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Application of Sensor Technology in the Liquor Industry

Qiupu Wu[1], Yi Yao[1,*]

[1]School of Automation & Information Engineering, Sichuan University of Science & Engineering, Yibin, Sichuan, China.

Abstract

With the continuous innovation and development of sensor technology, as well as the improvement of the degree of automation in liquor industry , sensor technology has been more and more widely used in liquor industry, which has a great impact on the improvement of liquor production technology and detection technology. This paper mainly discusses the classification, principle, research status and application of sensors in liquor industry.

Keywords

Sensor technology,detection technology, automation, liquor industry.

1. Development of Liquor Industry

Liquor is a kind of compound flavor beverage with ester as the main flavor, which is made of koji and yeast as saccharifying and fermenting agent, using starch (sugar) raw materials, through cooking, saccharification, fermentation, distillation, aging and blending. In China, liquor has a long history and is an indispensable drink on the table. After decades of development and market baptism, China's liquor industry has entered a period of deep adjustment. At present, the market structure of the whole liquor industry has been very reasonable [1]. Nowadays, China's liquor industry shows the following characteristics: the growth rate is slowing down, but it is still at a high level; the liquor market is more standardized and the structure is more reasonable; the liquor industry is concentrated in well-known liquor enterprises [1].

Although the domestic liquor industry has a good market situation, it is also facing a lot of pressure and challenges. With the change of people's life style and life concept, the idea of "health" has been deeply rooted in the hearts of the people, and the liquor consumption is becoming more and more diversified. In addition, the incidents of fake liquor and poisonous liquor, which has been banned repeatedly in the market, has seriously affected the market demand of liquor and brought a certain amount of resistance to the development of liquor industry. Therefore, the development of liquor detection technology is very urgent, which not only has a great impact on the improvement of liquor production, but also is closely related to liquor quality control. In recent years, with the development of various science and technology led to the development of liquor industry in China, sensor technology plays a very important role in liquor production and detection, and has a great impact on the improvement of liquor production and quality.Organization of the Text.

2. Sensor Technology and Research Status

In short, the sensor is a device that transmits the perception of the outside world to the computer processing through some special components; the sensor can convert non electrical quantities such as sound, light, force, temperature, magnetic induction intensity, chemical action and biological effect into electrical quantities or components with regulatory functions. The sensor is mainly composed of sensitive element and conversion element. The sensitive

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element refers to the part of the sensor that can directly feel or respond to the measurement; the conversion element refers to the part of the sensor that converts the measured sensing element feeling or responding into the electrical signal suitable for transmission or measurement. The sensor is characterized by high selectivity, specificity, fast detection speed, small size, simple operation and low price.

