CHEMICAL ENGINEERING TRANSACTIONS

VOL. 71, 2018

A publication of AIDIC
The Italian Association
of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Xiantang Zhang, Songrong Qian, Jianmin Xu
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ISBN 978-88-95608-68-6; **ISSN** 2283-9216

DOI: 10.3303/CET1871154

Chemical Production Management Based on Internet of Things

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In order to improve the effect of chemical production management and improve the information level of management, this paper attempts to study chemical production management by integrating the Internet of Things (IoT) technology into the design of the parts quality management system, with a view to achieving automatic acquisition and detection. The study finds that the data information tested by the wireless interface is basically correct within 15 metres around the factory, showing that the system designed in this paper can greatly improve the collection, acquisition and accessing of the quality management information of factories and has certain application value.

1. Introduction

With the advent of the network information era, automation and digitization have become the new development trends for chemical plants, which have also raised new requirements on the production management of chemical plants. Chemical production is usually accompanied by flammable, explosive, toxic and harmful substances, high temperature and high pressure, and any carelessness may lead to a serious safety incident, causing huge economic losses. Therefore, in the process of chemical production management, it is necessary to adhere to standardized, refined and information-based production management methods to improve the level of process technologies and reduce the likelihood of incidents or disasters. This paper integrates the Internet of Things (IOT) technology into the design of the parts quality management system, with a view to achieving automatic acquisition and detection.

2. Literature review

With the continuous development of the Internet, higher requirements have been put forward for the management and development of factories. How to promote the renewal and development of technological means of information acquisition in factories and how to achieve better upgrading and transformation of factories are the problems that managers must consider at present. Perathoner and Centi introduced the renewable energy in the chemical production field, which was a key strategic factor both to realize a sustainable, resource - efficient, low - carbon economy and society and to drive innovation and competiveness in the chemical production. The results show that how an important element to realize this scenario is to foster the paths converting carbon dioxide (CO_2) into feedstock for the chemical/process industry, which is one of the most efficient methods to rapidly introduce renewable energy into the chemical production chain. Some of the possible options to proceed in this direction are discussed, with focus on the technical barriers and enabling factors such as catalysis. The tight interconnection between CO_2 management and the use of renewable energy is also evidenced (Perathoner and Centi, 2014). According to the Food and Agricultural Organization, one - third of food produced globally for human consumption (nearly 1.3 billion tons) is lost along the food supply chain. Food waste has often been incinerated with other combustible municipal wastes for possible recovery of heat or other forms of energy, and the residual ash is disposed of in landfills. Compared with animal feed or traditional fuel for transportation, platform chemicals obviously have higher economic value, i.e. more profitable. Recently, technologies for production of value added bio - products (e.g.

Please cite this article as: Li C., Du X., Huang J., 2018, Chemical production management based on internet of things, Chemical Engineering Transactions, 71, 919-924 DOI:10.3303/CET1871154

organic acids, biodegradable polymers, etc.) from various kinds of food wastes have gained more and more interest. Therefore, Uçkun Kıran and Trzcinski attempted to examine the state of the art of the fermentation technologies of food waste for production of platform chemicals, with emphasis on the Asia‐Pacific region (Uçkun Kıran and Trzcinski, 2015). Important advances in modeling chemical production scheduling problems have been made in recent years, yet effective solution methods are still required. Merchan et al. used an algorithm that uses process network and customer demand information to formulate powerful valid inequalities that substantially improve the solution process. In particular, they extended the ideas recently developed for discrete‐time formulations to continuous‐time models and showed that these tightening methods led to a significant decrease in computational time, up to more than three orders of magnitude for some instances (Merchan et al., 2013). Lanzafame et al. first discussed the new scenario with the aim to point out, between the different possible options, those more relevant to enable this new future scenario for the chemical production, commenting in particular the different drivers (economic, technological and strategic, environmental and sustainability and socio-political) which guide the selection. The case of the use of non-fossil fuel based raw materials for the sustainable production of light olefins is discussed in more detail, but the production of other olefins and polyolefins, of drop-in intermediates and other platform molecules are also analysed. The final part discussed the role of catalysis in establishing this new scenario, summarizing the development of catalysts with respect to industrial targets for the production of light olefins by catalytic dehydration of ethanol and by CO_2 conversion via FTO process, the catalytic synthesis of butadiene from ethanol, butanol and butanediols, and the catalytic synthesis of HMF and its conversion to 2,5-FDCA, adipic acid, caprolactam and 1,6-hexanediol (Lanzafame et al., 2014).

