Diffuser optimum Imbibition

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Mathematics Industry Study Group
Study Group

Outline

Introduction

INTRODUCTION

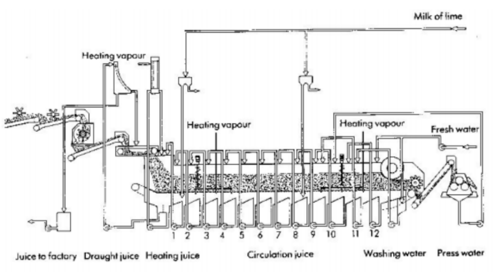

Figure 1: Schematic diagram of a diffuser

INTRODUCTION

- sugar cane is shredded to expose sap or juice.
- it is then fed into the diffuser and travels along a conveyor belt.
- Fresh water is added on the opposite side to wash the sugar containing juice out of the shredded cane.
- Water added needs to be evaporated before the sugar can be crystallized.
- This evaporation requires energy that comes from burning fuel in a boiler.
- Increase in production cost.

The Problem

- Need to reduce imbibition to save energy in the evaporator
- It has long been argued that reducing imbibition inevitably reduces extraction
- Can proper diffuser control mitigate the impact of reducing imbibition?

Research Questions

- Is the trend of reducing extraction an inevitable consequence of reducing imbibition
- Can recycle be used to mitigate the effect of using less imbibition?

Model

Compartmental Model

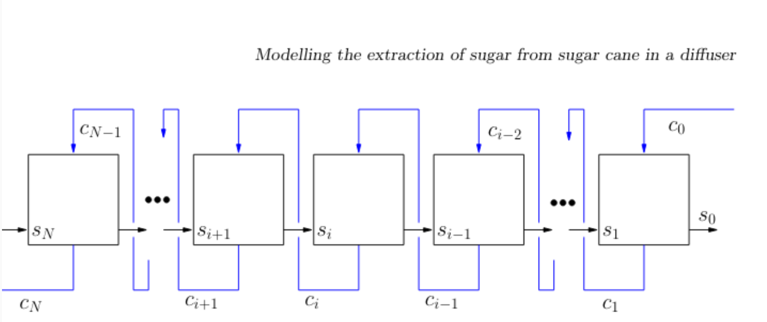

Figure 2: Schematic diagram of the model

Discrete Model

- Used to track sucrose concentration C in the juice and S in the shredded cane.
- we measure concentrations in $tonnes/m^3$.
- The i^{th} compartmental is supplied with a volume flux Q_v with sucrose concentration C_{i-1} from the compartment on the right.
- A volume flux of Q_h with sucrose concentration S_i is supplied from the left.
- The fluxes are related to the vertical,V and horizontal,U velocities by:

$$Q_h = Uhd$$
$$Q_v = Vld$$

MODEL

- The fluxes in and out balances, we obtain the equations:

$$Q_h(S_i - S_{i-1}) = \kappa_1(S_i - C_{i-1}) \quad (1)$$

$$Q_v(C_i - C_{i-1}) = \kappa_1(S_i - C_{i-1}) \quad (2)$$

$$\text{for } \; i = 1, 2, ..., N$$

Where i represents compartments

- $\kappa_1(m^3/hr)$ is the transfer coefficient of sucrose from the shredded cane to the juice.

Model

In order to solve equations 1 and 2 we take:

$$C_i = A + B\lambda^i \tag{3}$$

$$S_i = D + E\lambda^i \tag{4}$$

We set:

$$C_0 = 0$$

$$A = D$$

Thus:

$$A = -B = D$$

MODEL

The diffuser typically consists of 12-14 compartments. We take N = 12 to be number of compartments and fix $S_N = \Sigma$

Substituting the solutions into equations 1 and 2 we get:

$$E(1 - \frac{1}{\lambda}) = m(E - \frac{B}{\lambda}) \tag{5}$$

$$B(1 - \frac{1}{\lambda}) = p(1 - \frac{B}{\lambda}) \tag{6}$$

Where $m = \frac{\kappa_1}{Q_h}$ and $p = \frac{\kappa_1}{Q_v}$

MODEL

$$B = \frac{p\Sigma}{m\lambda^N - p} \tag{7}$$

$$E = \frac{m\Sigma}{m\lambda^N - p} \tag{8}$$

$$\lambda = \frac{1-p}{1-m} \tag{9}$$

We are now able to to obtain the solution for (1) and (2) to be:

$$\frac{C_i}{S_N} = \frac{p(\lambda^i - 1)}{m\lambda^N - p} \tag{10}$$

$$\frac{S_i}{S_N} = \frac{m\lambda^i - p}{m\lambda^N - p} \tag{11}$$

Plot of the Model

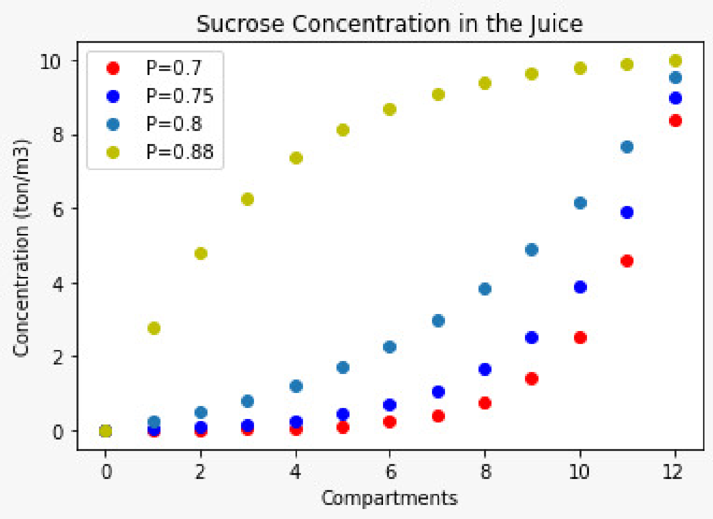

Figure 3: Sucrose concentration

Discussion

- Figure 3 above shows the concentration of sucrose in the juice for varying values of P.
- Note that $P = \frac{\kappa_1}{Vld}$. We do not have a value for κ_1, the transfer coefficient.
- However there is an inverse relationship between p and V.
- An increase in p results in decrease in V which subsequently results in a decrease in concentration of sugar in the juice.

Conclusion

CONCLUSION

- Thus we have shown that the reduced imbibition does impact extraction efficiency.
- The Question of whether recycle can be used to mitigate the effect of reduced imbibition is currently a work in progress and will be presented in the final report.

REFERENCES

- C. Breward, G. Hocking, H. Ockendon, C. Please, D. Schewendeman, Modelling the extraction of sugar from sugar cane in a diffuser.
- MISG 2012. Flow through sugarcane
- L. Soura, N.S. Barbosa, P.A. Santigo, P. Selghi. Modelling a multi-stage Diffuser for sucrose extraction in sugar cane bio-refineries.

Thank you!