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RESEARCH ON OPEN-ARCHITECTURE INTEGRATED EXPERIMENTAL PLATFORM WITH INTELLIGENT MONITORING IN SUGAR BOILING PROCESS

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ABSTRACT

The sugar boiling process is the most important element and the crucial link to the sugar production. Considering the existing problems in technology and equipment, this paper studies an open-architecture integrated experimental platform, which provides monitoring in scientific study of sugar boiling process. It has open input/output interfaces and could simulate the real production of sugar boiling process, based on its modular and reconfigurable hardware. The scalable and component-based software could automatically adjust the control parameters such as temperature and pressure, using different algorithms and various control strategies, by a soft sensor method of supersaturation. It provides an optimized monitoring technology to the actual production. A national invention patent has been applied.

Keywords: *Sugar Boiling, Open-Architecture, Integrated Experimental Platform*

1. INTRODUCTION

The sugar boiling process is the most important element and the crucial link to the sugar production. In order to make exhalation crystal meet requirements, different parameters related to supersaturation, such as temperature, vacuum and feed rate are needed to control [1]-[3]. It is a complicated physical and chemical process with mass transfer and heat transfer. Moreover, the constant change of purity, concentration, and vacuum, cause different crystallization effects [4]-[5].

It contains lots of uncertainties in sugar boiling process because of the complex process, confounding factors, time-varying and nonlinear process. A precise mechanism model of boiling sugar process is difficult to build, due to large inertia, lag behind, and strong coupling [6]-[8]. The accurate key parameters are also hard to obtain through traditional measure methods, such as point measurement or off-line measurement. It needs long time, high cost, and difficult stationing to directly research on sugar boiling tank for production.

Thus, in this paper, an integrated experimental platform designed for research is needed, which could simulate the actual sugar boiling production environment [9]-[10]. The integrated experimental platform provides monitoring in scientific study of sugar boiling process. Meanwhile, it can be used as a teaching platform for students major in control and sugar to carry out research-based teaching research.

The Section 2 describes overall structure of the integrated platform, Section 3 describes hardware design of the integrated platform, Section 4 presents development of monitoring and control software, and Part of experimental data, Section 5 gives a summary to the whole paper.

2. OVERALL STRUCTURE OF THE INTEGRATED PLATFORM

The platform is divided into two parts, hardware and software connected by Modbus and CANbus, as shown in Figure 1. Hardware includes auxiliary work modules, valve control module, tank module, and data acquisition module. Software includes real-time data acquisition component, supersaturation measurement component, and dynamic parameter optimization and control component.

3. HARDWARE DESIGN

3.1 Auxiliary Work Module.

Auxiliary work module consists of material box, steam generator, and water circulation vacuum

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pump, which is mainly used to supply heat and form a vacuum environment.

3.2 Valve Control Module.

Valve A controls vacuum in the tank. At the same time, valve B controls the gas regulator to adjust the temperature of syrup. Valve C controls material feed rate of three types, including water, syrup and seeds.

3.3 Tank MOdule.

Tank module consists of a cylindrical tank, a forced circulation stirring institution, and a tubular heat exchanger. A stirring motor tachometer is set on the forced circulation stirring institution, which is connected with real-time data acquisition components via Modbus. The tubular heat exchange gets heat from the steam generator through a pipe, on which there is a valve regulating to control the gas temperature.

