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Sugar Manufacturing and Process Performance Analysis – A Study

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ABSTRACT

Sugar is one of the most desirous commodity in every part of the world. It production requires a lot of planning from crop to final product development. In the present work it is analysed that sugar production is passed through a lot energy intensive processes. These energy intensive processes are necessary at every level of sugar production. Therefore, to plan any energy conservation policy it is rudiment to understand all these processes. Technology is making its way through human development with new inventions in science and engineering. A lot of new inventions are taking place day by day. The parameters to evaluate process performance are also numerous. These parameters may be inter-reliant or independent. Therefore, performance analysis of sugar manufacturing makes it necessary to look into the performance parameters and their interdependence so that their role in technology development may be fully understood.

Keywords: analysis, performance, processes, sugar

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INTRODUCTION

Sugarcane and sugar are known to India since Vedic times. The first mention of sugarcane in the world literature is found in ATHARVA VEDA. In the legends in Hindu mythology many references of sugarcane, syrup and crystalline sugar are found.

The words for sugar in most languages of world are derived from the Sanskrit word "Sharkara". It is from India that knowledge of sugarcane culture, production and use of sugar spread to different parts of world. During Alexander's invasion of India, Greeks learnt about sugarcane and sugar in 325 B.C. In 600 AD. Chinese learnt art of sugar manufacture from Indians. The cultivation of sugar was introduced to western world by the Spanish and Portuguese in 16th century.

Sugarcane being a C_4 crop is capable of fixing more CO_2 by efficient processes of photosynthesis and translocation. The sugars, synthesized in the leaves are translocated to the stem in the form of 'sucrose' and are converted into glucose and other sugars. The glucose molecules are used for the development of plant parts (structural units) in the growth phase. As soon as the processes related to growth and development start ceasing, the sugar accumulation starts and sucrose is formed by glucose and fructose after dehydration.

There are about 140 types of sugars. Among these there is a family of sugar with whose name the suffix 'ose' is associated, for example sucrose, dextrose, maltose, mannose, etc. The suffix indicates that whole family is built up from components of carbon, hydrogen and oxygen in different proportion. Inside this

family of carbohydrate composition of sugars, the chemical name of ordinary sugar is sucrose.

Sugar industry in India is fast expanding and modernizing. Undertaking machinery and equipments that are coming up with high technology and energy efficient design are very essential.

Efficiency at all stages of the manufacturing is only measure of survival through reduction of the cost of production and keeps up the economic viability. Efficiency is dependent on the skill with which the operatives are connected.

The importance of sugar industry therefore, is more relevant now, as it is an agro based industry and can provide cutting edge to Indian economy in its future global transactions. It is, therefore, essential to conduct a reconnaissance of the existing resources in terms of technology system and manpower skills.[1–3]

The technology up gradation of the industry therefore, should follow a two-pronged strategy consisting of synergies in the up gradation of the existing design of plant and processes & manpower training.

In nutshell, the objectives of sugar industry should be to maximize productivity through efficient use of technology and the vast skilled manpower resource it has at its command.[4–7]

Successful implementation of modern technologies for the purpose of improving the overall productivity calls for a higher level of skills of the operating personnel.

Whereas the class room can provide the necessary theoretical knowledge, the on the job training in the factory is essential to sharpen the skills of manpower employ.[8–11]

PRODUCTION PLANNING AND CONTROL

Sugar production is comprising of a lot of processes. These processes are accomplished with the help of following equipments:

(1) Economizers
(2) Two extra evaporator bodies
(3) One pan
(4) One vacuum filter
(5) One vacuum crystallizer
(6) Under feed rollers at mill and cane unloaders
(7) One water cooling crystallizer

However, sugar factory made some changes in previous process to produce competitive white and bold grain sugar to meet out the demand of modern market for better relegation and maximum possible sugar recovery. Maceration % on fibre was increased from 180 to 220% and water was used in melting of sugar in melter. Early mature cane varieties were introduced in the field. These common efforts improved both the quality and the recovery. Sugar industry achieved highest sugar recovery 10.29% in the year 2003–2004. In spite of our best efforts sugar scale relegation could not be improved due to bumper sugar production in the country in last 5 years.

In the year 2004–2005, 2008–2009 sugar industry in India faced cane shortage. Though, it was not for this mill but all over the country. Some of sugar mills were affected worst and other comparatively less. Drought, delays in cane payment and cane cycle were the main factor to bring down cane supply. It is estimated that sugar production will be 30 to 40% less as a whole this year over to last year in the country.

