Process Modeling using Sugars™ - Beet Factory

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Abstract

The Sugars™ for Windows® program does the complete mass, energy and color balance for beet and cane factories and refineries. The program is capable of modeling almost any sugar process. This paper illustrates a beet sugar factory with molasses desugarization using chromatographic separation. The completely integrated model starts with cossettes into the slicers and goes through the chromatographic separation of sucrose from molasses with evaporation of extract, betaine and raffinate. Also, it includes steam and electrical generation. Data import and export is shown for communication with other software. An example is given showing the export of turbo alternator data from the model that is then imported into Microsoft Excel® where the isentropic efficiency is modified using the Willans line to account for changes in the efficiency based on the turbine loading. The new isentropic efficiency is exported from Excel and imported back into Sugars for rebalancing of the model.

Introduction

Molasses desugarization (MDS) has proven to be an advantageous extension of beet sugar factories to increase their sugar yield and revenues. It hasn’t been successful in the cane sugar industry because of the much lower molasses purity in cane factories and problems with insoluble solids in the molasses that inhibit the flow of treated molasses through the resin columns [1]. Sugars has been used to build models of beet sugar factories with MDS. The model in this paper includes MDS with multi-component simulated moving bed chromatographic separation and evaporative concentration of extract, raffinate and a betaine rich fraction called: crossover non-sugars (CNS). The CNS and raffinate are used to produce a combined separator by-product (CSB) or they can be sold separately. In total, there are three different multiple effects (one for thin juice, one for extract and one for CNS). The raffinate is concentrated in four single effects: two of them using exhaust steam and two of them using reduced steam with mechanical vapor recompression (MVR). MVR is also used for both first effects of the extract and CNS evaporators [2].
Beet Factory Model

The beet factory model discussed in this paper has thirteen pages of diagrams: (1) “Diffusion”, (2) “Pulp Pressing and Pelletizing”, (3) “Juice Heating and Liming”, (4) “Carbonation”, (5) “Evaporation 1st – 3rd Effects”, (6) “Evaporation 4th and 5th Effects”, (7) “White Crystallization”, (8) “High Green and High Raw Crystallization”, (9) “MDS Molasses”, (10) “MDS Evaporation – A”, (11) “MDS Evaporation – B”, (12) “Steam Generation & Distribution” and (13) “Cold Water Distribution”. The “Diffusion” and “Pulp Pressing” pages are similar to what is done in most Sugars models of beet sugar factories and as such they are not shown in this paper for space considerations. Figure 1 shows the “Juice Heating and Liming” page. Cold and hot liming are used with some of the MDS extract added back into the cold limer tank. Figure 2 shows an enlarged view of where the extract is added. This is one of several alternate places that extract can be added back into the process to recover sucrose from the extract. The kiln and slaker are also shown in Figure 1. CO₂ gas from the kiln is sent to 1st and 2nd carbonation for purification. The model for carbonation is very much the same as used for other Sugars models and isn’t shown. After carbonation, the thin juice goes to evaporation.

Multiple-Effect evaporation is split into two pages. Figure 3 shows the 1st thru 3rd effects with thin juice heating preceding evaporation. The 2nd effect is split into two bodies in parallel on steam, but in series on juice. The 3rd effect is also split into two bodies in parallel on steam and in series on juice; however, the 1st body of the 3rd effect is a Robert and the 2nd body is a forced circulation body. Bleed vapors are fed to various users in the model; e.g., thin juice heaters, pans and juice tanks. Figure 4 shows the 4th and 5th effects. The 4th effect provides thick juice to crystallization and the 5th effect is used for standard liquor concentration.

Thick juice from evaporation along with some thin juice goes to the “White Crystallization” page (for brevity it isn’t shown in this paper). A high melter and a low raw melter are used to produce a standard liquor. The standard liquor is sent back to the 5th effect in evaporator where it is concentrate to 74% dry substance and then sent to the white pan. Massecuite from the pan goes to a centrifugal with high wash and high green run-offs. Centrifuged sugar goes to drying, cooling and a scalping screen before leaving the
model. The high wash is sent to the high melter and the high green flow goes to the high green tank on the "High Green and Low Raw Crystallization" page shown in Figure 5. If necessary, some thin juice can also be sent to the high green tank. High raw and low raw pans with corresponding continuous centrifugals in the conventional manner are used to produce crystalline sugar that goes to the high melter on the "White Crystallization" page and molasses that goes to MDS. A low raw crystallizer is used on the low raw massecuite and affination is used on the low raw sugar before sending it to the high melter on the "White Crystallization" page. Molasses from the low raw centrifugal is heated in a tank to 65°C before sending it to the "MDS Molasses" page. The molasses is at about 58% Purity and 80% Dry Substance (DS).

Molasses is heated and diluted on the "MDS Molasses" page to about 67°C at 65% DS (see Figure 6). After it is diluted, it is further heated to 85°C and then filtered in a pressure filter. Next, it is heated up to about 90°C and degassed before being sent to the separator column Train 1. Train 1 separates the molasses into an extract that is called upgrade and CNS or betaine rich fraction. Trains 2 and 3 are used to process upgrade after it has been concentrated by evaporation into extract and raffinate. The CNS and upgrade are sent to the "MDS Evaporation – A" page (Figure 7) for evaporation to concentrate them and raise their dry substance.

