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STATE-BASED APPROACH OF SUGAR BOILING PROCESS AUTOMATION IN BATCH VACUUM PAN

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ABSTRACT

In this paper, state base approach for implementation and design of A grade batch vacuum pan is proposed. Nexgenie NG16-ADL Programmable Logic Controller (PLC) is used to control the first batch vacuum pan. This design helps to improve operators' interaction and with less intervention with ease. This system designed for auto mode and manual mode in order to have better control over the system. This enhances the good grain size development for the centrifugal process. The operator on the pan floor can readily take readings and control the process environment using this system in real time. The operator may set desirable set point for every parameter or can carry the execution with default set point during the sugar boiling process. Different states have different set points for every parameter. Using Ladder Diagram (LD) and Function Block Diagram (FBD) as the main programming language for PLC, fully automated centralized control system for batch vacuum pan is proposed. Sugar boiling process in batch vacuum pans with state base design batch vacuum pans are automated, PID control loops are used for temperature, pressure vacuum, level, and brix. Every state uses different Setpoint to minimize operator intervention and also reduces the use of resources in the control environment. This leads to the better production of sugar crystals. The operator may take real time action using this.

INTRODUCTION

These days' factory automation helps to boost the production with ease. Many process industries require sugar as their basic ingredients in the product (Hugot, 1960). This has emerged from new trends in the cultivation of cane and sugar manufacturer. Sugarcane cultivation is becoming the main source of financial stability in many developing countries. This agro-based industry has the potential to develop many by-products. Baggas, ethanol, distillery plant is a subsidiary industry to the sugar factory (Eric fujiwara, 2012). The sugar industry has its own power satisfying generators. It can help to satisfy the other industry requirements. Technological advances in electronics leading the new scopes and possibilities explorations in this field (Nadaf Ayyaj, 2015). This is a bounty to deploy new designs with advancement enabling in saving of power, extra efforts, and resources that are being used in industry. The use of available resources in process automation with effective, optimized way can help to boost the good production.

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The purpose of this project is to automate batch vacuum pan in order to achieve good utilization of the sugar boiling process.

Overview of Sugar boiling process

After harvesting sugarcane is brought in trollies to the crane. Then it is fed to the shredder, finely cut fiber is then sent to the extraction process. At this state, thejuice is extracted from these fibers. This juice holds non-sugar content; this juice is then passed to purification state. Where various process performed in order to purify the juice (Nadaf Ayyaj, 2015). This purified juice is termed as syrup. This syrup at evaporator stage evaporates excess water from it. As water is removed this brings syrup more viscous. The dissolve solid in a solution is measured in brix (Unit named after famous chemist Adolf Brix). The syrup is then termed as massecuites, continues to boil in a vacuum pan to achieve saturation point (Katsuhiko Ogata, 2000). At the saturation point, theslurry is mixed (amixture of icing sugar and ethanol) in order to develop sugar crystals. This massecuite named as A-Heavy is then sent to a centrifugal machine for sugar separation. Residual part of the massecuites is then returned to b-vacuum pan for further extraction. The temperature is maintained for evaporation of excess water and to achieve syrup to supersaturation level. The pressure of steam is maintained for the boiling of massecuites in a Ziggler's tube of pan (John Stenerson, 1999). The brix is a measured throughout the different states of processes, e.g. saturation point, seeding point and used to extract maximum sugar from syrup by boiling. The level of the pan is maintained with an inlet of syrup. The vacuum is controlled by controlling finely sprayed cold water in the barometric condenser. Once the vacuum is set up boiling of syrup takes place at low temperature and helps to retain the sugar crystals, else sugar crystal gets melt in syrup and become impossible to recover.

Steps involved in batch pan boiling

The flow chart is as shown in figure 1 below. The vacuum pan boiling process involving the steps from.

- **Drawing in:** Syrup from the evaporator body is taken in first PAN and leveled up to nearly more than 20%. Then Agitator started and heating steam is applied. The steam pressure controller takes control over the steam flow using a temperature of the PAN set point.
- **Concentration:** Boiling of PAN continues until syrup becomes more viscous. Water gets evaporated. Concentration boosts up as time passes on and temperature and vacuum in this step in maintained. The density of liquid reaches to set point indication is made to the operator to start seeding.
- **Seeding:** In seeding step operator prepares the mixture of sugar powder and isopropyl alcohol and inject this solution to PAN using a seed inlet valve. Seeding valve is opened manually.
- **Graining:** After seeding is initiated crystals of sugar starts growing. This process is called graining.
- **First Boiling:** As soon as graining occurs the operator starts boiling under keen observation. Massecuites in pan become denser. Operator boils whole massecuites till the desired level is achieved.
- **Brixing up:** As the desired level of grain size is archived syrup inlet valve is closed this leads to rising to brix level. Brix rise is due to evaporation of water and massecuites become denser.
- **Discharging:** After the brix level rise in the discharge state. The vacuum break valve opened. Vacuum controller is made off. When normal pressure is reached hydraulic valve opened till complete PAN discharged into mingler units (previously to centrifugal step).
- **Streaming out:** Streaming out valve is activated for pre-set time. So that PAN is made empty.
- **PAN empty:** once streaming out is completed. The process repeats for the next batch.

