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The Design of an Automatic Sealing System for Solid-State Fermentation of Xiaoqu Qingxiang Baijiu

Jinsong Li[1], Huaishan Zhang[1], Chao Zhang[1], Tao Chen[1] and Jinsong Zhao[1, 2, 3, *]

[1]LuzhouLaojiao Group Co., Ltd., Luzhou, Sichuan 646000, China
[2]College of Bioengineering, Sichuan University of Science & Engineering, Zigong, Sichuan 643000, China
[3]National Engineering Research Center of Solid-State Brewing, Luzhou 646000, China

*Corresponding author e-mail: zhaojs@lzlj.com

Abstract. Although the mechanization is relatively high in the production process of Solid-State fermentation Xiaoqu Qingxiang Baijiu, the fermentation tank is manually sealed with plastic film, which increases labor intensity, cleaning difficult and reduces automation level. In this paper, an automatic sealing system for solid-state fermentation of Xiaoqu Qingxiang Baijiu is proposed. Firstly, the structure of the fermentation tank and the fermentation cover is designed. Secondly, the installation process of fermentation cover on the fermentation tank with industrial robots is designed. At last, the sealing effect of the fermentation cover was detected by the detection systems of the robot. Meanwhile, the corresponding control of the robot is programmed according to the detection results. This automatic sealing system has the characteristics of high sealing effect and a high degree of automation, which also has the advantages of simple structure, simple operation and the ability of reducing labor intensity. In addition, its use in practice could also satisfy the solid-state fermentation process requirements of Xiaoqu Qingxiang Baijiu.

1. Introduction

Solid-state fermentation was often utilized to produce Xiaoqu Qingxiang Baijiu in the southwest of China. To produce Xiaoqu Qingxiang Baijiu, sorghum and corn were used to raw material firstly, and then, it was made by the progress of raw materials cooking and steaming, bacteria culture and scarification, fermentation, and distillation etc. [1]. The fermentation of fermented grains was an important stage in the production of Xiaoqu Qingxiang Baijiu, the essence of which was that the liquor-making raw materials such as starch were transformed into alcohols, esters and other substances under the joint participation of various microorganisms such as yeasts, bacteria and fungi [2]. In the early stage of fermentation of fermented grains, despite the air existed in the fermentation tank was isolated, the yeast could multiply rapidly under the presence of oxygen that was formed in gaps among the fermented grains [3]. At the same time, the effect of alcoholic fermentation was weak. In the middle stage of fermentation, the oxygen in the gaps of the fermented grains was consumed by the yeast for itself growth and propagations to reach the maximum numbers. Alcohol was produced by anaerobic respiration of yeast, and at this moment, the alcohol content of fermented grains increased rapidly [4]. Alcohol fermentation had basically stopped due to the gradual aging or death of yeast in the last fermentation stage. If the fermented grains exposed to oxygen in the middle of fermentation, a lot of glucose were consumed by anaerobic respiration of yeasts, which could reduce the rate of alcohol yield. Therefore, the sealing of the fermentation tank directly affected the ability of yeasts, bacteria and other microorganisms to produce alcohol by fermentation in the actual production process [5].

2. Research of Fermentation Tank

Fermentation containers of Xiaoqu Qingxiang Baijiu mainly included stainless steel fermentation tanks, stone cellars and pottery jars, of which the stainless steel fermentation tanks and pottery jars were more suitable for the fermentation of Xiaoqu Qingxiang Baijiu [6].

The traditional pottery jars fermentation of Xiaoqu Qingxiang Baijiu could be summarized as the following: firstly, the fermented grains would be put in pottery jars and covered with non-toxic plastic film or quilts. Secondly, the stone slabs would be covered in non-toxic plastic film or quilts. Finally, steamed rice bran was used to seal the gap between pottery jars and stone slabs. Although traditional pottery jars fermentation could ensure the pure fragrance of Xiaoqu Qingxiang Baijiu, the sealing process was cumbersome. Besides, traditional pottery jars fermentation was difficult to reach the desired effect and could not ensure good operation of alcoholic fermentation [7].