The "MDS Evaporation – A" page shows the concentration of upgrade and CNS to a dry substance of about 70%. An MVR is used for both first effects of the CNS and upgrade evaporation. The upgrade is sent to Trains 2 and 3 on the MDS Molasses page for separation into extract and raffinate. The extract and raffinate are then sent to the "MDS Evaporation – B" page (Figure 8) for evaporation.

Raffinate that goes to the "MDS Evaporation - B page", flows to two forced circulation evaporators in parallel on both liquid and vapor. Each of these evaporators use MVR and then the raffinate is combined in a receiver whose output goes to a long tube evaporator on exhaust steam. From there the raffinate goes to a forced circulation evaporator as the final step in evaporation before it is combined with the CNS in a tank. The output flow from the tank has some going to the pelletizers and the rest is sold for animal feed as CSB. Extract from Train 2 goes to two effect evaporation using forced
circulation evaporators on the “MDS - Evaporation B” page. Some of the concentrated extract goes back to the cold limer tank 2170 on the “Juice Heating and Liming” page. The rest is cooled and sent to storage for processing at a later time.

Steam and electrical power for the process are provided by a coal fired boiler and turbo alternator as shown on the “Steam Generation & Distribution” page (Figure 9). All of the steam from the boiler goes to the turbo alternator except for a small amount that is reduced in pressure for the sugar dryer.

The “Cold Water Distribution” page of the model is not shown in this paper. It merely shows a simple collection of condensates and seal water into a tank with output flows for diffuser makeup water and raw juice heating. Also, the source of the cold water for the process is from a pond. Water treatment isn't included in the model.

Data Import/Export

Data import and export is an optional feature of Sugars that provides easy exchange of data with other software using XML (eXtensible Markup Language) files. Sugars will export XML data from the model as specified by the user and XML data can be imported directly into the model from other programs. Figure 10 shows the Sugars form for importing and exporting data. Exported data is controlled by the user to be only for stations that have an Equipment ID. Data for flows will only be exported for flows that leave stations with an Equipment ID or for flows that go into a station with an Equipment ID if the flow is from an external source. Sugars writes the data to an XML file in a format that conforms to a schema. Data that is imported has to conform to the same schema and it is checked to be within a range that is set by the user. An example of an XML file for import is shown in Figure 11. The XML data shown is for the properties of the turbo alternator 8120. When this data is imported by Sugars, it will check to see that the new data is within a tolerance that can be set by the user so that large changes in the data are detected to prevent unintended changes to the model for rebalancing. Also, a comparison report is available to compare all of the newly imported data with the older data that is already in the model.
Data that is exported can be read by other software; for example, data can be imported to Microsoft Excel and calculations done using the data from Sugars. The calculations can be used to revise the XML data so that new values can be imported by Sugars and a new balance done using the revised values. Figure 12 shows an Excel template that is provided with Sugars to import data into Excel and then export it back to an XML file for importing into the model. Figure 13 shows the station properties data for the distributor 8200 and turbo alternator 8120 stations. Distributor 8200 feeds steam from the boiler into the turbo alternator. Figure 14 shows an Excel calculation using the Willans line to calculate a new isentropic efficiency for the turbo alternator. The new efficiency then can be exported back to Sugars for rebalancing with the revised isentropic efficiency. Other characteristics can be changed in the same manner and new data from a data acquisition system can be imported to keep the model current with the factory operations. In addition, other data can be imported into Visio to be used as a reference for the results from the model, or to inform management with data that may be important to the operation of the factory.

Summary

The flexibility of the Sugars program is shown with a model of a beet sugar factory with molasses desugarization using chromatographic separation, three multiple effects and several single effects with mechanical vapor recompression for juice, extract, raffinate and betaine concentration along with all of the other equipment that makes up a complex factory. The optional data import and export feature allows the model to be easily updated with new data and data from the model to be exported for use by other software. The exported data can be used to do specialize calculations that can then be imported back into Sugars for rebalancing of the model.

Bibliography


Figure 1. Juice heating and liming showing where extract is added.

Figure 2. Extract added to Cold Limer Tank 2170.
Figure 3. Thin juice heating with 1st through 3rd effect evaporation.

Figure 4. Evaporation with 5th effect for standard liquor concentration.
Figure 5. High Green and Low Raw Crystallization with Molasses to MDS.

Figure 6. Molasses treatment and chromatographic separation for betaine, sucrose extract and raffinate.
Figure 7. CNS and upgrade evaporation.

Figure 8. Raffinate and extract evaporation.
Figure 9. Steam and electrical generation and steam distribution.

Figure 10. Sugars data import and export dialog.
Figure 11. XML data file example showing turbo alternator data.

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Figure 12. Excel import of Sugars XML data.
Figure 13. Excel imported Sugars XML stations data for the turbo alternator and distributor.

Figure 14. Excel turbo alternator Willans line calculation for isentropic efficiency.