Scales in evaporators of cane sugar factories – economic aspects of their removal and prevention

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Abstract Based on data from cane sugar factories in South and Central America and Southeast Asia the economic aspects of scaling are discussed. Costs for chemical and/or mechanical cleaning are shown, as well as costs and benefits of scale prevention. For the calculation of energy losses caused by scaling, a simplified model was used. Reducing the scale formation gives greater benefit to sugar factories than the removal of scale. The economic advantage of scale prevention comes from the savings of energy and bagasse. In many countries bagasse is no longer a waste to be burned but a fuel with a market price. Saving energy has become an interesting aspect for cane sugar factories as it has always been for beet sugar factories.

Key words Scale removal, economics of scale prevention

INTRODUCTION

The reduction of heat transfer caused by the formation of scales is a significant problem in cane sugar factories (Baier and Praus 2003). Scales in evaporators are quickly formed and require several cleaning stops during a crushing season. Depending on juice quality and evaporator station design, cleaning intervals of 2-30 days are reported for operation without scale prevention. While the concept of scale prevention by softening or dosing of polyacrylate is well established in the beet sugar industry, its application in the cane sugar industry is still limited. Many cane sugar factories are unsure if scale prevention could give an economic benefit compared to the mechanical or chemical removal of scales.

Here we evaluate the economic aspects of scale removal and prevention.

MATERIALS AND METHODS

Removal of scales

The cleaning procedures used for cost calculations have been successfully applied by hundreds of sugar factories all over the world. Costs for chemicals have been calculated with local market prices. For other costs, several comparative listings prepared by experienced engineers from factories in Latin American countries have been used (Pelaez 2016), representing factories of 3,000 to 15,000 t cane/day with cleaning intervals of 5-25 days.

Avoidance of scales

Polyacrylate is the chemical base for antiscalants used in cane sugar juice. It stabilizes small micro crystals of scale forming compounds by attaching with one end of its molecular chain to their surface, thus preventing any further growth. The micro crystals are stable throughout the process of sugar production and end up in the molasses. They have no influence on the further use of the molasses for fermentation or as feed. The dosing amounts used in the calculations are based on experiences in many factories all over the world and range from 6-15 ppm polyacrylate on cane (20-50 ppm of a typical commercial formulation).
Model of energy saving by scale prevention

For demonstrating the economic impact of scaling in a cane sugar factory a simplified model was used for the calculation of energy savings. Based on literature data (Baier and Praus 2003) of the heat transfer coefficient dependence on scale thickness, we calculated the steam demand. The increase of scale with time was taken into account, as well as the number of effects. From the resulting amount of steam, the amount of bagasse burned to produce the steam and from the price of bagasse the cost of the steam were calculated. Comparison was made between different types of scale prevention by including their costs in the model calculation. The model is simpler than, for example, the one published by Burke (2016), but complex enough to reflect the changes in energy demand with increasing scaling and shows the same tendencies. The prices for bagasse have been investigated for several countries during the seasons 2014-2016.

RESULTS AND DISCUSSION

Economic aspects of scaling

Our approach was to show where the most important costs and losses related to scale formation take place. Because the absolute numbers depend strongly on the economics of a specific country and local prices, the data are given as percentages. The data shown are averages with a variation of about 10%.

Costs and losses for cleaning stops

The majority of expenses resulting from cleaning stops, such as the price of chemicals and labour, are easy to summarize and well known to the factories. Sugar losses are often more difficult to summarize (Fernández and Vodopivec 2011), but are the main contribution to the costs and losses during cleaning stops as shown in the list below:

- Water (preparation of solution, hydrojet etc.) 1%
- Sugar losses (invert sugar, sweeten off of evaporators etc.) 44%
- Cleaning chemicals (NaOH, additives) 28%
- Fuel (bagasse, cold water for boilers etc.) 9%
- Days lost by reduced milling during stops 8%
- Labour 4%
- Maintenance, spare parts and fuel for hydrojet 3%
- Repairs of evaporators 3%

Comparison of costs and losses during cleaning stops with the cost of a scale prevention that is able to double the time between stops shows that scale prevention is about 50% less expensive than scale removal. Because sugar losses contribute 44% to the costs of cleaning, comparisons without taking it into account often give results without a clear preference.

Costs and losses during operation of evaporators

Between the cleaning stops the increasing scale formation causes a decrease in heat transfer. The more the scale builds up the more energy is wasted.