Food supply chain waste emerged as a resource with a significant potential to be employed as a raw material for the production of fuels and chemicals given the abundant volumes globally generated, its contained diversity of functionalised chemical components and the opportunity to be utilised for higher value applications. Lin et al. aimed to provide a general overview of the current and most innovative uses of food supply chain waste, providing a range of worldwide case-studies from around the globe. They focused on examples illustrating the use of citrus peel, waste cooking oil and cashew shell nut liquid in countries such as China, the UK, Tanzania, Spain, Greece or Morocco. They emphasised 2nd generation food waste valorisation and re-use strategies for the production of higher value and marketable products rather than conventional food waste processing (incineration for energy recovery, feed or composting) while highlighting issues linked to the use of food waste as a sustainable raw material. The influence of food regulations on food supply chain waste valorisation will also be addressed as well as our society's behavior towards food supply chain waste (Lin et al., 2013). Modular continuous production concepts are already successfully applied in research, development, and piloting of a series of chemical compounds in the markets of fine chemistry and pharmaceutical products. Bieringer et al. reported the first case studies for the application of those concepts in industrial scale. One core element of these production concepts are micro‐ and milli‐structured devices assisting continuous‐flow processes due to their superior transport characteristics and small holdup. In small‐scale production concepts, these special devices have to be considered together with conventional technology. The platform concept developed by TU Dortmund University for chemical manufacturing simplifies the scale‐up process from lab to container scale and beyond on different levels in flow rate, temperature, or other process conditions (Bieringer et al., 2013). Andersen et al. pointed out that short-chain carboxylates such as acetate were easily produced through mixed culture fermentation of many biological waste streams, although routinely digested to biogas and combusted rather than harvested. They also developed a pipeline to extract and upgrade short-chain carboxylates to esters via membrane electrolysis and biphasic esterification. Carboxylate-rich broths were electrolyzed in a cathodic chamber from which anions flux across an anion exchange membrane into an anodic chamber, resulting in a clean acid concentrate with neither solids nor biomass. Next, the aqueous carboxylic acid concentrate reacted with added alcohol in a water-excluding phase to generate volatile esters. The results showed that the processing pipeline enabled direct production of fine chemicals following undefined mixed culture fermentation, embedding carbon in industrial chemicals rather than returning them to the atmosphere as carbon dioxide (Andersen et al., 2014). Iryani et al. held that sugarcane bagasse, the solid waste material produced in the sugar industry, was subjected to treatment in hot compressed water. They performed the experiments in a batch-type reactor containing slurry of 10mL of water and 1.2 g of solids. The reactor was heated to temperatures ranging between 200°C and 300°C for reaction times of 3 to 30min. The product was separated into liquid and solid fractions. Each fraction was analyzed to investigate the alteration of the main lignocellulosic polymers by hot compressed water. The results for the liquid fractions showed that increased temperatures and reaction times completely dissolved hemicellulose and cellulose in the water, leaving lignin in the solid product (Iryani et al., 2014). Zhu and Fan put forward a technique for hydrogen production route of CaO sorption‐enhanced methane steam reforming (SEMSR) thermally coupled with chemical looping combustion (CLC), which perceived as an improvement of previous methane steam reforming (MSR) thermally coupled with CLC technology (CLC - MSR). The results indicated that the performances of this system examined included the composition of reformer gas, yield of reformer gas, methane conversion, the overall energy efficiency, and energy efficiency of this process (Zhu and Fan, 2015). Mixed-integer programs for chemical production scheduling are computationally challenging. To address this challenge, Velez and Maravelias proposed three reformulations of the widely used state–task network formulation. Specifically, they introduced additional constraints to define the number of batches of each task as an integer variable. Moreover, they also studied different branching strategies and variable selection rules and compared them. The results suggested that the proposed solution methods would lead to orders-of-magnitude reductions in the computational requirements for the solution of scheduling problems (Velez and Maravelias, 2013).