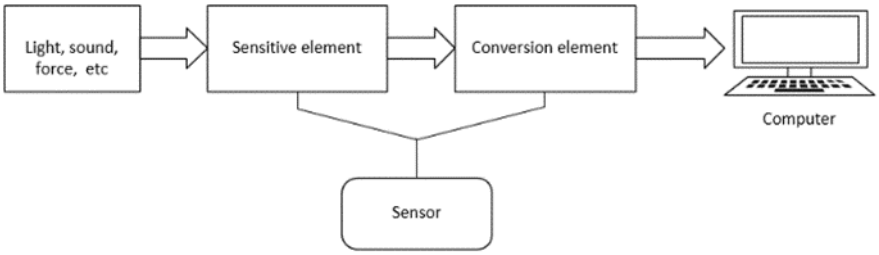

Figure 1: Sensor composition

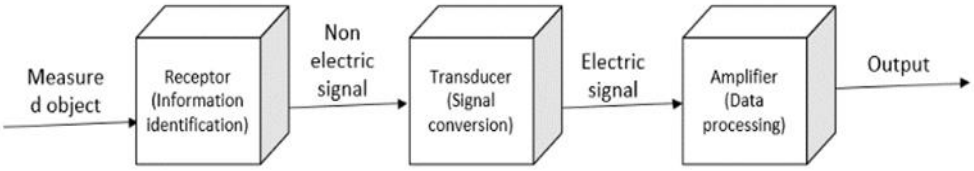

Figure 2: Basic principle of sensor

With the progress of computer technology, the development speed of sensor technology is also relatively rapid. Sensor technology [2] mainly includes three generations. The first generation belongs to structural sensors, which can transform and feel the signal through the change of structural parameters. For example, the resistance strain sensor uses the strain effect of resistance material to convert the internal deformation of engineering structure device into resistance change; the second generation belongs to solid sensors, the special properties of materials (magnetic materials, dielectrics, semiconductors) are used to convert signals, such as photosensitive sensors, thermocouple sensors, Hall sensors, etc.; the third generation belongs to intelligent sensors, which have certain ability of data processing, self diagnosis, detection and self-adaptive to the surrounding information, and is the product of the combination of detection technology and computer technology. Since the beginning of 1950s, it has gone through three stages of development, from the most primitive structural sensor to solid-state sensor and the latest intelligent sensor micro-electro-mechanical system (MEMS) [3]. With the development of microelectronic technology, integrated circuit technology and processing technology, MEMS sensor with the advantages of small size, light weight, low power consumption, high reliability, high sensitivity, easy integration and harsh working environment, has greatly promoted the development of sensor miniaturization, intelligence, multifunction and networking. MEMS sensors [4] are gradually occupying the sensor market, becoming the mainstream direction of the development of intelligent sensors, and gradually replace the dominant position of traditional mechanical sensors, and have been favored by consumer electronics, automotive industry, aerospace, machinery, chemical industry, medicine and other fields.

Sensors have a wide range of types and applications, and play an indispensable role in many fields, such as family life, transportation, medical treatment, automobile industry, machinery manufacturing, food production and so on. Sensor technology [2] has broad development prospects and application space, and is a technology industry with good development prospects.

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3. Application of Sensor Technology in Liquor Industry

The sensor [3], as a detection device, can sense the measured information and transform the sensed information into electrical signal or other information output according to certain rules, so as to meet the requirements of information transmission, processing, storage, display, recording and control. According to the human's five basic perception function including vision, hearing, touch smell and taste, the sensors can be divided into 10 categories: thermal sensors, photosensitive elements, gas sensors, force sensors, magnetic sensors, humidity sensors, sound sensors, radiation sensitive elements, color sensors and taste sensors. These sensors can be classified into three categories: physical, chemical and biological. Physical sensors are divided into structural sensors (physical laws) and physical properties sensors (material properties) [3]. This paper summarizes the application of sensor technology in liquor industry from four aspects: Physics, chemistry, biology and composite. It mainly introduces the application of sensor technology in liquor detection, including the detection of fermented grains before entering the pit, the detection after entering the cellar, the detection of yellow water after out of the cellar, and the detection of the quality of liquor products.

3.1. Application of Physical Sensors in Liquor Industry

The physical sensor [5] is a sensor made by using the physical properties of some transformation elements or the special properties of some functional materials. It uses some physical effects to convert the measured physical quantities into energy signals that are easy to be processed. There is a definite correlation between the input and output. These physical properties include: light, sound, pressure, temperature, etc.

Temperature is one of the important factors affecting microbial fermentation, and the change of fermented grains temperature is the result of the joint action of environmental temperature (mainly ground temperature) and microbial growth and metabolism in cellars[6]. The temperature sensor can determine whether liquor fermentation is normal by detecting the temperature before, during and after liquor fermentation, and to a certain extent, the quality of liquor is monitored. Huang Zhiguo[6] et al. used the cellar temperature detection system to detect the temperature of fermented grains in three cellars of a winecery in South Sichuan, drew the temperature change curve, and fitted the data model. The results show that the temperature change curve basically conforms to the traditional experience of "slow in the front, rise in the middle, and drop slowly after", indicating that the temperature curve model can be used to predict the change trend of temperature curve in the whole fermentation process.