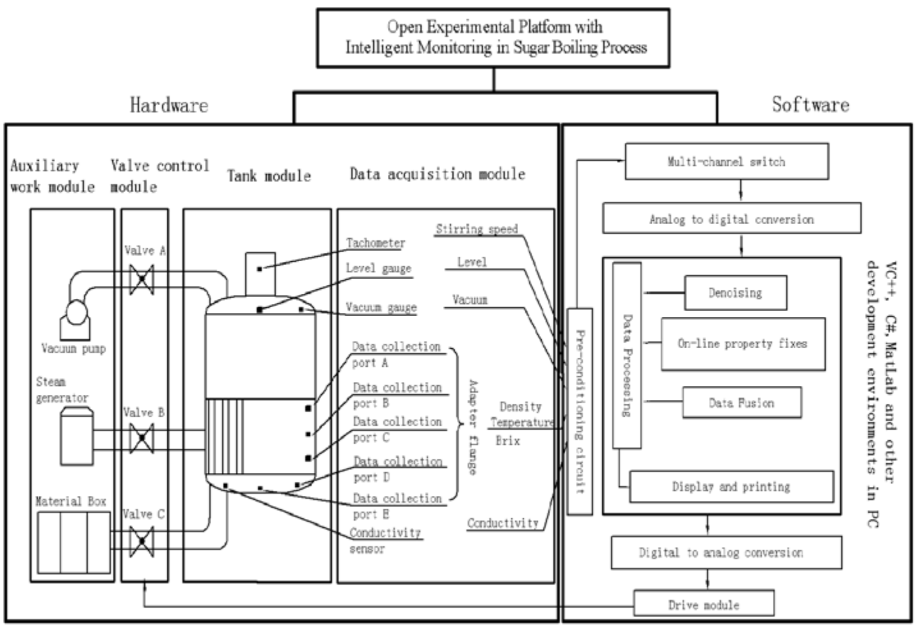

Figure 1: Overall Structure Of The Integrated Platform

3.4 Data Acquisition Module.

Data acquisition modules can be divided into three parts: three data collection ports on the side used to capture the syrup mixture density and temperature data on vertical direction; a tank vacuum gauge, a tachometer and a level gauge located in the top; two data collection ports and a conductivity sensor in the bottom is used to capture data on horizontal direction. All these measuring instruments are connected with real-time data acquisition components via Modbus.

3.5 Modular Design.

Date from data acquisition module is converted to digital signal through pre-conditioning circuit, multi-channel switch and A/D conversion. Then it is shown in the host computer and is used for data processing. After that, the processed signal is converted to analog signal through the driver module to adjust the valve control module. All the hardware interfaces are standard flange interface and modular designed. With an adapter flange, it can connect different instruments such as thermometers, density meter, hammer meter, and conductivity sensor. This platform could compare the distribution of temperature difference, density difference and other important parameters, using the same kinds of measuring instruments located in different places; on the contrary, it also could show the impact of different parameters in the same process, using different measuring instruments.

4. DEVELOPMENT OF MONITORING AND CONTROL SOFTWARE

4.1 Real-Time Data Acquisition Component.

As shown in Figure 2, real-time data acquisition component is connected to data acquisition module via Modbus. Analog signals measured is converted to digital signals and uploaded to the real-time data acquisition component, and then converted to CAN-bus protocol, finally, forwards to the experimental development platform, to achieve real-time online monitoring of the controlled object. The host

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computer could be connected to a remote monitoring computer in network through OPC interface to improve administrator's work efficiency.

4.2 Supersaturation Measurement Component.

Supersaturation measurement is divided into principal component of extraction module, offline modules, online modules, interface management module, data sharing unit module and the external interface module, as shown in Fig.3.

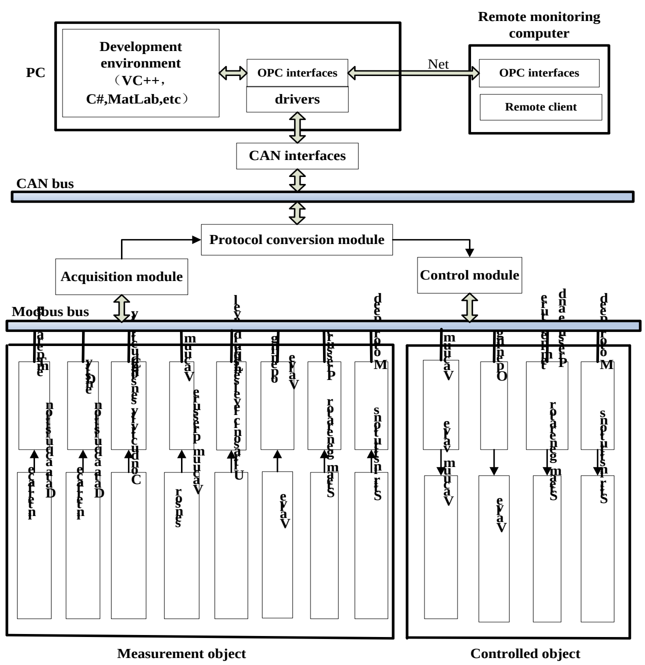

Figure 2: Monitoring and Control System

External interface module receives data from real-time data acquisition component and stores it in data sharing unit module. Principal component of extraction module analyses this data, using partial least squares method to extract the principal component and eliminate the non-linear and noise-related between auxiliary variables, in order to improve the accuracy of soft-sensor. Off-line module selects appropriate kernel function parameters and the penalty factor parameters to construct off-line model.

