SHORT, NON-REFEREED PAPER

PRESSURE HEAD AS A MEASURE OF JUICE HOLDUP IN A CANE DIFFUSER BED: EVALUATION ON A PLANT SCALE

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Abstract

To improve the extraction process in a cane diffuser, it is necessary to keep the percolation rates close to the maximum. To achieve this, the liquid flow rates in a stage-wise counter-current cane diffuser must be monitored and controlled through the automation of the spray position responsible for distributing the liquid onto the bed surface according to the settings selected. Currently, the liquid holdup is controlled by inspection at the sight glasses installed at points along the diffuser. The limitation of this measure is due to the manual collection of data and the sampling time. Therefore this method in practice is not ideal.

Many of the conventional methods to measure the liquid level are not suitable for this application. Some researchers introduced new methodologies which used pressure transmitters to measure the pressure head. However, the results were particularly noisy and questionable, and this method was therefore not widely adopted. No subsequent work has been registered that validates or invalidates these results.

The aim of this short paper is to test the viability of using a pressure manometer to assess the liquid holdup in a cane diffuser bed. To achieve this purpose, the pressure head was measured on a plant scale at the Maidstone factory in a Tongaat Hulett diffuser. The experimental data was compared with the theoretical pressure head computed using Darcy´s equations.

Keywords: permeability, holdup, flooding, full-scale test, hydrostatic head

Introduction

To avoid flooding and keep the brix profile unaltered, the liquid holdup in a cane diffuser bed should be controlled. Currently, to prevent flooding, the operator can control and adjust the liquid spray position based on visual inspection of the liquid holdup at the sight glass. However, this type of measurement can be highly inaccurate because the sight glasses are not installed in all stages of the diffuser, and the liquid interface level might not be clearly visible to the operator due to the amount of foam present. In addition, the viewable area of the sight glass only permits observation of the level of the liquid holdup near the side walls of the diffuser. This is a small area of the entire stage of the diffuser. Moreover, if, for any reason, the sight glass is damaged the visibility is compromised, and the measurement cannot be done.

The liquid holdup does not have a stable level as it changes throughout the cane bed and along of the diffuser. These fast fluctuations of the liquid holdup are a critical problem because the operators record the data manually. Variations occur due to the physical nature of cane, operating conditions and cane preparation. As mentioned above, the liquid holdup should be assessed online in order to estimate the optimal percolation rate enabling sucrose extraction maximisation. Therefore, different experiments have been carried out to measure the liquid holdup in the cane bed through manometers, conductivity meters, and floating devices. However, some of these did not present satisfactory results, or they are still in the testing phase.

The results of using the pressure as a measure of the liquid level were particularly noisy and questionable, therefore this method was not widely adopted, but no subsequent work has been registered that validates or invalidates these results. It will be studied whether the pressure head can be used as a measure of the liquid holdup. Moreover, permeability effects on the variation of the pressure will be evaluated. Different functions of permeability were tested, since pressure head variations depend on the permeability of the material and the level of the liquid above the screen of the diffuser.

The pressure head was measured for the first time on a plant scale in South Africa at Amatikulu mill using a bubbler system in one side of the cane bed, and the pressure profile down the bed was calculated by the Carman-Kozeny equation. These trials involved installing a tube into the side of the diffuser and measuring the back pressure, thus obtaining the hydrostatic head. A simpler arrangement was incorporated at Felixton mill, where an electronic pressure/level transmitter with a flush mounting diaphragm was attached directly to the side of the diffuser. The electronic pressure transmitters were installed vertically, at distances of 450, 850, 1 050 and 1 450 mm above the screen, and the outputs were logged. This work was detailed by Rein and Ingham (1992).

The use of a bubbler system to measure the liquid level was assessed for two seasons in six of the 16 stages at Amatikulu mill, in order to adjust and control the spray flap position. The extraction was improved in the latter season due to an increased, finer preparation, and the adjustment and control of the flaps that control the liquid level. Without adjustable sprays, the normal consequence of finer preparations is reduced percolation velocities and then flooding. According to Rein and Ingham (1992) the cost of automation of the diffuser's sprays is justified by the reduction of the imbibition liquid. This could save coal, as shown at Felixton mill where the installation would be paid within a quarter of the season. Based on these results, a patent was taken out on the automatic adjustment of diffuser sprays. However, the Felixton sensors never gained acceptance, and they fell into disrepair and were removed. Pressure sensors were fitted on all the stages of the Maidstone diffuser when it was installed in the 1990s, but these were also eventually removed. In order to validate or invalidate these results, the trial tests were done on a full-scale, and the experimental data were compared with the theoretical data of pressure head.

Methods

The experimental trials were done at the Maidstone factory in a Tongaat Hulett design of cane diffuser (the 'Maidstone diffuser') using four manometers to measure the pressure head at the fourth stage of the diffuser. The diffuser has 11 stages; each stage is 9 m wide and 4.1 m in length.

To measure the pressure head four pressure tapping points were made on the wall of the diffuser, where four sockets (1/2 inch), nipples and isolation valves were installed adjacent to one of the sight glasses. These sockets could be removed to be cleaned, thus preventing the bagasse blocking the flow of liquid in the tube. The sockets were fitted with clear plastic tubing and were located in the cane bed, orientated perpendicular to the flow direction and measuring relative to atmospheric pressure, as shown in Figure 1.

Figure 1. Installation of the manometers in the wall of the diffuser and plastic tubes used as manometers.

The plastic tubes were fixed on a wooden panel to visualise the pressure head in the tube. The measures of the liquid holdup were recorded based on observation at the sight glass at the fourth stage.

Location of the tapping points in the wall of the diffuser:

P_1 = first tapping point at 0.72 m above the screen of the diffuser
P_2 = second tapping point at 0.97 m above the screen of the diffuser
P_3 = third tapping point 1.170 m above the screen of the diffuser
P_4 = fourth tapping point 1.315 m above the screen of the diffuser.

Using these tapping points, the pressure head was measured at different heights above the screen of the diffuser. If the liquid level dropped below the level of a tapping point, the associated manometer was then not able to provide a reading. To compare the theoretical pressure curve with the experimental pressure curve, the experimental pressure curve that was the best fit with the theoretical results was chosen from the four curves of the pressure head measured at different heights above the screen of the diffuser.

Results and Discussion

The Darcy's equation was used to determine how the pressure head is affected by different functions of permeability (linear, quadratic and exponential).

To find the constants relating to each permeability function, a program in Matlab was written. This program finds an interval of values for every constant to get a family of curves of theoretical pressure head, thus determining which has the best fit between the experimental pressure curves and the theoretical pressure curves.

The results of this trial show that the functions of permeability do not alter the pressure data significantly and the mean permeability depends on the permeability function chosen.

Conclusion

The variation in cane bed height over time only slightly affects the pressure head, and therefore a constant cane bed height could be used in the mathematical model. Finally, the results of these trials demonstrate a strong relationship between the liquid holdup and pressure head and the results have a confidence interval of 80 to 96%. Reproducibility tests have confirmed these results.

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