Water Integration In Sugar Industry

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Abstract: The sugar industry uses much water and produces a significant amount of wastewater for disposal. Efficient utilization of water is vital in the process industries, not only to reduce the cost of the supply and discharge of freshwater associated with the process but also to minimize environmental problems associated with the use and discharge of water. This paper presents the analysis of fresh water used and wastewater discharged in a sugar manufacturing process. In order to reduce the load of the cooling water system. The system was modified to an open recirculation cooling water system. Also, the excess condensate internal water and the discharged water from cooling water system were analyzed and optimized using pinch analysis and mathematical optimization techniques by Resource Conversation Networks spreadsheet software.

Index Terms: Cooling water system, Cascade table, Sugarcane industry, Resource Conversation Networks, Water balance, Water pinch analysis, Water integration.

1 Introduction

THE sugar industry uses a large quantity of water and also discharges a huge amount of effluent into an environment. The water content in sugarcane is about 0.70 m^3/ton of cane crushed; out of which about 0.50 to 0.60 m^3/ton of cane crushed is utilized in the process and 0.10 to 0.20 m^3/ton of cane crushed will be excess water available in any sugar factory. This water can replace freshwater requirement and conserve natural resource [1]. The condenser water is one of the large water requirements of the sugar factory [2]. An open recirculation cooling system save a tremendous amount of fresh water compared to the alternative method- once-through cooling. An open recirculation cooling system uses the same water repeatedly to cool process equipment. Heat absorbed from the process must be dissipated to allow reuse of the water. Cooling towers, spray ponds, and evaporative condensers are used for this purpose [3].For better cooling tower performance and increased cooling tower capacity, modification of the cooling water network is very important. An extensive report on recirculating cooling water systems has already been provided by many authors. Smith et al. developed and described a grass root design method [4]. Significant efforts have been made to improve water efficiency in the process industries over a few decades, because accessing clean water resources near industrial plants has become more difficult, and stricter environmental regulations have been introduced to control water resources and protect ecosystems [2]. The Water Integration technique and Water Pinch Analysis have been commonly accepted as tools for the synthesis of water networks in the process industries [2]. Water pinch analysis (WPA) considers water reuse opportunities by carefully analyzing the flows and qualities of different streams. Possible water reuse options are identified by matching different “sources” and “sinks”. Counter-intuitively, “sources” are defined as streams coming out of processes carrying, often multiple, contaminants - whilst “sinks” are streams going into processes that often have specific water quality requirements. Water pinch fundamentals developed by Wang & Smith and El-Halwagi and Manousiouthakis have been the basis of many water use optimization methods [5].

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Pinch analysis can be used for both new processes that are to be designed and for retrofit of existing processes, [6].WPA proposes for wastewater to be reused in a process that requires less pure water, instead of being discharged into wastewater treatment [2]. WPA has been proven to give beneficial water savings. Table 1 shows some of the savings from WPA applications in industry reported by Tainsh and Rudman [2].

2 PROCEDURE

To accomplish the objective of minimized fresh water consumption and waste water disposal the water pinch analysis methodology was used. This methodology can be broken down into six steps for good results [7]:

1. Find flow data. Develop a simple flowsheet model of the water system, showing where water is used (including utility services), and where (waste) water is generated.
2. Develop a water balance accurate to within 10% of the metered amounts of the larger streams. Define the appropriate data for the Water Pinch analysis, i.e. determine water ‘sources’ and ‘sinks’.
3. Find contaminant data. Select key contaminants. In this paper was selected BOD and TDS as key contaminants.
4. Run water pinch analysis. Carry out the water pinch analysis to determine optimum matches between sources and sinks. Examine the sensitivity plots, relax constraints. Consider process modifications and regeneration options that may result in lower targets.
5. Review design. Examine the resulting network design. It is usually necessary at this point to evaluate the design and determine which additional contaminants should be considered, which matches should be forbidden, and which matches (if any) should be forced.
6. Repeat steps 3-5 until a practical design has been evolved manuscript.

2.1 Water Balance of Guneid Sugar Industry

The study was carried out in Al Guneid Sugar Industry that processes 230 tons of cane per hour. At first, the sugar manufacturing data were collected, then the current baseline of information on plant water use and wastewater generated was defined. Water and wastewater flow rates in the main process units were quantified based on the water balance of al Guneid sugar industry and data from references. The analysis data for each section is given in Fig 1 and Tables 2, 3, 4, 5 and 6.

2.2 Process Change from Once-Through to Open Recirculation Cooling System

The cooling system used for cooling milling, turbine and injection for evaporator and vacuum pan in Guneid industry are the once-through cooling system, which requires a large quantity of water and therefore discharge it as waste water. In order to management the water in the sugar industry the cooling system was changed to Open-recirculation cooling systems. The water discharged from turbine milling, the turbine for electric generation and barometric condenser were recirculation using the cooling tower for turbine milling and turbine of electric generation and spray pond for the barometric condenser. The water utility used for cooling system changed as shown below in fig 2.

