MODELLING THE EXTRACTION PROCESSES OF MILLING TRAINS

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Abstract

Australian sugar factories have made limited use of a milling train extraction model developed at The University of Queensland about 30 years ago. In recent years, the Sugar Research Institute (SRI) made modifications to that model in an effort to make the performance indicators in the model more relevant to factory engineers. This has been achieved by replacing the performance indicator known as the imbibition coefficient with two other performance indicators, 'crushing factor' and 'mixing efficiency'. The crushing factor describes the preparation that occurs in a milling unit while the mixing efficiency describes how well the imbibition mixes with the feed bagasse to a milling unit. This paper describes the current model and the differences between the original model and the current model. It describes the ways in which the model is intended to be used and the information required before the model will fulfil its potential.

In summary, the extraction model can be used for the analysis of performance of an existing milling train or the prediction of the performance of a milling train as a result in a change to the milling plant. The model in its current form can be used to analyse the performance of an existing milling train by calculating the performance indicators. However, its use in predicting the performance of a milling train is limited because the factors affecting the new performance indicators are not known.

Introduction

The required crushing rates through the milling units of Australian sugar factories are continually increasing. Since upgrading milling plant is expensive, there is a strong desire to achieve increases in crushing rate through existing milling units, and often such increases in crushing rate through existing milling units can be made. However, the sugar losses in final bagasse often increase as a result. Predicting the change in the amount of sugar extracted from the bagasse resulting from a change in milling conditions cannot be done accurately. An accurate milling train extraction model would be able to make this prediction and assist in making financial decisions regarding milling plant.

For more than 30 years, Australian sugar factories have made limited use of milling train extraction models. The current extraction model had its origins at The University of Queensland (Munro, 1964; Russell, 1968) and resulted in the development of a computer package known as 'MILSIM'. Since that time, SRI has maintained MILSIM for Australian factories.

The key concepts of The University of Queensland model were the reabsorption factor which quantified the amount of juice extracted from a milling unit, and the imbibition coefficient which quantified the amount of brix in the extracted juice.

KEYWORDS: Milling Train, Extraction, Reabsorption Factor, Crushing Factor, Mixing Efficiency, Model.

While the reabsorption factor has been readily accepted by the industry, only limited use has been made of the imbibition coefficient.

In recent years, the SRI has modified the extraction model in an effort to improve the accuracy of its predictions and replace the imbibition coefficient with concepts which have more meaning to factory engineers. Edwards (1995) described the problems associated with the imbibition coefficient and introduced concepts described by Allan and Saranin (1955) to improve the model.

The imbibition coefficient described the mixing of imbibition with juice in the bagasse. One of the main impediments to 'perfect' mixing is the amount of juice remaining in closed cells because that juice is unavailable for extraction. Edwards (1995) replaced the imbibition coefficient in the model with a 'crushing factor' which was based on the number of closed cells. The crushing factor describes the number of cells in the bagasse which are opened as a result of passing through a milling unit. Based on the results of Allan and Saranin (1955), it was assumed that, once cells were opened, mixing of imbibition with the available juice was close to perfect. Recent experiments have shown that the mixing of imbibition with the available juice is somewhat less than perfect. To account for this imperfect mixing, a 'mixing efficiency' has also been introduced. The current model uses both the crushing factor and mixing efficiency to replace the imbibition coefficient.

This paper describes the current extraction model and defines its uses and deficiencies. Further work aimed at improving the usefulness of the model is outlined.

Benefits of extraction modelling

The extraction model has two main uses:

- The analysis of the performance of an existing milling train; and
- The prediction of the resultant change in performance of a milling train as a result of changes to milling plant.

To analyse the performance of an existing milling train, the results of bagasse analysis in combination with knowledge of imbibition flows and milling unit compactions are used to calculate the various performance indicators. In the current model, those indicators are the reabsorption factor, the crushing factor, and the mixing efficiency. By comparing the calculated values for those indicators against typical numbers for those indicators, insight into the reasons for a particular extraction performance can be gained. For example, if the reason for a drop in extraction can be attributed to a change in reabsorption factor for a particular milling unit, the factors affecting reabsorption factor can be examined to see which of them may be responsible for the change.