PLC based design for new proposed system

The PLC programming is done with CodeSys software Different function blocks like PID, PWM, Alarm handler have created. The PLC transitions and state ladder equation are written using following formula.

Tr*= Executing St $\times$ Work Done --------------(1)

St*= (St*+∑ Incoming Tr*) $\times \overline{outgoingTr*}$ --------------(2)

∵ Tr = Transition, St = State, * = number.

PID control loops are designed for state-based design.

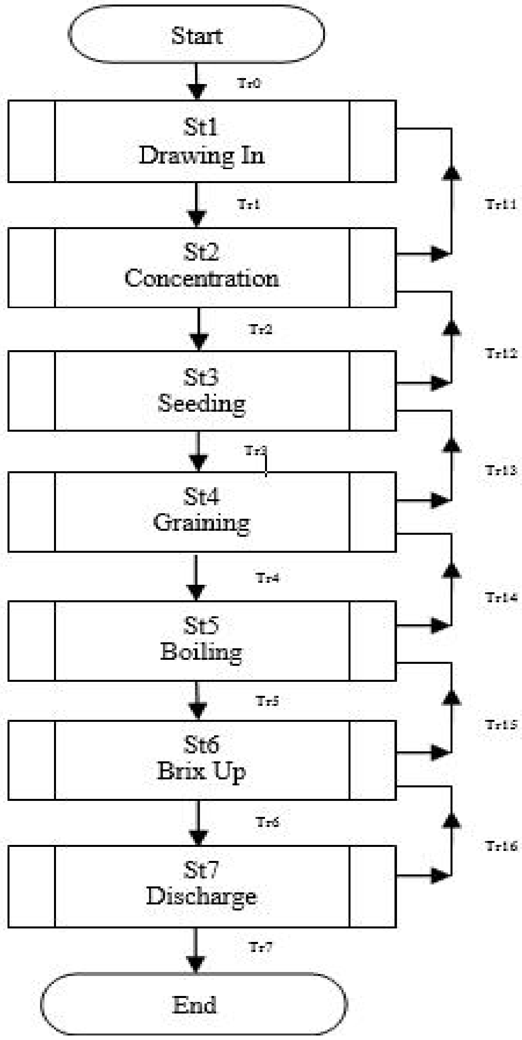

Fig. 1. Flowchart of pan boiling

- Regulation of vacuum is achieved by adjusting cold water spray in the barometric condenser. The full span of vacuum during single process cycle is 14.7 PSIA - 12.4 PSIA. The vacuum in the pan is generated if vapor from pan cooled suddenly in the barometric condenser.
- Regulation of pressure is achieved by adjusting entry of steam valve to Calandria. The pressure is maintained in the span of 0 PSIG – 8 PSIG through the single process cycle. The pressure control valve uses pressure sensor at the next end to the valve towards the Calandria. By increasing the flow rate pressure can be increased and by decreasing the flow rate pressure can be decreased in the calandria.
- Regulation of temperature is achieved by adjusting steam in calandria. The full span of temperature during single process cycle is 30^{o} C - 70^{o} C. The temperature and steam pressure valve operates exclusively in an alternate fashion. For St2, St5, St6 Temperature controller takes part in single process cycle and for rest of the state, pressure controller takes part in boiling the syrup.
- Regulation of brix is achieved differently in the state. Factors that affect brix is boiling (evaporation of water from clear syrup). The span of brix during single process cycle is 30^{o} Bx - 94^{o} Bx. The boiling rate in St2, St5, St6 take part in single process cycle and develop the brix.

- Regulation of level is achieved in St2. The span of level during single process cycle is 20^o Ton - 80^o Ton. The boiling under vacuum and in steam pressure brings the level up. The level is achieved by controlling syrup inlet valve. There is also another on-off control valve which brings level are hot water and cold water.