In recent years, with the gradual automation of brewing equipment, pottery jars were gradually replaced by stainless steel fermentation tanks [8]. Instead of pottery jars fermentation, stainless steel fermentation tank system of ground constant temperature was developed by Hubei Jingjiu Company [9]. To improve labor efficiency, reduce labor intensity, and avoid material spillage during the transportation of fermented grains, the system of stainless steel fermentation tank could be summarized as the following: firstly, the fermented grains would be put in a stainless steel fermentation tank by conveyor belt and covered with non-toxic plastic film by manual labor. Then, stainless steel fermentation tanks were sent into or out of the constant temperature fermentation room by forklifts, elevated vehicles or other equipment [10]. Besides, its practical application achieved good results.

With the characteristic of large quantity and small volume, the manual sealing stainless steel fermentation tank increased labor intensity and reduced automation. Besides, plastic film and fermented grains are mutually contaminated in the fermentation process [11]. In order to reuse the plastic film to seal, stainless steel fermentation tank, the plastic film need to be manually cleaned, which increased the labor intensity further [12]. Therefore, in order to minimize manual labor intensive and realize the fermentation intelligence, it was urgent to design a solid-state fermentation automatic sealing system for Xiaoqu Qingxiang Baijiu.

In this paper, an automatic sealing system for solid-state fermentation of Xiaoqu Qingxiang Baijiu is proposed. Firstly, the structure of the fermentation tank and the fermentation cover is designed. Secondly, the installation process of fermentation cover on the fermentation tank with industrial robots is designed. At last, the sealing effect of the fermentation cover was detected by the detection systems of the robot. Meanwhile, the corresponding control of the robot is programmed according to the detection results. This automatic sealing system has the characteristics of high sealing effect and a high degree of automation, which also has the advantages of simple structure, simple operation and the ability of reducing labor intensity. In addition, its use in practice could also satisfy the solid-state fermentation process requirements of Xiaoqu Qingxiang Baijiu.

3. Automatic Sealing System Design

3.1. System Functions and Composition

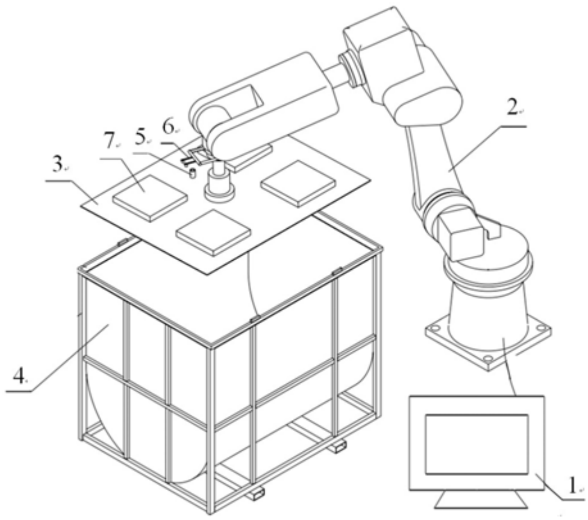

Figure 1. The automatic sealing system of fermentation tank.

1-computer, 2-robot, 3-fermentation cover, 4-fermentation tank, 5-one-way valve, 6-detecting system, 7- transparent protective plate.

The automatic sealing system of Xiaoqu Qingxiang fermentation tank consisted of a fermentation tank, a fermentation cover, a computer and a robot, as shown in Fig. 1. The computer was used to control the movement of the robot. The fermentation cover was installed on the fermentation tank by the robot. The robot detection system was used to detect the sealing property of the fermentation cover and the fermentation tank, which ensured that fermentation cover and the fermentation tank formed a sealed fermentation chamber to make the fermented grains isolating from the air.