As an analysis tool, the extraction model can be used to 'trouble-shoot' a milling train to resolve extraction problems or it can be used to identify areas where extraction improvements could be made.

To predict the extraction performance of a particular milling train configuration, relationships have to be known so that the performance indicators can be calculated for the particular configuration. The performance indicators are then used to predict the bagasse analysis and extractions of each milling unit.

Used as a prediction tool, factories can predict the performance of proposed milling train configurations. The configurations may involve the replacement, addition, or removal of a milling unit, a change in added water rate, or a change in milling speed, for example. By predicting extraction performance, the change in the amount of sugar lost in bagasse can be calculated and so the change in income from the sale of the sugar can be estimated. By having an accurate prediction of the benefit of the change in milling train configuration, the cost of making that change can be assessed with little risk.

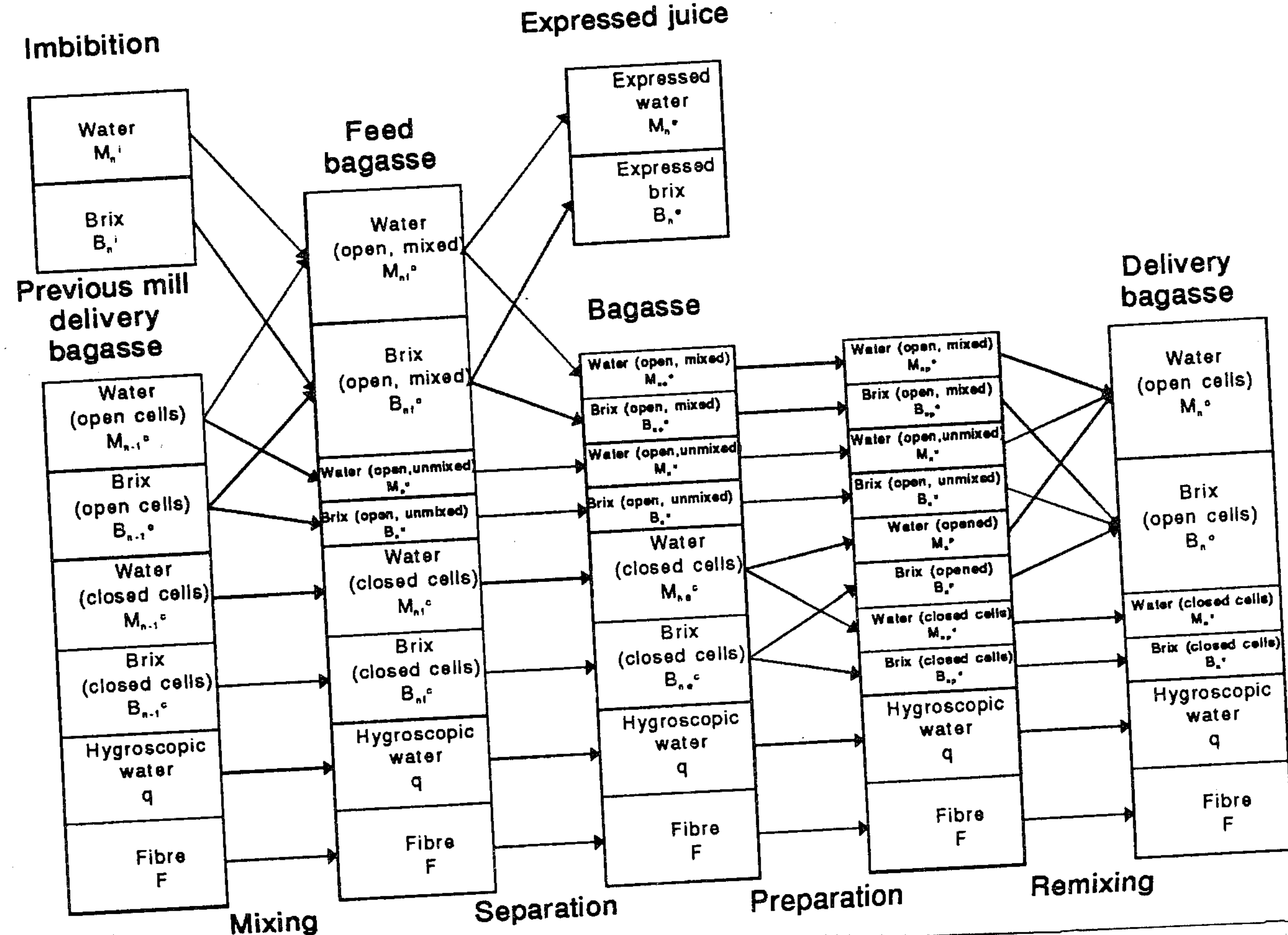

Fig. 1—The model of the crushing process.