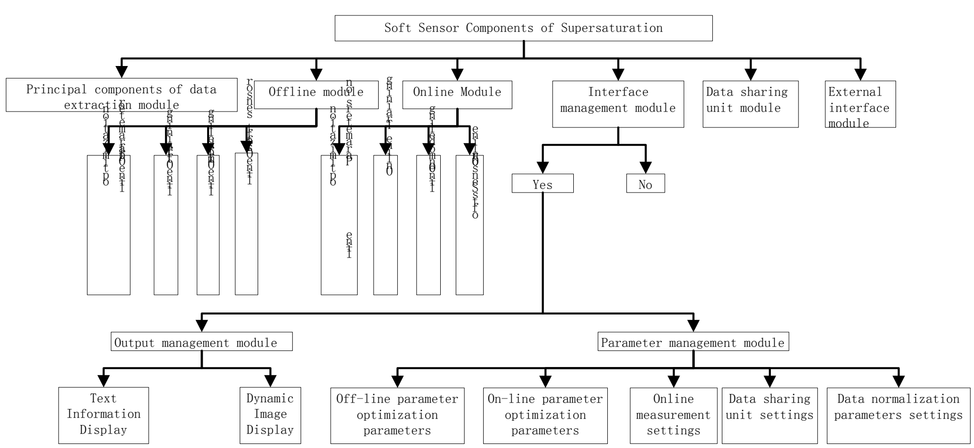

Figure 3: Supersaturation Measurement Component

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The flowchart of supersaturation soft-sensing algorithm is shown in Fig. 4. According to the data of syrup conductivity, syrup density, syrup temperature, vacuum, vapor pressure and bowl level, soft measurement is calculated based on kernel partial least squares method. Online modeling is based on offline modeling, and it's not a fixed model, but a changing model with online learning and updating, on condition that whether exists linear correlation between auxiliary variables and sample dictionary in the high-dimensional feature space after normalization. If no, keep going; if yes, do local fine-tuning, and update feature transformation matrix to accurately extract the auxiliary variables in the next time.