3.2. Fermentation Tank Design

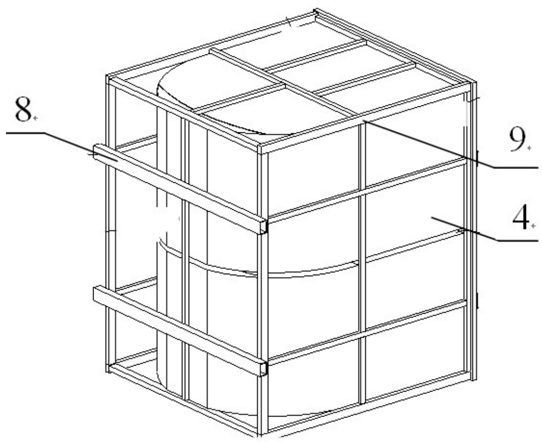

Figure 2. The structure of Fermentation tank.

4-fermentation tank, 8- stainless steel tank, 9- reinforced square pipe.

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The fermentation tank was designed with rectangular to facilitate the transportation of forklifts. A reinforced square pipe was installed around the fermentation tank to strengthen the structural strength of the fermentation tank. The interior of the fermentation tank was designed with arc for storage of fermented grains. The stainless steel tank was designed at the bottom of the fermentation tank to facilitate the transportation of the forklift truck to stainless steel fermentation tank, as shown in Fig. 2.

3.3. Fermentation Cover Design

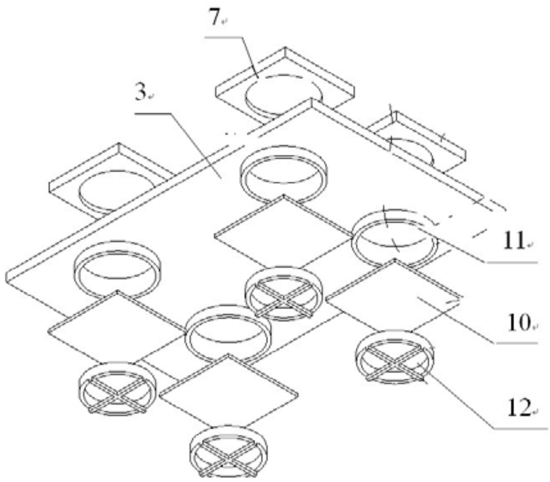

Figure 3. The structure of fermentation cover.

3-fermentation cover, 7- transparent protective plate, 10- silicone rubber film, 11-fixed ring, 12-screw nut.

The fermentation cover was designed with a one-way valve, a silicone rubber film, a transparent protective plate, a foamed silicone pad, a fixed ring, and a screw nut, as shown in Fig. 3.

The one-way valve was installed on the fermentation cover. If the pressure in the fermentation tank reached the maximum of the one-way set valve, the carbon dioxide produced by fermentation could be automatically discharged through one-way valve. Besides, the gas outside of the fermentation tank could be prevented from entering the fermentation tank to avoid affecting the fermentation.

The fermentation cover was designed with four through holes. Four fixed ring was welded below the through holes, and the silicone rubber film was mounted on the fixed ring through the screw nut which designed a cross structure to prevent the contact between the silicone rubber film and the fermented grains, which reduced the cleaning difficult. After installing silicone rubber film, the tightness between fermentation cover and the fermentation tanks would be detected by observing the changes of the silicone rubber film. As the pressure in the fermentation chamber increased by the production of carbon dioxide in the fermentation chamber in the process of fermentation, the silicone rubber film could be expanded outside the fermentation chamber to balance the air pressure, which avoided the influence of high pressure in the fermentation tank on the fermentation.

The transparent protective plate was adhered to the cover of the fermentation tank. The sealing cavity can be formed between the silicone rubber film and the transparent protective plate, and the silicone rubber film can be protected from being contaminated by the outside and the through hole can be further sealed.

The foamed silicone pad was glued around the fermentation cover. Contacting part of the foamed silica gel pad and the fermentation notch were designed with a beveled surface to ensure the tightness, as showed in Fig. 4.