Factory implemented some equipment based on latest technology in place of obsolete design and worn out equipments in the year 1998–2001, 2003 and 2004 to improve the technical efficiency of plant

and competitive sugar quality and achieved result accordingly. Such equipments are listed here under:

1. Sugar grader
2. Sugar stacker
3. Toothed under feed roller
4. Cooling and condensing system
5. Provision to clean body individually
6. PLC control machines
7. Single element control

MANUFACTURE OF SUGAR

The sugar commonly used is white crystalline in shape. The present system of sugar manufacture is subdivided into following stages:

- Extraction of juice from sugarcane by milling
- Clarification of juice
- Concentration of juice by evaporation to syrup
- Crystallisation of sugar by vacuum pan boiling
- Drying and cooling of sugar
- Sugar grading and packing

Sugarcane Milling

Sugarcane received at the factory is weighed on the platform scale and fed into cane carrier by mechanical unloaders of grab type. During its travel to milling, the cane is prepared for crushing by the preparatory devices.

The preparatory devices consist of kicker, cutters and leveller. The leveller and cutter consist of knives, whose number depends upon width of carrier. The knives rotate about 600 rpm for cutting the cane travelling on carrier. The milling plant usually consists of four mills each of 3 rollers which are hydraulically loaded. The preparatory cane passes through these mills where it is subjected to repeated application of high pressure. The spent cane is discharged from the last mill, and juice is collected from the mills and pumped into the boiling house for processing.

In the process of milling hot water is applied on the mills to increase the extraction of sugar. Compound maceration is followed by application of dilute juice on penultimate mills.[12–14]

In this system water is spread over the blanket of cane before last mill. The diluted juice from this mill is spread on the blanket to the preceding mill and so on. Hence, the system gives a counter current process, thus improving the extraction of sucrose.[15,16]

Milling in this manner gives about 92–95% extraction. The discharged bagasse from last mill contains fibre, sugar and about 50% moisture. This bagasse is elevated by bagasse conveyor to a height convenient for being finally discharged into boiler furnace for burning. Heat is utilised to generate steam at required pressure and temperature. The steam produced is used for generation of power and the direct steam drive prime motors. The exhaust steam available from prime movers is utilised for process heating and evaporation, etc.

Clarification of Juice

The juice as extracted out of cane is composed of primary juice expressed by first crushing unit called 1st mill and diluted juice from second crushing unit called as secondary juice. Both these juices are combined together and termed as mixed juice. The mixed juice is a sugar solution which consists of about 84% water, 13% sucrose, 3% nonsugar impurities. The principle non-sugars are invert sugars (1.5%) and inorganic ash (0.5%). The mixed juice when sent for processing is termed as raw juice and its pH ranges from 4.7 to 5.7. At this pH, the juice is prone to microbial as well as

chemical inversion. It is advisable to process the juice as quickly as possible to prevent loss of crystallisable sugar, and to avoid oxidation which causes coloration. In order to achieve maximum recovery of sugar, it is essential that raw juice must be free from all non-sucrose solids. The presence of each part of non-sugar in juice causes 0.4 part of sucrose to be noncrystallisable. Lower the purity of juice, larger is the amount of sucrose lost in final molasses. To get rid of impurities, the juice is subjected to clarification treatment.

Essentially, the good clarification process to be adopted is the one that enables maximum removal of impurities. The raw juice is strained at mills and sent to the juice weighing scales where juice is weighed and its weight is recorded. There are three types of clarification processes for sugarcane juice:
(1) Defecation
(2) Sulphitation
(3) Carbonation

The first method is often used for producing raw sugar for subsequent refining, while the other two are generally used when it is desired to make direct consumption or plantation of white sugar. Essentially, the treatment of cane juice in any of the different method aims at neutralizing the natural acidity and precipitating as much non-sugars as possible out of it to obtain a neutral, clear, amber coloured juice. Many different products like phosphates, magnesia were tried for clarification of raw juice but still lime remains the most economical agent for juice clarification. Sugar mills in India mostly follow sulphitation process as described below.

Sulphitation Process
This is standard and conventional process followed with various modifications such as pre-sulphitation, pre liming for obtaining good quality of white sugar. The juice is heated to 70°C after making up its p_2o_5 level to 300 ppm. Optimum dose of milk of lime is added and sulphur dioxide gas is simultaneously applied to bring down the PH to 7.0. During this process, phosphate and calcium salts are formed and the flocks absorb the impurities and colour.

The sulphited juice is again heated to 100°C in the secondary juice heaters and is allowed to settle in continuous clarifier. The effect of heat and precipitation of $CaSO_3$ results in settling of most of impurities. The clarified juice is drawn out from the clarifier and the mud is filtered in the continuous rotary filters. The consumption of lime and sulphur no cane is 0.11 to 0.20% and 0.04 to 0.10%, respectively.

Evaporation
The juice as received from clarification station contains water and sucrose together with water added to mills for the purpose of maceration and water used for washing the filter cake. The clear juice is stored in a clear juice tank from where it is pumped to the evaporator first body through pre-heater.

The function of pre-heater is to raise the temperature of clear juice to boiling point temperature of first vessel. In this way, pre-heater plays important role in augmenting evaporator capacity. Otherwise, initial heating has to take place in lower part of tube in the first vessel of evaporators.

