates the use of a novel in-line bulk density measurement technique [1,2] in combination with the capacitance probe to give an improved moisture measurement. The measurement technique is applicable to real time, in-line measurement of free flowing particulate materials.

Bulk density measurement

The bulk density of the flowing powder was measured in-line by allowing the powder to flow through a small measuring vessel attached to a load cell, see Figure 1. The flow of material out of the vessel was controlled so that the measuring vessel remained full with a free surface at the inlet. The volume of the material in the vessel is defined by this free surface, and combined with measurement of the mass of material in the vessel a flowing bulk density for the material can be calculated. Further details of this measurement technique are described by Davies and Fenton [1] and Davies et al [2].

Capacitance measurement

In this work a capacitance probe, based on a proprietary level sensor, was added to the bulk density measuring vessel, as shown in Figure 1. In the figure the load cell for measuring the vessel mass, and the feed conditioning vessel can be seen. Also seen in the figure is an acoustic based particle size measurement instrument, details of which are given by Tallon et al [3]. Results incorporating the particle size measurement are not however reported here.

The output of the capacitance probe was calibrated off-line against moisture content. The result, given in Figure 2, shows some degree of scatter particularly over the lower range of moisture content.

Bulk density compensated moisture measurement

Experiments were conducted in which batches of a granular industrial product were prepared with a known and uniform moisture content. These batches of material were discharged from the hopper shown in Figure 1 and passed through the measurement vessel. The bulk density and capacitance were continuously recorded during the run.

Figure 3 shows the results of a typical run. The bulk density varied during the run, which is attributed predominantly to particle size segregation in the batch flow from the hopper. In all runs in this work the bulk density decreased during the run with a slight increase at the end. The capacitance signal also changed as the bulk density of the material changed, indicating the effect that bulk density has on the measurement.

A correlation was developed between the capacitance signal, the moisture content, and the bulk density by assuming the measured capacitance signal was equal to the sum of terms proportional to the moisture content, the bulk density, the squares of these values, and to the product of the moisture content and bulk density. Proportionality constants were calculated to

