

ENERGY SAVING IN SUGAR MANUFACTURING PROCESS

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Abstract: This paper presents a thermo-energetic analysis of the processes in a sugar mill. This study is motivated by the deficiency of thermoenergetic studies on that processes and environmental impacts. This study provides solutions for rational energy use and optimizations according to the constraints imposed on juice concentration at evaporator outlet and the constraint imposed on power balance of the factory.

Keywords: sugar, energy saving, reverse osmosis, cooling crystallization

1. INTRODUCTION

The rapidly changing markets for sugar and energy provide an excellent opportunity to develop innovative methods to optimize the energy use from the sugar plants. In the sugar manufacturing plant, de-bottlenecking, selective process changes and improved heat recovery are needed. The cost of sugar manufacturing depends highly on the multiple-stage evaporator's steam consumption. More precisely, the sugar evaporation processes should be designed in such a way that the energy used is optimized, and the required quality of the final product is achieved.

In Romania there are 9 sugar mills, from among 5 process raw sugar (Buzau, Liesti, Urziceni, Calarasi, Corabia), while other 2 (Roman and Oradea) process raw sugar (extracted from sugar cane) and sugar beets and other 2 (Ludus and Bod) process only sugar beets. The estimated annually sugar production is 109 164 tons extracted from sugar beet and 329 636 tons extracted from raw sugar. The capacities of Romanian sugar factories are usually 1000 to 4000 tons/24 hours.

2. SYSTEM DESCRIPTION

The technology of sugar production from sugar beets is well known [1, 2]. The process is portioned into six main units, namely: raw juice production, juice clarification, juice concentration, sugar refining, sugar drying and steam/power production. There are also three auxiliary units, namely: the vacuum system, hot water processing-storage system and lime and carbon dioxide production. The process block diagram showing these units interlinked by means of main process streams and, vapour and liquid water streams is given in Fig. 1. The cossettes (sliced beet fed to diffuser) preparation steps, beet transportation and washing and slicing steps are not included in the analysis. The raw juice production unit consists of the diffuser, pulp press and other auxiliary equipment. The juice purification unit is comprised of the multiple effect evaporator system, sugar refining unit, vacuum pans, cooling crystallizers, centrifuges and granulator. The main equipments of the steam/power unit are steam generator, degasifier, feeding pump and steam turbine. Vacuum system consists of a barometric condensers and cooling tower.

The hot water processing-storage system includes hot water storage tanks and nozzle-type steam traps, in which hot water is adiabatically evaporated under reduced pressure in order to profit by its thermal energy by producing some more steam. Because the process contains several hot and cold streams, a certain level of heat integration is

performed by means of various heat exchangers for an efficient energy economy. Sugar production processes can differ depending upon the kind of the diffuser, the juice clarification method, the number and mode of operation of the evaporators, the sugar refining scheme and the number and type of crystallizing pans.