As stated earlier in this section, it is usual to assume the brix in open cells is the same as the pol in open cells. While brix in open cells can be measured in the same way as pol in open cells, the brix measurement is less precise than the pol measurement. However, even the pol in open cells measurement is not precise enough. It is recommended that the pol in open cells measurements, particularly for the last few bagasses where the pol quantities are small, be repeated several times to try and improve the precision of the measurement.

The lack of precision of the pol in open cells measurement makes the mixing efficiency and crushing factor calculations less precise than the imbibition coefficient calculation. It is assumed that the extra information to be gained from the mixing efficiency/crushing factor model will outweigh the loss in precision of the values of the performance indicators.

The analysis of results

Once the performance indicators have been calculated from experimental data, it is necessary to determine if the value of each performance indicator is satisfactory. While typical values for reabsorption factor are well known and can be calculated from historical milling train analysis data in most factories, there is little data with which to compare the mixing efficiency and crushing factor.

In the 1996 crushing season, SRI arranged milling trials in 27 Australian sugar factories. One of the aims of the trials was to determine typical values for mixing efficiency and crushing factor so that there is a basis to determine if the mixing efficiency and crushing factor are adequate for each milling unit. Another aim was to determine the factors that influence the mixing efficiency and crushing factor. At the time of writing this paper, the analysis of the data from those trials was not complete.

Data required for milling train performance prediction

Much of the data required for milling train performance prediction is the same as that required for milling train performance analysis. These are the prepared cane moisture%bagasse, brix%bagasse, and brix in open cells, crushing rate, mill speed for each milling unit, work opening for each milling unit, quantity of added water for each milling unit, and the mills to which the expressed juice from each mill goes. Instead of the bagasse analysis, however, the performance indicators reabsorption factor, crushing factor, and mixing efficiency are used.

To use the extraction model for prediction purposes, it is necessary to know how the performance indicators vary as the parameters in the model are changed. The reabsorption factor, having been part of the model since it was first developed, is quite well defined as a function of delivery nip compaction, roll speed, and bagasse fineness (Russell, 1968). To date, there has been no attempt to define crushing factor and mixing efficiency in a similar way. Unfortunately, the pol in open cells of bagasses has rarely been measured in factory experiments or routine factory analysis. As a consequence, there is little existing data with which to develop the crushing factor and mixing efficiency relationships.

Until the factors affecting the crushing factor and the mixing efficiency have been determined and their effects quantified, the current extraction model is of limited benefit in milling train performance prediction.

Summary of differences in required data

To use the extraction model for analysis, the constituents of the bagasse must be known from milling train analysis. The moisture%bagasse, the brix%bagasse and the pol in open cells are sufficient to define the bagasse constituents. The extraction model calculates the performance indicators reabsorption factor, crushing factor, and mixing efficiency.

To use the extraction model for prediction, either the performance indicators reabsorption factor, crushing factor, and mixing efficiency must be known or they must be estimated or calculated from known values such as mill speed or delivery compaction. The extraction model calculates the bagasse constituents and hence the mill extractions.

Conclusions

Modelling of the extraction performance of an existing milling train can provide insight into the causes of low extraction and methods to improve extraction through the use of the performance indicators mixing efficiency, reabsorption factor, and crushing factor. SRI's extraction model can be used for this purpose in its current form.

When planning a change in milling plant, it would be beneficial to be able to predict the effect of that change on extraction. If the effect of the change on extraction could be accurately predicted, the economic benefit of the change could be assessed when weighed against the cost of the change. In order to use the SRI extraction model for this purpose, it is necessary to know the effect of the change on the performance indicators mixing efficiency, reabsorption factor, and crushing factor. At present, only the reabsorption factor is well defined. Further work is required to determine the parameters which affect the mixing efficiency and crushing factor.

Acknowledgments

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