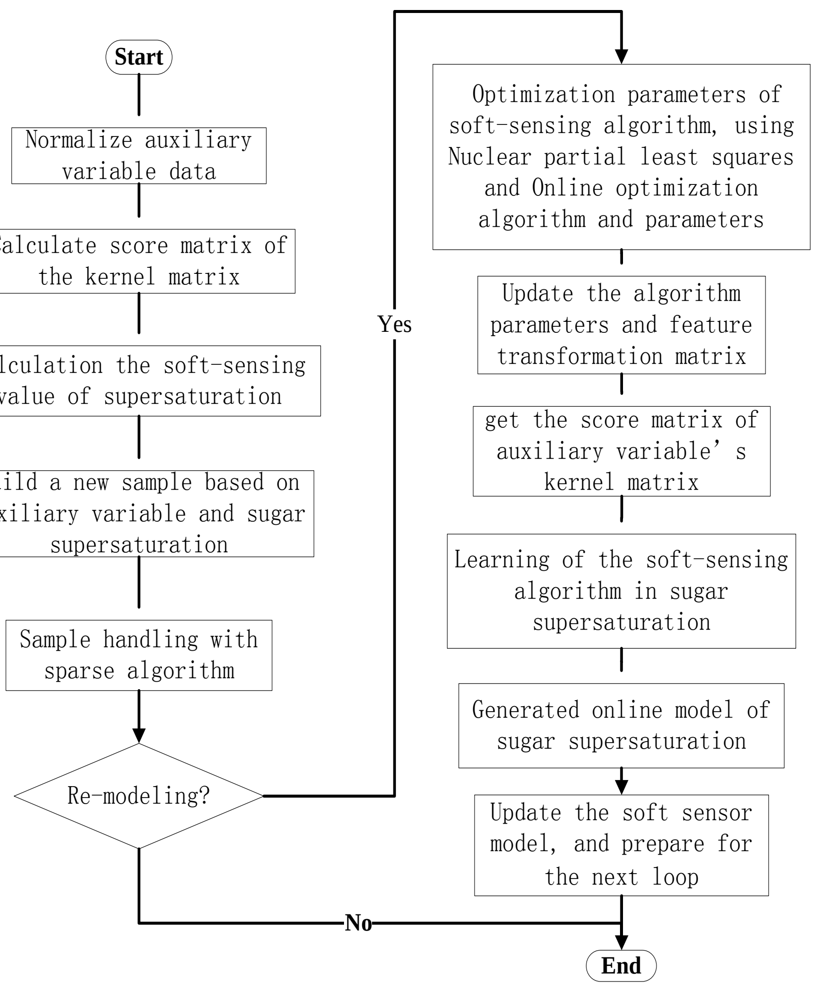

Figure 4: Flowchart of Supersaturation Soft-Sensing Algorithm

4.3 Dynamic parameter Optimization and Control component.

As shown in Fig. 5, check if the parameters which expressed by nonlinear equations are in fault-tolerant feasible region and meet constraints of physical laws. And then do decomposition of variables and lower-dimensional optimization, select the best one with optima Robustness. After that, output optimal control parameters to output module. Meanwhile, update the initial model.

This control method can eliminate as much as possible the large inertia, delay, strong coupling and non-linear impact on the sugar boiling process. It provides VC++, C#, Matlab programming environment and mixed language programming with an open interface.

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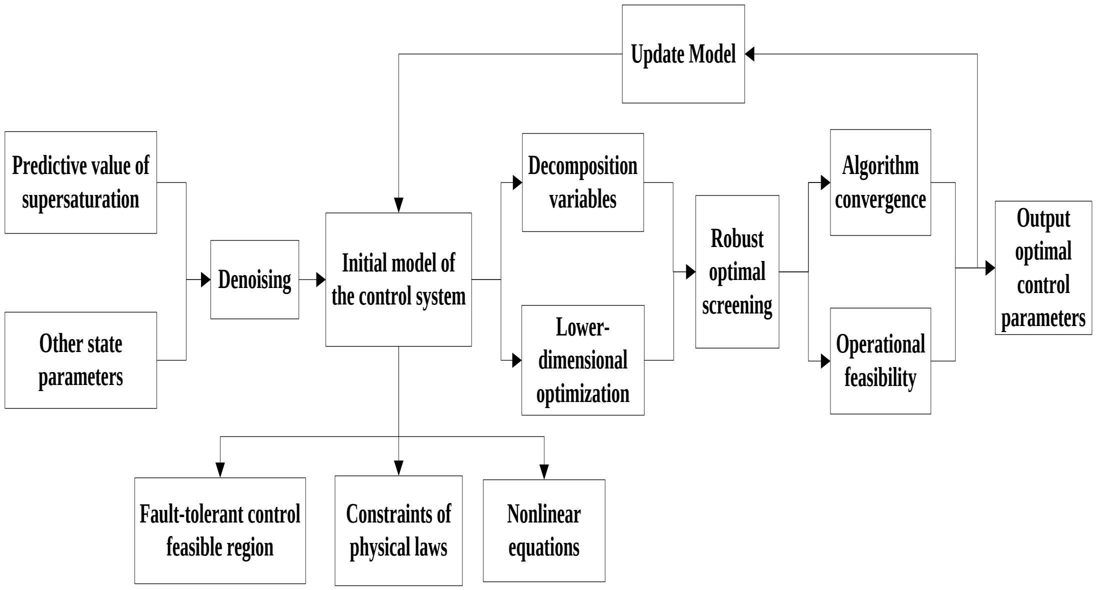

Figure 5: Dynamic Parameter Optimization and Control

4.4 System Operating Interface.

As shown in Fig.6, the monitoring software of the host computer can vividly show the experimental platform online running state through the colorful pictures. Click on the monitoring interface related button, it can set the corresponding control parameters, and realize real time or remote on-line monitoring in the sugar boiling real-time dynamic process. Table 1 shows a part of experimental data of the experimental platform.