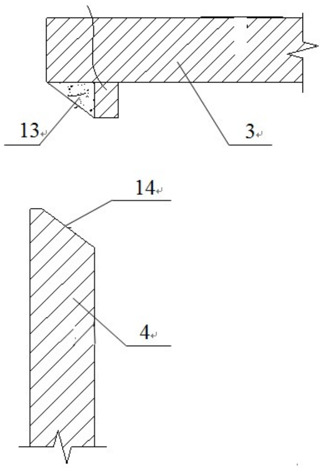

Figure 4. The sealing structure of the fermentation tank.

3-fermentation cover, 4-fermentation tank, 13-foamed silicone pad, 14- beveled surface.

3.4. Robot Design
The robot was designed with grippers for gripping the fermentation cover and detecting system for detecting the deformation of the silicone rubber film. The fermentation cover was installed on the fermentation tanks through the gripper with a sucker and the air in the fermentation tanks was extracted by using sucker. The changes of the silicone rubber film were detected by the detecting system to determine the sealing ability.

3.5. System Working Principle
Firstly, the computer issued a command to the robot. Secondly, the sucker of the robot gripper adsorbed the fermentation cover and installed it on the fermentation with the instruction of the computer. After fermentation cover installed on the fermentation, the robot applied a certain pressure on the fermentation, so that the slope of the fermentation cover with the elastic block was tightly integrated. Then, the pose of the robot would be changed to ensure the sucker of the robot connected with the one-way valve. Finally, changes of silicone rubber film would be observed by the robot detection system after the robot extracted the air inside the fermentation tank through the one-way valve.

The seal was good when the robot detection system detected that the silicone rubber film was recessed into the fermentation tank. Otherwise, the pose of the robot will be changed to separate robot sucker from one-way valve. And the fermentation tank cover and fermentation tank separated by the robot. The fermentation cover was reinstalled in the fermentation tanks or replaced with a new fermentation cover until the robot detection system detected that the silicone rubber film was recessed in the fermentation tanks.

4. Economic Benefit Analysis
Luzhou Laojiao Group Co., Ltd. was planning to build a brewing base with an annual output of 40,000 tons of Xiaoqu Qingxiang Baijiu. 12,000 fermentation tanks would be needed. If plastic film were used to seal the fermentation tank, four workers would be required to seal 800 fermentation tanks each day, and two workers are required to clean 800 plastic film. If robots were used in the fermentation of Xiaoqu Qingxiang Baijiu, the automatic sealing of the fermentation tanks could be realized with 2 robots, and it could reduce 4 workers who added silicone rubber film on the fermentation tanks, which could save 400,000 yuan per year. In addition, the silicone rubber film did not contact with fermented grains, which could effectively avoid the pollution of the silicone rubber film caused by fermenting

grains, and reduce cleaning process. So, 2 cleaning workers could be reduced, which would save 200,000 yuan per year. The robot investments were 1.2 million yuan, and the investment cost could be recovered in 2 years. Therefore, using the robot to realize the fermentation tanks, automatic sealing of the Xiaoqu Qingxiang Baijiu had a wide range of application prospects.

5. Summarize

The automatic sealing system for the fermentation tank was designed in this paper. Firstly, the fermentation cover was designed to automatically install on the fermentation tank to realize the seal of the fermentation tank. Then, the suckers of the robot could extract the gas in the fermentation tank through the one-way valve, because the robot was designed with suckers and the fermentation cover was designed with one-way valves. At last, the deformation of the silicone rubber film was detected by the robot to judge the sealing effect of the fermentation tank. The automatic sealing system in this paper has the characteristics of good sealing effect and a high degree of automation, which also had the advantages including simple structure, simple operation and low labor intensity. In addition, its use in practice could also satisfy the solid-state fermentation process requirements of Xiaoqu Qingxiang Baijiu.

Acknowledgements

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