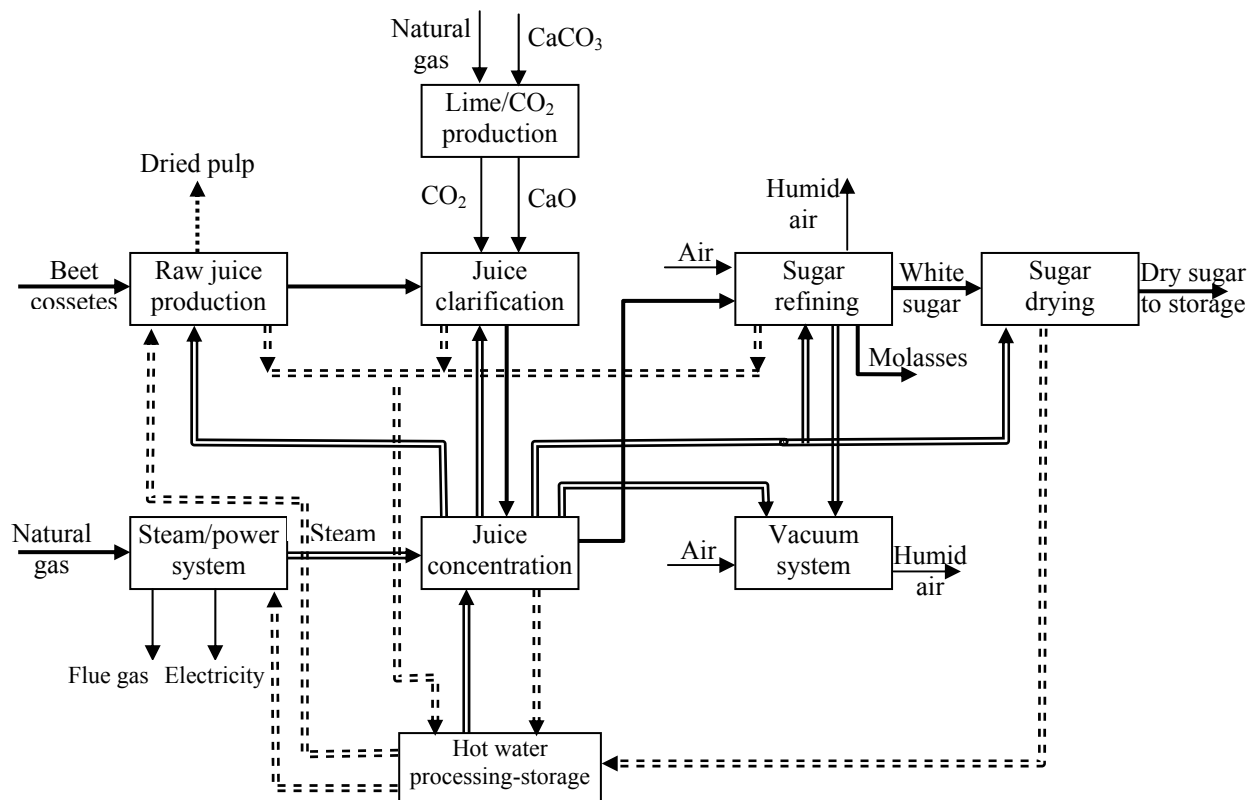


Fig. 1. Simplified flow sheet of the sugar manufacturing process.

The sugar extraction process from raw sugar can be broadly classified into the following steps. The juice obtained by raw sugar dissolving is heated, after which it is treated with various chemical reagents like lime, sulphuric acid, phosphoric acid, carbonic acid, magnesia etc to remove the impurities. It is then passed through a set of evaporators, in which the water is evaporated and syrup is formed in the end (the saccharose concentration increases to 69.5 - 70° Brix but without presenting crystallized sucrose).

The evaporation process more used in Romania is with multiple effects, in parallel currents (the broth and vapour are fed in the preevaporator, proceeding parallel through the first until the last effect). In general, the circuit is composed by five similar equipments. Because of the high viscosity, the syrup cannot be more concentrated in common evaporators and it is heated in a vacuum pan and then is heated in a vacuum pan before being sent into a centrifugal machine, in which the white sugar crystals are separated out. The sugar crystallization carries out in two or three stages depending on the syrup purity.

The crystallized sugar from the centrifuge has about 2% of humidity. To be stored, the sugar should have a humidity of 0.04%. This can be obtained in the sugar dryer, usually of the rotating type. The dryer has two areas. In the first one the sugar is dried by hot air and in the second area is cooled by cooling air. Both drying and cooling air is aspirated by a centrifugal fan and led to a cyclone to recover the sugar drawn by the air. The drying air is heated in a heat exchanger using saturated steam, and cooling air is cooled using a refrigeration system.

3. MINIMISATION OF ENERGY CONSUMPTION

To reduce the energy consumption in a sugar factory, the evaporator subsystem and the process heating subsystem should be analysed to make improved heat recovery possible.

The most energy intensive steps of the sugar manufacturing process are:

- extraction of juice from sliced beet sugar;
- juice purification to reduce its content of non-sugars;
- evaporation to remove excess water and concentrate the juice;
- evaporating crystallisation of sugar from concentrated juice.

In each of these steps, heating is required as either temperatures of process streams must be increased, or water must be evaporated.

In classical sugar factories, evaporation is one of the most energy intensive unit operations which mainly used for concentrating thin sugar juice. After filtration of sugar thin juice, the feed enters into the multieffect evaporators with around 15% sugar. Brix degree is defined as the percent of dry substance in a solution. The Brix degree of the concentrated sugar solution is more than 60. Due to the high latent heat, evaporation of water consumes huge amount of thermal energy and fuel which results in higher operating costs and environmental problems. Furthermore, heating sugar juice could lower the product quality by changing the colour and flavour.