Field implementation picture showing PLC Panel

Fig. 2. PLC Panel

Fig. 3. Pressure Valve

Fig. 4. Syrup Valve

Fig. 5. Transmitters

RESULTS AND DISCUSSIONS

This vacuum batch pan automation project will certainly bring besides with its easiness which will permit the sugar industry to mark max profit at lowest charge. Few of the benefits that will be observed after the execution are as follows

Readings before Automation

Table 1. Before Automation

State	Temperature	Pressure	Brix	Level	Vacuum	Time in minutes
1.Drwaing in	38	1	0	0	14.70	0
2.Drwaing in	40.20	1.62	38.30	12.50	14.51	8
3.Drwaing in	40.50	2.10	38.95	22.47	13.65	16
4. Concentration	41.20	2.95	38.80	30.00	13.17	24
5. Concentration	41.50	3.65	40.65	32.44	12.86	32
6. Seeding	42.90	3.56	52.28	35.60	12.81	40
7. Seeding	43.65	3.50	60.13	35.62	12.70	48
8. Graining	46.41	3.87	62.65	46.36	12.65	57
9. Graining	55.78	3.91	62.20	52.80	12.50	64
10. Graining	55.35	2.97	68.15	69.40	12.44	72
11. Boiling	56.71	2.75	73.56	72.18	12.43	80
12. Boiling	56.12	2.62	74.65	70.39	12.50	88
13. Boiling	61.31	3.52	76.51	73.50	12.65	96
14. Brixing Up	62.25	4.62	78.95	70.84	12.50	104
15. Brixing Up	65.75	4.35	81.70	70.14	12.65	112
16. Brixing Up	64.45	3.87	83.20	70.56	12.40	120
17. Brixing Up	64.65	3.85	85.65	70.68	12.43	128
18. Discharge	64.48	4.85	88.23	70.69	13.58	136
19. Discharge	64.31	4.25	88.25	60.78	14.27	144
20. Discharge	40.2	0	0	0	14.70	152

Table 2. After Automation

State	Temperature	Pressure	Brix	Level	Vacuum	Time in minutes
1.Drwaing in	38.05	0	0	0	14.70	0
2.Drwaing in	38.65	2.83	28.34	10.23	13.10	8
3.Drwaing in	38.54	2.85	28.53	20.54	12.60	16
4. Concentration	39.57	2.90	28.80	30.28	12.70	24
5. Concentration	40.56	3.52	60.00	30.44	12.61	32
6. Seeding	42.57	3.56	60.24	30.45	12.53	40
7. Seeding	44.45	3.52	60.23	30.58	12.40	48
8. Graining	45.62	2.95	60.25	50.85	12.42	57
9. Graining	50.41	2.93	60.21	60.54	12.42	64
10. Graining	50.46	2.98	70.52	70.55	12.41	72
11. Boiling	52.45	4.13	70.65	70.65	12.46	80
12. Boiling	55.64	4.15	70.65	70.34	12.47	88
13. Boiling	60.54	7.52	80.00	70.95	12.42	96
14. Brixing Up	60.45	7.52	80.21	70.82	12.41	104
15. Brixing Up	64.87	5.85	80.32	69.65	12.31	112
16. Brixing Up	65.33	5.80	90.24	68.71	12.56	120
17. Brixing Up	65.87	7.84	90.10	67.28	12.43	128
18. Discharge	65.78	7.85	90.32	63.22	13.68	136
19. Discharge	65.11	4.21	40.30	50.15	14.20	144
20. Discharge	40.23	0	0	0	14.70	152

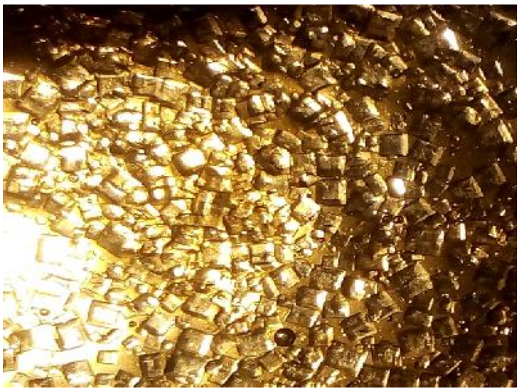

Fig. 6. Unequal sized Grain

Fig. 7. Uniform Grains

- Faster and clean Production.
- Max sucrose extraction from the syrup.
- Lowest manual labor cost.
- Optimized steam to syrup ratio. Better steam economy
- Greater loss recovery.
- Very good crystal size.

Conclusion

By using PLC, batch vacuum pan can be automated for good result. State based automation technique is very useful for batch pan processing application. Fig 6 shows unclear crystal under manual control and Fig 7 shows clear and equal sized crystal. State based approach for sugar boiling process in batch vacuum pan leads good efficiency in sugar extraction from syrup with little or effective use of available resources.