To sum up, the above researches mainly studied the management of chemical production, but there are few studies combine the management of chemical production with Internet of Things. Therefore, based on the above findings, the principles and methods of the chemical production management are introduced. The information acquisition system hardware is described, two port docking modes are studied, and digital information data management is also discussed. Moreover, a series of tests are made, and the test results are analysed. The results show that the digital factory quality management information acquisition system designed promotes the technology of data acquisition, acquisition and access of factory quality management information greatly, realizes the exchange and integration of factory information data in China, and meets the requirements of the times and society for information acquisition of factory parts.

3. Principle and Method

In order to achieve better acquisition of quality management information in a factory, it is necessary to digitalize the factory production, fully grasp the manufacturing process of parts, continuously improve the manufacturing and production capacity of the factory, strengthen the integration of the factory and the Internet, and build a cloud database of quality management information. This requires data management of products. Only by implementing big-data-based information management and building a digital quality management system can we achieve comprehensive management on design, technology and process. At present, there are three main problems in the digital management of factories in China:

The first is that most factories are still using traditional methods for collecting quality management information. The second is the backward equipment. Most of the domestic factories still use three-coordinate measuring instruments and old testing appliances, which have seriously hindered the innovation and development of these factories. The third is the quality problem of the products. The backward quality management information equipment and means of information acquisition leads to waste of human, material and financial resources.

This paper mainly targets the MES and ERP systems in domestic factories and attempts to achieve automation, digitization and high efficiency of factory production management. The main principle is to construct a digital quality management information acquisition system in the context of the Internet and achieve the wired and wireless transmission of quality management information acquisition via intelligent interfaces and terminals, and finally conduct unified management of archives to form a factory quality management information data platform. In most of the factories in China, each workshop is equipped with an inspection station, which is responsible for the inspection of equipment and products in the whole workshop. It has detailed inspection gauges, which clearly indicate the specific data of the parts. These measuring tools used by the domestic factories are mainly manufactured by Mahr and Mitutoyo. However, due to the lack of uniform standards between factories, the use of hardware devices also varies. Therefore, the hardware of the quality management information system can be selected according to the actual situation of the equipment in the factory. The proposed system mainly consists of two modules - an information acquisition port and an information terminal server. The digital detector collects the factory quality management information into the server via different information ports for unified quality information management and exchange and analysis of the information with the enterprise's own systems. The hardware of the system is shown in Figure 1.

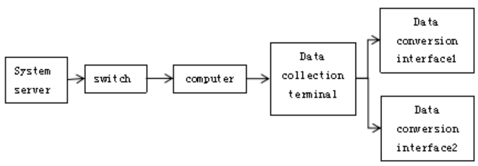

Figure 1: Information auquisition system hardware

The terminal server of the factory digital quality management system is mainly responsible for information exchange and processing and for monitoring the operation of the system, so it is a core component of the whole system. The terminal server of the system mainly includes two parts - the serial port and the router. The former is used to convert information data into network signals to ensure the normal transmission of information while the latter is used to connect the system network and the factory network. In this way, an information data platform can be built to realize the factory digital management. In order to better achieve the conversion of the serial network signals, it is necessary to enhance the global mode supported by the system; in other words, it needs to support the TCP server mode, the TCP client mode, the UDP mode, the couplet mode and the reverse terminal mode, and users should be allowed to access the serial port through the interfaces and inspect and repair them. The serial port is required to have multiple interfaces to achieve simultaneous docking of different models. The operating state of the interfaces should be monitored in real time to ensure continuous transmission of information data.
The docking of the information data ports ensures that the detected information data can be effectively transmitted, and that the network signals can be unified and finally collected into the terminal server through different ports. However, the port models in the domestic market are different, and manufacturers have different choices, so the digital quality management information acquisition system cannot be widely promoted and applied. Here it is recommended using consistent information interfaces to transmit the information data to the serial server through the information acquisition detector, and then sending them to the terminal server through the TCP/IP protocol. Mahr's and Mitutoyo's inspection gauge interfaces can be divided into three output ports and one request port (data output (DATA), clock output (CLOCK), ready status output (READY) and data request port). The REQUEST and DATA terminals are connected to the external interrupt port of the MCU. If a low-level request data is sent to REQUEST, the return data can be read on the DATA port. The return data format is a string of binary numbers, as shown in Figure 2.