The sensors used in liquor industry based on optical principle include infrared spectrum sensor, fluorescence array sensor, optical fiber concentration sensor, etc. The infrared spectrum sensor mainly uses the principle of infrared spectrum: when a beam of infrared light with continuous wavelength passes through the material, and the vibration frequency or rotation frequency of a group in the material molecule is the same as that of the infrared light, the molecule can absorb energy from the original ground state vibration (rotation) kinetic energy level to the vibration (rotation) kinetic energy level with higher energy. After the molecule absorbs infrared radiation,the vibration and rotation energy level transition occurs,and the light at that wavelength is absorbed by the material.The essence of infrared spectroscopy is an analytical method to determine the molecular structure of substances and identify compounds according to the relative vibration and rotation of atoms in molecules. The infrared spectra are obtained by recording the infrared absorption of molecules.

The detection of liquor by infrared spectrometer includes many aspects, mainly applied to infrared sensors, including a variety of spectrometers such as near-infrared spectroscopy and mid-infrared spectrometer, which mainly detects the concentration of various parameters in alcohol: acid, ester, etc. . By analyzing the spectrum obtained by the infrared sensor, the

concentration of alcohol, acid, ester and aldehyde in liquor is obtained. The principle of laser Raman spectroscopy and infrared spectroscopy are similar, and it is also a molecular vibration spectrum, which is a scattering spectrum of inelastic collisions. Each type of molecular vibration has its corresponding characteristic spectrum. Compared with infrared spectroscopy, Raman spectroscopy has a very small effect on the detection of moisture content in the sample, and is considered to be an ideal method for analyzing aqueous samples.

Optical sensors are generally pollution-free, destructive and convenient. Li Yeli et al.[7] introduced the infrared spectroscopy technology, Raman spectroscopy technology and other detection technologies, which played a rapid and efficient role in the detection of components in liquor. Lv Huiying [8] et al.,used portable Raman spectrometer to directly measure the ethanol content in liquor, compared the prediction results of different models using single wave number, single peak interval and multiple characteristic peak intervals, indicating that the 800~1150cm-1 interval was used to establish The prediction result of the model is the best, the corrected mean square error (RMSEC) is 0.4537, and the predicted root mean square error (RMSEP) is 0.5575.Wu Zhengjie [9] et al., through the discussion of ethanol quantitative analysis of a variety of Raman spectral normalization methods, put forward the use of the highest point in the ethanol spectrum at the highest concentration as the reference for normalization of ethanol quantitative analysis method, its effectiveness and accuracy are better than the internal label method and ratio method, and have good anti-jamming ability, and after combining baseline calibration treatment, not only can effectively eliminate the data differences between groups, but also significantly improve the accuracy of ethanol quantitative analysis. Zhang Ling [10] et al. combined near-infrared spectroscopy with stoichiometry, and determined the ethanol content in the calibration set sample by the calibration model established by partial least squares. The predicted value and the real value basically coincided with each other, which was used for further determination. Predict the sample of Beijing Erguotou, repeat 10 times, measure its NIR spectrum, and substitute the mathematical correction model to calculate the ethanol content and relative standard deviation. The results are basically stable, indicating that the determination of ethanol content by near infrared spectroscopy has high precision. Li Jiguang [11] and others used near-infrared spectrophotometry to detect the ethanol content in liquor, and established regression equations based on the near-infrared short wave spectral characteristics of some concentration ethanol solutions, so as to predict the ethanol content of real liquor samples. Fan Mingming [12] used near-infrared spectroscopy analysis technology combined with chemometrics to conduct online monitoring of liquor and PLC control program for online control, and quantitatively analyzed the index of alcohol concentration in liquor to achieve automatic wine picking and picking wine. Simulated wine picking on the online test simulation test bench. The results prove that the alcohol concentration measured by the simulation test is within the predetermined alcohol concentration range, indicating that the test bench can complete the function of online detection and control of wine picking.