In a realistic scenario for a sugar factory in Thailand (Fig. 1), where a scale formation up to 1.5 mm is allowed before a cleaning stop, the heat transfer is reduced by more than 60%. With the application of well-chosen scale prevention, scale formation can be reduced to a maximum of 0.1 mm during the same period, resulting in a loss of heat transfer of less than 10%. The cost calculation model shows that good scale prevention is more economic after a third of the time between cleaning stops, while an insufficient scale prevention that would allow 1.0 mm of scale will need two-thirds of the time to cover its costs. The average benefit of good scale prevention for the factory resulting from energy savings during the operation of the evaporators is 2% of the price of 1 t of bagasse per t of cane, e.g. with a bagasse price of 400 Baht the benefit will be 8 Baht per tonne of cane.
Development of heat transfer and costs during operation with and without scale prevention. Calculations used: price of 1 t of bagasse 440 Baht; Cost of 1 t of steam 195 Baht; Number of effects 5; Brix in clarified juice 15; Brix in syrup 65; Operation between cleanings 30 days; Scale after operation without prevention 1.5 mm; Scale after operation with poor prevention 1.0 mm; Scale after operation with good prevention 0.1 mm.

The model was tested with data from factories in Thailand, Philippines, Mexico, Guatemala, Egypt, Colombia and Brazil. While the relation of costs and their development with time is similar, the absolute benefit depends strongly on the local price for bagasse. We used prices for bagasse as in Table 1.

Table 1. Values of 1 t of bagasse in 2014-2016.

<table>
<thead>
<tr>
<th>Country</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td>440 Baht (= 12 USD)</td>
</tr>
<tr>
<td>Egypt</td>
<td>20 € (= 22 USD)</td>
</tr>
<tr>
<td>Brazil</td>
<td>100 R$ (= 29 USD)</td>
</tr>
<tr>
<td>Mexico</td>
<td>39 USD</td>
</tr>
<tr>
<td>Philippines</td>
<td>2000 Peso (= 43 USD)</td>
</tr>
<tr>
<td>Guatemala</td>
<td>360 GTO (= 47 USD)</td>
</tr>
<tr>
<td>Colombia</td>
<td>50 USD</td>
</tr>
</tbody>
</table>

Instead of loss of energy, scaling may lead to a loss of capacity and a longer duration of the season resulting in higher operation costs of the factory. This aspect is of interest in factories where the capacity of the evaporator station is a bottleneck and other parts of the factory, such as mills, juice purification and sugar house, could work with higher capacity. The economic benefit of a higher evaporation capacity depends on the gap between the existing capacity and the optimum capacity of the factory. An increase in capacity of 10% will at least pay the cost of the scale prevention.
REFERENCES

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Incrustations dans les évaporateurs des usines de canne à sucre – aspects économiques de leur élimination et de la prévention

Résumé. Les aspects économiques des incrustations sont discutés, basés sur des données provenant des usines en Amérique Centrale et du Sud, et en Asie du sud-est. Les coûts du nettoyage chimique et/ou mécanique sont donnés, ainsi que les coûts et les avantages de la prévention des incrustations. On a utilisé un modèle simplifié pour le calcul des pertes d'énergie causées par l'encrassement. Réduire la formation des incrustations donne plus d'avantages aux sucreries que leur enlèvement. Les économies d'énergie et de bagasse sont les causes de cet avantage. Dans de nombreux pays, la bagasse n'est plus un déchet pour être brûlé, mais une source d'énergie avec une valeur financière. L'économie d'énergie est devenue un aspect intéressant pour les sucreries de canne, comme cela a toujours été le cas pour celles de betterave.

Mots-clés: Incrustations, économie, prévention

Incrustaciones en evaporadores de fábricas de azúcar de caña - económicos aspectos de su eliminación y prevención

Resumen. Basado en datos de azucareras de caña en América del Sur y Central y el Sudeste Asiático se discuten los aspectos económicos de la formación de incrustaciones. Se muestran los costos para limpieza química y/o mecánica así como los costos y beneficios de la prevención de las incrustaciones. Para el cálculo de las pérdidas de energía por la formación de incrustaciones, se utilizó un modelo simplificado. La reducción de la formación de incrustaciones da un mayor beneficio a azucareras que la eliminación de incrustaciones. La ventaja económica de la prevención de incrustaciones resulta de los ahorros de energía y bagazo. En muchos países el bagazo no es nada más un desecho para ser quemado pero un combustible con un precio de mercado. Ahorrar energía se ha desarrollado a un aspecto interesante para las azucareras de caña como había sido siempre para las azucareras de remolacha.

Palabras clave: Eliminación de incrustaciones, aspecto económico de la prevención de incrustaciones