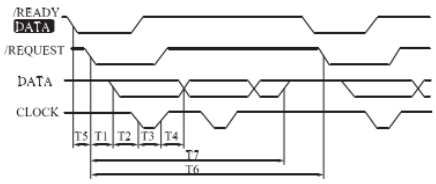

Figure 2: Data output timing diagram

Therefore, according to the format of the interfaces and the actual situation of the factory equipment, two port docking modes are designed: wired and wireless port docking modes. The former takes the 8052 MCU as the main control chip and its working principle is to convert the information data collected by the detector into unified network signals through the 8052 MCU, and finally pass it to the terminal server through the serial port docking server. The wireless information docking port mainly uses the CC2530F256 chip, which is the wireless communication chip for IEEE 802.15.4. In order to save the transmission time and facilitate the transmission equipment and facilities, it is suggested the factory digital quality management system adopt the wireless data transmission mode. The digital measuring gauge is connected to the CC2530 through the gauge interface circuit, and the MCU reads the detected information of the measuring gauge, and sends it to the receiving end through the transmission protocol. The receiving end then uploads the data to the data acquisition terminal server through the serial port, and the data acquisition of the digital gauge is completed, as shown in Figure 3.

Figure 3: Principle of the data acquisition terminal server

To realize digital information data management, a simulation system must be designed and installed. The software design of the digital factory quality management information system includes two major parts, namely the information data terminal system software and the system service software. The latter mainly achieves the digitization, automation and mechanization of the factory quality management information based on the feedback of information data, which involves some special software. The former can be self-designed through research. The design process in Figure 4 can be used as a reference, which realizes the acquisition of factory information data through the combination of equipment and network.

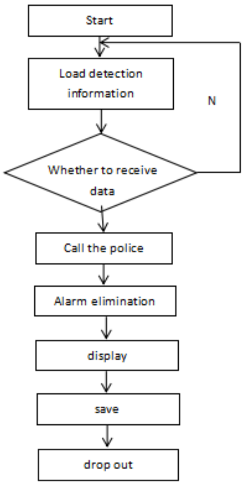

Figure 4: Design scheme for digital information data management

4. Results and analysis

This paper tested the functions of this system and obtained some basic data to prove its actual efficiency. According to the factory's testing equipment and measuring gauges, the author built a factory quality management information monitoring platform, and divided the parts information of the factory into ten groups. Then the system was used to read and write the parts of each group three times, and finally the test results were obtained, as shown in Table 1 and 2.

Table 1: 20m test results

Size	Wired data conversion interface			Wireless data conversion interface		
10.125	10.125	10.125	10.125	10.125	10.125	10.125
-5.632	-5.632	-5.632	-5.632	-5.632	-5.632	-5.632
-8.612	-8.612	-8.612	-8.612	-8.612	-8.612	-8.612
25.001	25.001	25.001	25.001	25.001	25.001	25.001
12.013	12.013	12.013	12.013	12.013	12.013	12.013
10.055	10.055	10.055	10.055	10.055	10.055	10.055
18.012	18.012	18.012	18.012	18.012	18.012	18.012
17.035	17.035	17.035	17.035	17.035	17.035	17.035
30.015	30.015	30.015	30.015	30.015	30.015	30.015
40.011	40.011	40.011	40.011	40.011	40.011	40.011

Table 2: 50m test results

Size	Wired data conversion interface			Wireless data conversion interface		
12.415	12.415	12.415	12.415	12.415	/	12.415
-7.013	-7.013	-7.013	-7.013	-7.013	-7.013	-7.013
-9.716	-9.716	-9.716	-9.716	-9.716	/	-9.716
27.225	27.225	27.225	27.225	27.225	27.225	27.225
13.013	13.013	13.013	13.013	13.013	/	13.013
11.770	11.770	11.770	11.770	11.770	11.770	11.770
20.117	20.117	20.117	20.117	20.117	20.117	20.117
16.910	16.910	16.910	16.910	16.910	16.910	16.910
30.015	30.015	30.015	30.015	30.015	30.015	30.015
42.640	42.640	42.640	42.640	42.640	42.640	42.640

5. Conclusions

Now we are in a big data era, where the IoT is rapidly developing and widely applied. So based on IoT, this paper attempts to build a digital factory quality management information acquisition system to improve the

collection, acquisition and accessing of the factory quality management information. The purpose is to find a way to promote the factory information and data exchange and integration and meet the social requirements for the acquisition of factory parts information.
However, there are still some deficiencies in this paper, so the actual chemical production process may encounter some deviations from the system design. In the future, studies will be done on specific parts of the chemical production management.

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