Visual array sensor [13] is a new developed sensing technology that uses sensor array to detect sample characteristic response signal, and displays the detection result in the form of spectrum through signal recognition processing system, so as to realize detection visualization. After the sensitive substance on the sensor array reacts with the target material, obvious spectral changes occur, and the visible spectrum changes from red to red (R) Three color channels, green (g) and blue (b), are mixed and superimposed according to different proportions. Different spectra can be obtained by adjusting the intensity values of the three color components. The sensor images before and after the reaction are converted into RGB data by using the principle of RGB color mode to realize the specific combination of substances. The application of visual array sensor in liquor industry includes detection of liquor age and identification of liquor with different flavor types. The sensitive substances on the visual array

sensor used by Huo Danqun [13] et al. can specifically identify and respond to trace components in liquor, significantly reducing the interference of high-concentration ethanol, and using temperature sensors and cameras to obtain spectral images of liquor gas Visualization was implemented, and the five major types of liquor in China were tested and different data analysis methods were used. The results show that the visual array sensor can not only identify substances with little content in liquor, but also detect the interaction between different aroma substances. The action produces a response, which provides a new idea and method for the rapid detection of liquor, which can be applied to the online quality detection and authenticity identification of various flavor liquors.In order to measure the temperature and alcohol solubility in liquor distillation, Li Da [14] et al. made a fiber optic sensor based on Mach Zende meter (MZI) and fiber Bragg grating (FBG) cascade that can simultaneously measure the temperature and alcohol concentration. FBG is using femtosecond laser carving the line by line in single mode fiber (SMF) in the production cycle is 2.2, the Bragg wavelength is 1592.21 nm, the depth of the transmission spectrum can be up to 23 dB order 4 optical fiber Bragg grating, MZI is fine fiber and SMF adopting fiber core displacement and taper waist enlarge welding technology of cavity length is 8.7 mm, contrast ratio of 28.5 dB transmission interference optical fiber sensor, based on the theory of multiple beam interference sensor simultaneously measured temperature and the concentration of ethanol solution, the structure has potential application prospect in liquor-making industry.

3.2. Application of Chemical Sensors in Liquor Industry

Chemical sensor [5] is a device that can qualitatively and quantitatively convert the existing forms of various chemical substances (electrolytes, compounds, molecules, ions, etc.) into useful signals and output them. In order to realize the rapid identification of different flavor liquor, Zou Xiaobo [15] et al. established a taste sensor array composed of 12 different ion selective electrodes to detect eight different flavor types of liquor. In the analysis process, the principal component analysis method is used to analyze and identify the experimental data. The research shows that this taste sensor array has a good ability to distinguish different flavors of liquor.

Electronic nose and electronic tongue are widely used in liquor industry, including identification of different types of liquor, detection of liquor adulteration, identification and classification of liquor brands, analysis of liquor characteristics (i.e. analysis and identification of liquor brand, purity, flavor type, origin, quality grade, liquor age and alcohol content) and detection of yellow water components in liquor fermentation process.

The electronic nose [16] is mainly composed of functional components such as a sensor array integrating a variety of gas sensors, a signal acquisition circuit, and a pattern recognition system. It uses a sensor array with cross-sensitivity to the gas to be measured to mix the odor in the gas to be measured The information is transformed into a measurable physical signal group related to composition, concentration or time, and a digital signal is obtained through a signal acquisition circuit. After the pattern recognition system analyzes the digital signal containing the comprehensive odor information and hidden features of the gas to be measured, the rapid, systematic and accurate identification and analysis of the volatile gas sample is realized.The application of electronic nose in liquor mainly focuses on the detection of authenticity, flavor, origin, flavor type and age of liquor. Ma zeliang [17] et al. established a new method that could quickly identify liquor adulteration by using the self-developed electronic nose detection system. Firstly, the sensor array was used to obtain the liquor fingerprint data, and then the characteristic information in the feedback information was extracted by discrete wavelet transform (DWT). Then principal component analysis (PCA) was used to identify adulterated liquor samples of different purity. Artificial colony optimization least squares support vector machine (ABC-LSSVM) was used to quantitatively predict adulterated liquor samples of