REFERENCE

Astrom, K.J., Hagglund, T. 2004. "Revisiting the Ziegler-Nichols step response method for PID control [J]". *Journal of Process Control*, 14, 634-650.

Behary, M. 2004. Fac. of Eng., Univ. of Mauritius, Reduit, Mauritius ; R. T. F. Ah King ; H. C. S. Rughooputh " Automation of sugar boiling process in batch vacuum pans using ABB-Freelance PLC (AC 800F) and conductor NT SCADA" Industrial Technology, 2004. IEEE ICIT '04. *IEEE International Conference on* (Volume:2) , pages 853 - 858 Vol. 2, 8-10 Dec. 2004

Chokshi, N. and McFarlane, D. 2008. "A distributed architecture for reconfigurable control of continuous process operations," *Journal of Intelligent Manufacturing*, vol. 19, Apr., pp. 215-232.

Eric fujiwara, eduardo ono, and carlos kenichi Suzuki "Application of an optical fiber sensor for the determination of sucrose and ethanol concentrations in process streams and effluents of sugarcane bioethanol industry" , IEEE sensors journal, vol. 12, no. 9, page no2839 – 2843, september 2012.

Favre-Bulle, B. and Zeichen, G. 2006. Zukunft der Forschung in den Produktionswissenschqften, Verein zur Förderung der Modernisierung der Produktionstechnologien in Österreich - VPTÖ.

Hamaguchi, T., Hattori, T., Sakamoto, M., Eguchi, H., Hashimoto, Y. and Itoh, T. 2004. "Multi-agent Structure for Batch Process Control," Proceedings of the IEEE *International Conference on Control Applications*, Vol. 2, pp. 1090-1095.

Hong, X. and Jiancheng, S. 2007. "Multi-Agent Based Scheduling for Batch Process," Proceedings of the 8th IEEE International Conference on Electronic Measurement and Instruments (ICEMI'07), pp. 2-464-2-467.

Hugot, E. 1960. "Handbook of cane sugar engineering" ISBN: 978-1-4832 3190-7,Elsevier Publishing.

John Stenerson, Fundamentals of Programmable Logic Controllers, Sensors, And Communications, 1999, Prentice Hall.

Katsuhiko Ogata, 2000. Modern Control Engineering, 2000, Prentice-Hall of India.

Lee, J. M., Yoo, C. K., Lee, I. B. 2004. Enhanced process monitoring of fed-batch penicillin cultivation using time-varying and multivariate statistical analysis[J]. *Journal of Biotechnology*, 110(2): 119-136.

Nadaf Ayyaj, I., Kulkarni, S. V. Shaha, P. P., Bhanarkar, M. K, 2015. "PLC Based Control System for Brix Measurement". *International Journal of Engineering Research and General Science*, ISSN 2091-2730, volume 3 issue 5, Year, page 1062-1065.

Nadaf Ayyaj, I., Kulkarni, S. V., Shaha, P. P., Bhanarkar, M. K. 2015. "Advanced High-Speed Frequency to Voltage Converter for Industrial Controllers". *International Journal of Engineering Research and General Science*, ISSN 2091-2730, volume 3 issue 4, Year, page 347-352.

Nomikos, P., MacGregor, J. F. 1995. Multivariate SPC. charts for monitoring batch processes. Technometrics, 37(1): 41-59.

Patel, S. R., Gudi, R. D. 2009. Improved monitoring and discrimination of batch processes using correspondence analysis, 2009. In American Control Conference, 2009: 3434-3439.

Peltola, J., Christensen, J. H., Sierla, S. and Koskinen, K. 2007. "A Migration Path to IEC 61499 for the Batch Process Industry," in Proc. 5th IEEE International Conference on Industrial Informatics, pp. 811-816.

Seilonen, I., Pirttioja, T. and Koskinen, K. 2009. "Extending process automation systems with multi-agent techniques," *Eng. Appl. Artif. Intell.*, vol. 22, pp. 1056-1067.

Sünder, C., Zoitl, A. and Dutzler, C. 2006. "Functional structure-based modelling of automation systems," in *Int. J. Manufacturing Research*, Vol. 1, Iss. 4, pp. 405-420, 2006.

Venkatasubramanian, V., Rengaswamy, R. and S.N. Kavuri, 2003. "A review of process fault detection and diagnosis: Part II: Qualitative models and search strategies," *Computers & Chemical Engineering*, vol. 27, März. 2003, pp. 313-326.

Yoo, C.K., Lee, J.M., Vanrolleghem, P.A. and Lee, I.B. 2004. "On-line monitoring of batch processes using multiway independent component analysis," *Chemometrics and Intelligent Laboratory Systems*, vol. 71, pp. 151-163.

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