Finding low energy consuming alternative processes have been of scientists' interest. Membrane processes with no phase inversion could be considered as the best candidates for this purpose. These processes are very energy effective and could replace current energy intensive processes like evaporation and distillation solely or in hybrid configuration. Dehydration of sugar solutions is one of the capabilities of membranes. Some of the membrane processes such as membrane distillation, osmotic distillation, nanofiltration and reverse osmosis (RO) could be applied to sugar syrup concentration. The possibility of employing reverse osmosis in sugar industry is subject of researches from several years ago [4]. The benefits and advantages of membrane technology over common evaporation including lower cost are clearly shown. A hybrid process involving pre-concentration of the feed by RO followed by further concentrating the RO retentate by osmotic distillation, could yield a highly concentrated product of an excellent quality, but at significant reduction in processing cost. For instance, this reduces the evaporator capacity requirements by one-half.

Vapour and hot condensate generated in the evaporator, as well as other hot process streams, are the carriers of heat that can partly be recovered in a heat exchanger network (HEN). Excess vapour is condensed, and waste heat is transferred to cooling water and subsequently discharged from the process to atmospheric air flowing through cooling towers installed in the water circuit. Because the evaporation of raw juice occurs in the pressure range below the atmospheric pressure that is, in the temperature range 40-85°C, the temperatures of vapours and condensates are therefore low, limiting the possibilities of heat recovery. Considerable energy-saving potential can however be found in the evaporator scheme and use of vapour recompression. For any evaporator scheme possibly including a vapour recompression circuit, process-to-process heat recovery in the HEN should be maximised. This problem may be coupled with process design if its solution includes optimising vapour flows in the evaporation subsystem. If these flows are fixed, then the amount of heat to be recovered is fixed as well.

In the process heating subsystem, structural changes in the HEN and changes in the allocation of heating duties to individual exchangers are allowed. It should, however, be noted that changed heating duties in the HEN necessitate adjustments of the evaporation process because flows of heating vapours extracted from the individual evaporation stages are changed. As can be seen, the retrofit design problem is a complex one involving interactions between the process and the energy system. Additional complexity stems from the fact that the required process changes are subject to various constraints relating to the process or to the existing equipment. For example, changes in vapour flows extracted to process heating must not increase juice concentration at evaporator outlet above the predetermined value, and it may also be necessary to account for constraints reflecting the need for relying on heat transfer surfaces of the existing evaporator units.

The steam is generated in almost all sugar factories using natural gas. In addition to being the most economic fuel option in many countries, the natural gas makes possible to choose between various options of the power plant. A solution commonly used is the combined heat and power generation. Characteristic of sugar factories is the tendency towards self-sufficiency in power. Ideally, the interaction between the power plant and the process plant should make it possible to operate the factory without power export or import. While supplying the

necessary steam flow to the process, the power plant should generate as much power as is needed for driving factory equipment including possibility a vapour compressor. As the power consumed by the compressor drive depends on the vapour flow, this constraint must be accounted for when designing the evaporation process. As a consequence, the optimum evaporation design depends on the ratio of power to heat characterising the power plant. There are three possible power plant solutions. Steam cycle that includes a boiler supplying steam to a back-pressure turbine coupled with an electric generator is a commonly used option. Steam from the turbine exhaust is de-superheated by condensate injection and supplied to the process. In order to increase the flexibility of the power plant with respect to the ratio of power to heat supplied a part of the flow of boiler steam can bypass the turbine via a throttling valve. For a small factory the power plant would include a boiler operated at steam parameters 25 bar and 400°C, and a turbine operated at 1.2 bar back-pressure. Another solution is one based on gas turbine cycle. It has the advantage that for equal amount of heat supplied, it can generate more power than the steam turbine cycle. The gas turbine drives an electric generator, and the exhaust gas at about 500°C flows to a heat recovery boiler producing saturated steam at 1.2 bar that is 105°C; steam is supplied to the process. To increase the flexibility of the power plant with respect to the ratio of power to heat supplied, the heat recovery boiler can be equipped with additional burner. The third solution is based on an internal combustion engine which can be fuelled partially with ethanol produced from molasses. The engine drives an electric generator, and the exhaust gas at about 500°C flows to a heat recovery boiler producing saturated steam at 1.2 bar that is 105°C; steam is supplied to the process.

4. CONCLUSION

In this paper energy consumption in sugar factory was investigated. Significant energy saving can be gained by replacing or combining the evaporation process with low energy consuming processes such as membranes; vapour recompression applied to evaporation process (simultaneously combined heat transfer area in the HEN is reduced) and by re-design of the evaporator and the process heating subsystem using a procedure that combines pinch analysis algorithm with evaporator simulator.

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