different purity. The results showed that PCA was effective in distinguishing adulterated liquor, and the accuracy was up to 100. Abc-lssvm prediction model has higher quantitative prediction performance for liquor purity. This study can provide technical support for the qualitative identification and quantitative prediction of adulterated liquor. Zhang Song [18] et al. measured four kinds of liquor with the same flavor by self-made portable electronic nose, and studied the influence of different evaporation temperature on liquor measurement results. Principal component analysis (PCA) was used to analyze sensor signals, and artificial neural network (ANN) was used to identify four kinds of liquor. Wang Hui [19] et al. collected fingerprints of liquor test samples of different flavor types using saw znose4200 electronic nose, and analyzed and compared the fingerprints of liquor test samples. By comparing the differences of peak areas, the characteristic peaks of samples were extracted, and the recognition models were established by principal component analysis, canonical discriminant analysis and cluster analysis. The results showed that there were similarities and significant differences among the three flavor types and six kinds of liquor. The fingerprint model established by using the collected data could well express the relationship between the flavor components of different flavor types of liquor. By comparing the characteristics of different flavor liquor, the extracted characteristic information can distinguish different flavor liquor, and the correct rate is 100%. Therefore, the use of acoustic wave electronic nose provides technical support for Liquor Identification and classification of different flavor types in the process of liquor production and sales. Ke Yongbin [20] et al. designed and composed an electronic nose system for liquor detection with five different TGS gas sensors, realizing the rapid identification of representative liquor samples of Luzhou flavor, Maotai flavor, Qingxiang and rice flavor. Wang Lichuan [21] et al. used the array composed of seven TGS sensors to dynamically measure and classify eight kinds of liquor sold in the market. Combining with principal component analysis (PCA), the relationship between sensor array signal and liquor brand, flavor type, raw material, origin, alcohol content and other characteristics of liquor was analyzed. The results showed that the sensor signal showed strong clustering on the above liquor characteristics. According to the characteristics of raw materials, the best classification effect can be obtained.

Electronic tongue [22] is a detection method for analyzing and identifying liquid, which is mainly composed of taste sensor array, signal conditioning analysis and pattern recognition. Zhou Xiaoyang [22] et al. used the sensor relaxation characteristics of electronic tongue to conduct DFA analysis on yellow water, and established a model for sensor data through BP neural network, and obtained a method for rapid detection of wine precision, acidity, reducing sugar and residual starch in yellow water. Ma zeliang [23] et al. developed a set of electronic tongue detection system for beverage quality based on virtual instrument and Internet of things, which is applied to liquor brand differentiation and purity detection. In the system detection, the sensor array is used to scan the samples with large amplitude pulse to obtain the taste fingerprint data of various orange juice and liquor. Then, discrete wavelet transform (DWT) is used to extract the eigenvalue information in the feedback information. Then, principal component analysis (PCA) and partial least squares regression analysis (PLSR) are used to realize the qualitative and quantitative analysis of liquor. The results showed that the recognition rate of the system for different brands of liquor reached 100%, the determination coefficient R2 of prediction set of purity prediction model was 0.998, and the relative analysis error RPD of the model was 3.272. The system had the advantages of fast detection speed, simple operation, low cost, stability and reliability, and easy query of results. Deng Li [24] studied the recognition ability of electronic tongue for different types of wine. All the samples were diluted according to the ratio of wine to water = 1:2 (V / V), then detected by ts-5000z taste analysis system, and then the sensor signals were analyzed by principal component analysis (PCA), radar chart analysis and stability analysis. The results showed that the electronic tongue could effectively distinguish the taste of different types of wine. Tian Ting [25]