5. SUMMARY

This paper studies an open-architecture integrated experimental platform, which provides monitoring in scientific study of sugar boiling process. Meanwhile, it can be used as a teaching platform for students major in control and sugar to carry out research-based teaching research.

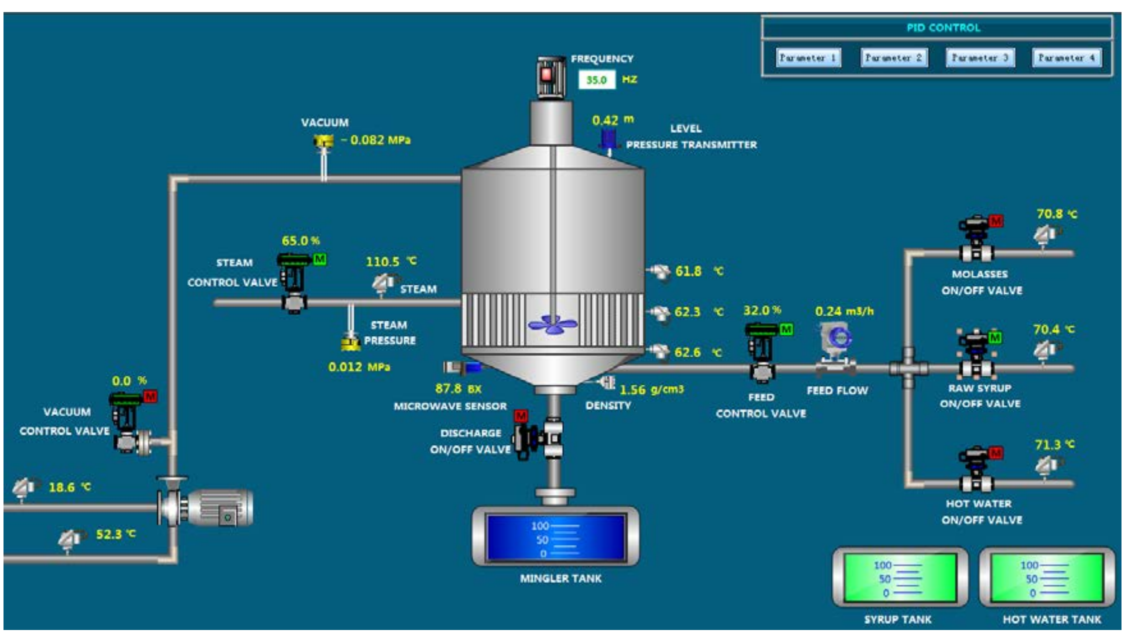

Figure 6: System Operating Interface

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Table 1: Part of Experimental Data of the Experimental Platform

Time	Density [g/cm^3]	Conductivity [μS/m]	Vacuum [MPa]	Temperature [℃]	Steam pressure [MPa]	Flow [m^3/h]
2012-12-17 20:25:36	1.26	2551.50	-0.082	65.28	0.016	0.26
2012-12-17 20:26:11	1.26	2522.89	-0.081	66.01	0.016	0.26
2012-12-17 20:27:02	1.26	2518.50	-0.082	65.58	0.014	1.62
2012-12-17 20:28:08	1.26	2539.67	-0.082	64.19	0.015	1.18
2012-12-17 20:29:03	1.26	2551.31	-0.083	62.62	0.012	0.23
2012-12-17 20:30:23	1.26	2550.74	-0.083	62.53	0.014	0.29
2012-12-17 20:40:06	1.27	2556.27	-0.082	64.79	0.014	0.30
2012-12-17 20:50:35	1.28	2556.08	-0.078	67.75	0.015	0.27
2012-12-17 21:00:08	1.29	2566.38	-0.078	67.49	0.013	0.24
2012-12-17 21:10:01	1.30	2549.21	-0.078	68.68	0.014	0.17

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