2.3 Determination of Water 'Sources' and 'Sinks' Data and Selection of key Contaminants for Water Pinch Analysis

After analyzing the water network for Al Guneid Sugar Factory, the water processes are grouped into plant sections (process and utility). Processes chosen are preferably close geographically, and are also chemically related. The system can be modelled either as a single contaminant or multi contaminate. The main contaminants that prevent direct reuse in the water system are chosen. Entire water sources and sinks flowrates and quality requirements for each water-using process are extracted from the data sheet. The water sources data are obtained by identifying the maximum concentration limit and the minimum flowrate limit of the wastewater source from each process. The water sinks data are usually obtained from historical variations, emergency water substitution, estimates from engineers, vendors and operators, and description in equipment list [2].

2.4 Water pinch analysis using Resource Conversation Networks software sheet (RCNet.xls):

Pinch analysis is used to determine minimum flowrate targets for fresh water and wastewater discharged. To perform the targeting task, material cascade analysis is used. Next, mathematical optimization technique based on the superstructural model is used to design the Resource Conversation Networks that achieves the flowrate targets [11].

3 RESULTS AND DISCUSSIONS

3.1 Water Used For Process

From the analysis of water balance in sugar factory the source and sink were identified and TDS was the contaminant chosen for analysis of water used for process, the requirement data were shown below in Table7. The results are shown in Table 8 above there is no need for fresh water and the excess condensate is 65.24 t /h which it's the wastewater discharged from the entire process. Based on mathematical optimization software (resource conservation network) Process water network is designed to fulfil the flow rate targets obtained from pinch analysis as shown in fig 3 above.

3.2 Water used for utility:

After modification of cooling system the fresh water flow rates requirement changed as follow in Table 9 and the discharged wastewater flow rates changed as shown below in Table 10. The excess condensate water determined from pinch analysis of process water and water purged from boiler and turbine cooling tower used consider as a source for pinch analysis for utility water. BOD and TDS were the contaminant chosen for analysis for water used for utility, the data collected were shown below in Table 11. The results shown in Table 12 the fresh water requirement is 112.77 t/h and the wastewater discharged is 15.77 t/h The results shown in Table 13 the flow target fresh water requirement is 96 t/h and the wastewater discharged is 0.0 t/h. By comparison the results shown in Table 12 and 13 above the flow target are different, therefore the selected of the most critical contaminates or used the multiple contaminate method are necessary to obtain the accurate result. Based on mathematical optimization software (resource conservation network) utility water network is designed to fulfil the flow rate targets obtained from pinch analysis as shown in figure 5 and 6 above.

4 Conclusion

1. The water balance for sugar factory was determined
2. From Pinch analysis of process water, the minimum flow target of fresh water was found to be 0.0 t/h and waste water discharged was found to be 65.24 t/h. This shows that the vapor condensate in sugar factory meets its process water requirement. According to flow target obtained the process water network was designed based on mathematical Optimization software.
3. For utility water, the freshwater required was reduced from 8042.42 t/h to 212.67 t/h and waste water discharged was reduced from 8065.42 to 73.40 after recycling of water due to the modification of the cooling system.
4. From Pinch analysis of utility water, the flow target of fresh water was reduced from 212.68 to 112 t/h and waste water discharged was reduced from 73.40 t/h to 15.76 t/h when used BOD as contaminates. While the fresh water was reduced from 212.68 to 96 t/h and waste water discharged was reduced from 73.397 t/h to 0.00 t/h when used TDS as contaminates According to flow target obtained the utility water network was designed based on mathematical Optimization software.

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References

[1] Baban Gunjal and Apama Gunjal, "Water Conservation in Sugar Industry", Nature Environment and Pollution Technology, an International Quarterly Scientific Journal, ISSN: 0972-6268, Vol. 12, No. 2, pp. 325-330, 2013.

[2] Jiří J. Klemeš, "Handbook of Process Integration (PI)", Woodhead Publishing Limited, 2013.

[3] Copyright ©General Electric Company, "Handbook of industrial water treatment", www.gewater.com, 1997-2012.

[4] Lj. MATIJAŠEVIĆ et al., Analysis of Cooling Water Systems in a Petroleum Refinery, Chem. Biochem. Eng. Q., 28 (4) 451–457 (2014).

[5] Bernard A. Agana, "Factors required to enhance water recycling at two major Australian industrial manufacturing sites", Ph.D.

thesis, Victoria University College of Engineering and Science, 2013.

[6] Alexandra Rolén, "Water Pinch Analysis of a Ligno cellulosic Ethanol Production Process", MSc thesis, Goteborg, Sweden 2015.

[7] Yoo K., Lee T., Jung H. and Hang Ch., "Water Reuse Network Design in Process Industries": State of the art. Monograph (Eco-Industrial Park Workshop), 2006.

[8] E. Hugot, "Handbook Of Cane Sugar Engineering", Third, Completely Revised, Edition, Elsevier Science Publishers 1986.

[9] Meilyn González Cortés, Harry Verelst, Rubén Espinosa Pedraja, Erenio González Suarez, "Water and Wastewater Management in a Sugar Process Production", Chemical Engineering Transaction, ISSN 1974-9791, vol. 25, Hong Long Lam Copyright 2011.

[10] Mauro F. Chavez-Rodriguez, "Water Reuse And Recycling According to Stream Qualities In Sugar–Ethanol Plants", Energy for Sustainable Development 17, pp 546–554, 2013.

[11] Sustainable Process Integration Research Group, "RCNet (Resource Conversation Networks) Software User Guide for version 4.0", Centre of Excellence for Green Technologies, University of Nottingham Malaysia.