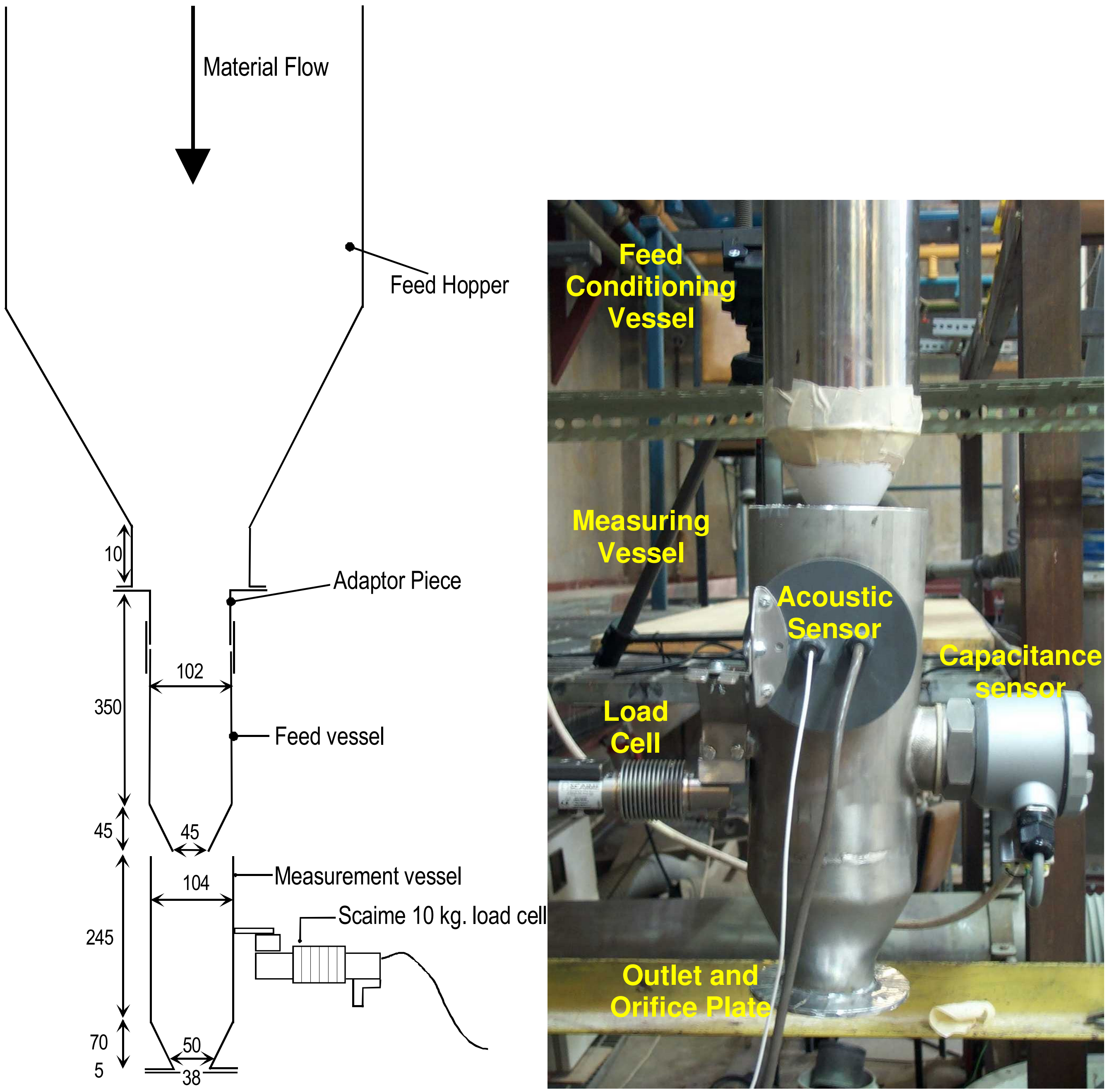

Figure 1 – Schematic of experimental apparatus for continuous measurement of particle bulk density, and detail of instrumentation used for moisture content measurement.

minimise the sum of the squared deviations between calculated and actual moisture content.

Figure 4 shows a comparison of predicted versus calculated moisture contents, both with and without bulk density compensation. The standard deviation of the error with bulk density compensation is approximately half that when bulk density is not accounted for.

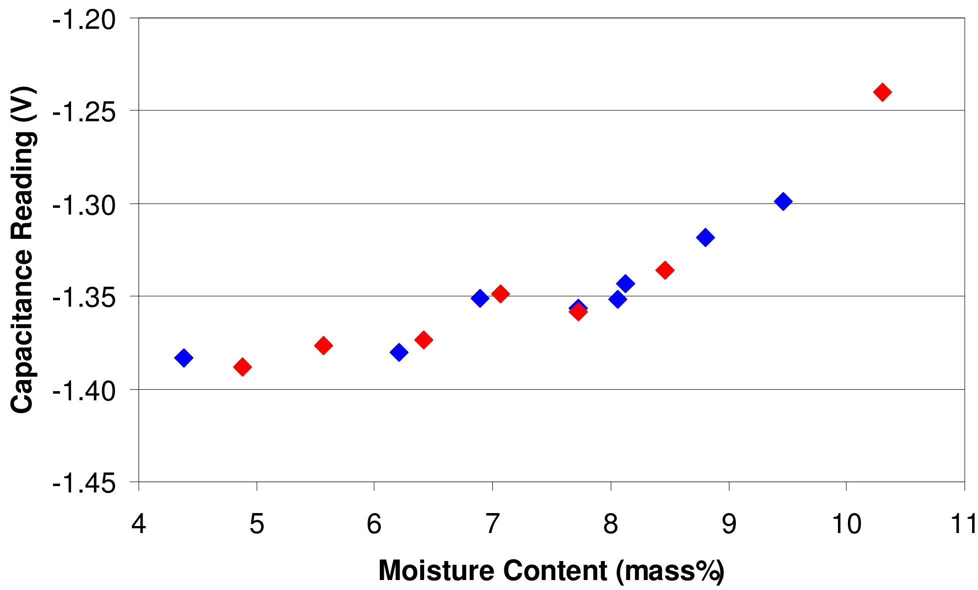

Figure 2 – Off-line calibration of capacitance reading vs moisture content.