et al. used electronic tongue technology to detect and distinguish Maotai flavor liquor from the first to the seventh rounds. The results showed that the principal component analysis method could effectively distinguish different rounds of liquor, and the discriminant factor function analysis could accurately identify the types of liquor in rounds, with the accuracy rate of 91.43%. Menhong [26] et al. used two different electronic nose and electronic tongue fusion systems to collect the gas flavor information of liquor samples of different brands in order to achieve rapid identification of liquor quality. Principal component analysis and K-means method were used to cluster the detection results, and support vector machine method was used to predict and classify liquor brands. The results show that the gas flavor information fusion technology can achieve the goal of improving the quality of liquor. For liquor brand identification, the fusion system of electronic nose and electronic tongue based on MQ and MP gas sensors has a better recognition effect on liquor category, which is better than that based on TGS gas sensor.

3.3. Application of Biosensor Sensors in Liquor Industry

Biosensor [7] is a kind of special chemical sensor. It uses bioactive units (such as enzymes, proteins, antigens, antibodies, nucleic acids, cells, biofilm microorganisms and other bioactive materials) as sensitive elements. It can identify the detected objects with high selectivity, capture the interaction between the target and the sensitive elements through various physical and chemical transducers, and then use the degree of action to separate them. Scattered or continuous signals are expressed to obtain the type and content of the tested substance. Biosensors have the advantages of good selectivity, good reproducibility, tracking and monitoring, but their service life is short.

Application of biosensors in liquor industry [27]:

(1) The activity of α - amylase was determined by biosensor. α - amylase is an important enzyme to make amylose into dextrin. It can accomplish saccharification together with other enzymes in liquor production. The principle is that α - amylase can decompose starch into dextrin and maltose, so that these small molecules can pass through the first dialysis membrane, and then be decomposed into glucose by glucoamylase, and then the glucose will pass through the second dialysis membrane and be dissolved and absorbed by the bacteria cultured in glucose. Then, the respiratory rate changes caused by the bacteria taking up the substrate are measured by the respiratory electrode, and finally the respiratory rate is determined. The linear relationship between α - amylase activity and α - amylase activity can be obtained.

(2) The immobilized microbial electrode and oxygen electrode were used to measure the respiratory activity of microorganisms, so as to detect the ethanol concentration in liquor production and obtain the alcohol content in samples.

(3) The content of starch is an important quality index to measure the quality of raw materials. The change of sugar content is related to whether the whole fermentation process of liquor is normal or not, and it is also an important basis for calculating liquor yield.

3.4. Application of Composite Sensors in Liquor Industry

The advantage of sensor is fast detection speed, but the disadvantage is single detection component, so single type of sensor can not meet the needs of practical engineering application. Composite sensor technology is the inevitable trend of sensor development, and the combination of multiple sensor technology is the inevitable trend of future development. Interdisciplinary sensor technology is emerging as the times require. For example, new ethanol sensor technology involves many disciplines such as physics, chemistry, biology, materials and computer; infrared spectrum sensing technology combined with electronic nose technology is used to detect the changes of main parameters of liquor in the fermentation process. Hou Changjun [28] et al. established a cross response liquid array sensor by simulating the taste system of mammals, which provided a new method for identifying liquor flavor types. Seven

dyes and one porphyrin compound were selected as sensing units to construct a liquid array sensor, and the spectral response signals of eight sensing units were collected to form the fingerprint of the analyte, To achieve the purpose of recognition, the response data were collected by 96 well plate microplate, and the data were processed by principal component analysis (PCA), hierarchical clustering analysis (HCA) and discriminant analysis (LDA). The results showed that the accuracy of the array for 9 liquor samples was 100%.

4. Summary and Prospect

Sensor technology is widely used in liquor industry, covering almost all aspects of production and detection, but there is still a lot of room for progress. Online real-time monitoring and automatic production are only preliminary development, and many technologies need to be improved to meet the actual production and detection needs. Sensor technology is a highly comprehensive technology, combining physics, biology, chemistry, materials, computer, control science and automation and other disciplines; the application of sensor technology will be further expanded in the future, and the automation and intelligence of liquor industry will be further improved under the drive of science and technology.

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