The evaporation is carried out in multiple-effect evaporators quite often preceded by single or double- effect vapour cells. All modern multiple effects are vertical tube evaporators based on Rillieux's principles. The saturated steam (exhaust of prime movers) is admitted in calandria (steam space) of the first vessel where it parts with its latent heat to the juice inside the vertical tubes and gets condensed. The

condensates are continuously removed & fresh steam intake continues. The juice inside the tube which is already at boiling point absorbs latent heat from steam and evaporates. The vapour thus liberated by boiling juice passes through pipe into steam space of next vessel and juice is evaporated for the second time by the vapour from its preceding vessel(i.e. by its own vapour). The process is repeated in subsequent vessels generally comprising of four effects thus known as Quadruple effects.

The vapour space of last vessel of quadruple effect is connected to the condenser where vapours are condensed by bringing them into intimate contact with cold water. The non-condensable gases are removed from calandrias under vacuum to save condensers or ejectors.
The condensate of first calandria which has higher temperature and is free from sugar traces, is sent to the boiler feed tank through the pump. The condensates from second, third and fourth calandria are removed by means of pump through equalizing system, since these calandrias work under vacuum. The second condensates may contain some sugar traces & are as such used for process and maceration. The high density (60° to 65° brix) syrup accumulating in the last vessel is evacuated under vacuum by means of a pump and is sent to storage tanks on pan floor after sulphitation.

Crystallisation-Pan Boiling
The sulphited syrup is subjected to boiling in the vacuum pans where its concentration leads to the super saturation and formation of crystals. A three or four stage boiling scheme is selected keeping in view the size of sugar crystals desired and the exhaustion of mother liquor.

Various massecuites i.e. A, B, C are formed after boiling in pans treated in the crystallizers where residual salting out of sugar to exhaust the mother liquor takes place. Three or four stages exhaustion minimizes the sugar loss in last or final mother liquor which is called final molasses and is sent out to storage and disposal.

Centrifuging
The curing of A, B and C massecuites is done in centrifugals to separate the respective molasses from sugar crystals. A massecuite where from commercial sugar is received is cured in vertical batch type machines with automated and recycling controls, sugar in the basket is washed with water and/or steam and molasses is fractionated into heavy and light fractions.
B massecuite is cured in vertical continuous machines where B molasses is separated. B sugar is magmised to be used as footing for A or melted and melt is used for building A massecuite. C massecuite is also cured in continuous centrifugals, mostly in two stages to obtain Final Molasses, which is sent out, C light molasses is used back in boiling. C sugar is melted and used for A boiling.

Drying and Cooling of Sugar
If this wet sugar is sent to godown it deteriorates considerably during storage by the action of bacteria on film of molasses which envelopes it. By sugar conditioning, it is meant to lower the moisture content of sugar to 0.02 to 0.05% and to cool down the sugar for packing. In the process of conditioning, the sugar crystals produced in the centrifugal machine dries in basket and cools on the grass Hooper conveyor. This conveyor discharges the sugar in the foot of sugar elevator which delivers it into graders.

Sugar Grading
Sugar discharged from the elevators is fed to the graders where it is screened into different size graders before storage in

godowns. In vibrating screen, the vibrating frame is mounted on the springs and belt driven rotating shaft is mounted on the vibrating frame. The desired magnitude of vibrations is achieved by means of variable unbalanced flywheel mounted on the shaft. This unit is composed of three to four decks. In each deck, the wire screen of desired opening is held in position under tension by clamp at the slope of 35^0 to the horizontal. The sugar obtained from elevators is fed on the top of grader and is collected in bags from different spouts for different sizes.

Storage

The sugar packed in 100 kg bags is stacked in the sugar godowns. To prevent its deterioration in storage the godown as constructed to provide storage facilities free from humidity to prevent the sugar from absorbing moisture. Humidity is controlled to below 60–65% for deterioration free storage.

CONCLUSIONS

A lot of precautions are necessary for sugar storage. The humidity of godown atmosphere should be maintained as low as possible, perfectly in region 0f 50% and never above 60%. These conditions can only be secured if godown is tightly closed and floor is cemented. The doors of godown should not be opened in dry weather and as far as possible never in monsoon period, except when handling the sugar. Temperature in godown should be maintained as constant as possible. The temperature of godown should be maintained a few degrees higher than outside temp. At the same time the temperature much above outside temperature must be avoided as sweating of walls will affect the sugar piled close to these.

The following requirements are important:

(1) Bags of sugar are stacked 2–3 feet away from walls of godown in order to prevent these bags from the heat of walls.
(2) Bags are piled upto a height of about 25 feet and a margin of about 10 feet is left from height of roof. If the pile goes higher, the danger arises that bottom layer may be crushed.
(3) Lowest layer of bags should not rest on concrete floor but should be insulated from it by means of a layer of gunny bags filled with perfectly dry bagasse.
(4) Uppermost layer of sugar bags should be covered with tarpaulin cloth in order to prevent the bags from heat of roof and to hold up any moisture dripping from the roof either by condensation or leakages.
(5) Lanes 2 or 3 feet wide should be provided after every 20 or 25 feet long stack for facility of proper handling of sugar bags & ventilation.

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