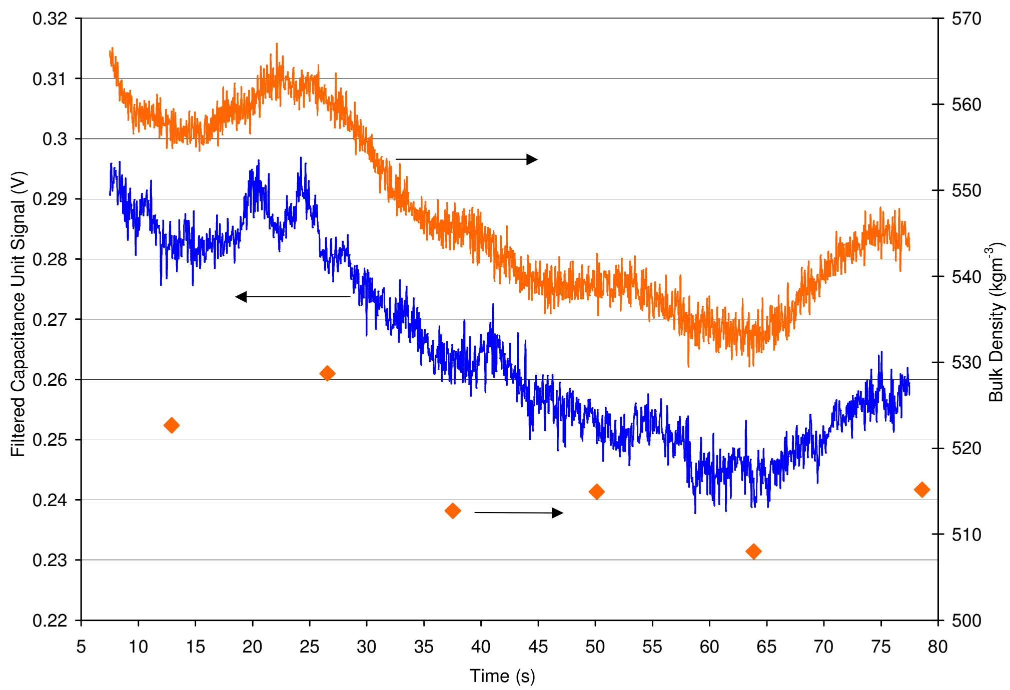

Figure 3 – Typical recording of bulk density and capacitance probe response for discharge of a batch of material through the measuring vessel. Filled diamonds represent loose poured bulk density measured off-line from grab samples.

Conclusion

This paper describes a method for combining a novel approach to in-line bulk density measurement with a capacitance probe, to measure moisture content. Allowance for variations in bulk density in this work resulted in a 50% reduction in the standard deviation of the error in the moisture content measurement. The resulting system could be used in-line to measure both the bulk density of a flowing particulate material, and to give an improved moisture content reading based on capacitance measurement.

References

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3. Tallon, S., Davies, C.E., Kirkegaard, M., (2003), “An acoustic method for in-line particle size measurement in flowing bulk solids”, Journal of Process mechanical engineering, ImechE, Vol 217, Part E, pp 33-39.

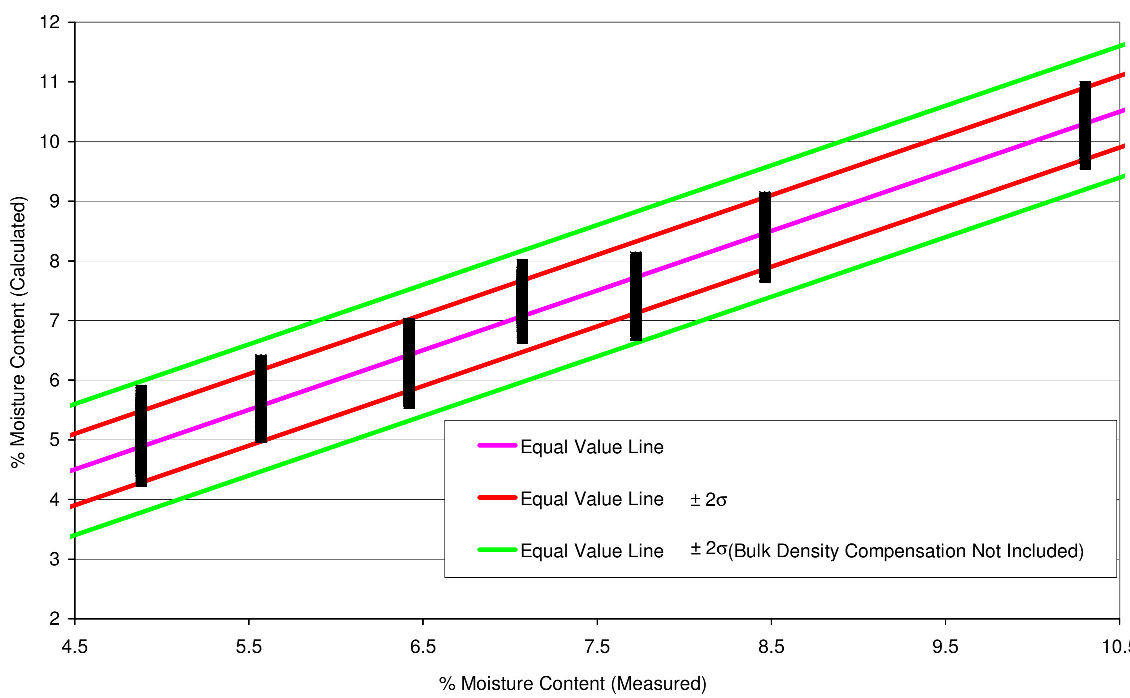

Figure 4 – comparison of errors in moisture content measurement with and without bulk density compensation.