Development of New Monitoring System in Packaging Line for Perfect Quality Control

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ABSTRACT

The reduction of oxygen uptake after beer filtration is quite important to improve the flavor stability of bottled or canned beer. It is possible to continuously measure the dissolved oxygen content in beer before filling by in-line DO meter but the measurement of O2 pick-up at the filler is quite difficult. Normally, several packaged beer samples are selected and analyzed to determine the amount of oxygen pick-up. It is impossible, by this method, to assure the oxygen content of every bottled or canned product. We are developing a new monitoring system consisting of several in-line sensors such as O2, CO2, gas flow rate, pressure sensors and TV monitors. This system has enabled us to calculate the material balance of oxygen during the filling process. With the aid of a computer, the simulation of total oxygen content of canned beer has become possible and the correlation coefficient between the simulated value and the actually measured value of total oxygen content was more than 0.9. This monitoring system is also useful to find out the factors that affect the O2 pick-up and the practical countermeasures that can be taken to reduce it.

Keywords: total oxygen, monitoring system, quality control, can filler

INTRODUCTION

The reduction of total oxygen content in packaged beer is very important to maintain product freshness in the market. For this purpose, many breweries have made a great deal of effort to avoid picking up oxygen after fermentation, especially during the filtration and filling processes. We have made many improvements to reduce oxygen pick-up in those areas. The DO (dissolved oxygen) content of in-line beer or BBT (bright beer tank) can be easily monitored by in-line DO meter, but determining the amount of oxygen picked up by each can at the filler is almost impossible because the analysis of total oxygen content in a can usually means destruction of the package. Therefore, normally only several packaged beer samples are selected and analyzed by the off-line method. It is, however, impossible to assure the oxygen content of every bottled or canned beer by such off-line method.

On the other hand, the recent remarkable progress of computer technology has enabled us to analyze the enormous amount of data in micro seconds. Additionally there are novel sensors also available. By combining such tools we have tried to develop a new monitoring system which allows us to monitor the total oxygen content in every product and at the same time to know the factors or defect points that cause the oxygen pick-up.
RESULTS AND DISCUSSION

Monitoring system in can filler

Fig. 1 shows the outline of Tonegawa Brewery’s computer network system. The local area network (LAN) system picks up the on-line data from local sensors and these data are stocked at the data server station. The stocked data can be analyzed by personal computers which are installed both at filler operation room and quality control room. The operating conditions of the entire can line can also be monitored by this system. As the number of conventional monitoring items are not enough for establishing the simulation equation for total oxygen content in every can, another 16 monitoring items were selected (fig. 2). Several sensors such as CO₂ gauges, CO₂ flow rate gauges, DO meters, oxygen meter vacuum pump gauge, flow rate gauges and CCD cameras were newly installed to monitor the 16 new items (fig.3). Fig.4 shows examples of historical trend data and their frequency histogram. Fig.5 shows how the primary CO₂ pressure, the secondary CO₂ and the vacuum pressure are influencing each other.

Establishment of multiple regression equation to simulate total oxygen content in every can

Fig.6 shows the process that we used to establish the multiple regression equation. In the first step, 8 important items were selected on the basis of simple regression between 16 monitoring items and total oxygen content of each canned beer. In the second step, 5 items were picked up on the basis of multiple regression analysis between the 8 items initially selected and total oxygen content. Filler inlet DO had naturally the greatest contribution to the total oxygen content in a canned beer but vacuum pressure and primary CO₂ pressure were found to have a significant influence on the total oxygen content (fig.7). The influence of vacuum flow rate, seamer flow rate and primary CO₂ rate were almost negligible in the operating fluctuation range. The multiple regression equation to simulate total oxygen content was established with 5 monitoring items. Access software was used for the calculation of total oxygen content. Fig.8 shows the result of the comparison of the simulated value and actual total oxygen in each canned beer. The trend was almost the same and the correlation coefficient was 0.815. As the degree of deviation between the actual and simulated value in the early stage and later stage was somewhat greater than expected, the monitoring items were revised again. Fig.9 shows the result of multiple regression analysis performed the second time, with new monitoring items. The total oxygen content of the filler bowl CO₂ gas was found to have a significantly high contribution ratio. It was also clarified that the oxygen in the filler bowl was mainly due to the impurity in the CO₂ gas which was used to replace air in the empty can before filling. The total oxygen content in each can was simulated again by using the new multiple regression equation(fig.10). The agreement between the simulated value and the actual was quite high, which showed 0.948 of correlation coefficient.
FIGURE 2
New monitoring items.

FIGURE 3
Filler system and sensors.
Historical trend data

- Primary CO2 flow rate
- Secondary CO2 flow rate
- Vacuum flow rate
- Primary CO2 pressure
- Secondary CO2 pressure
- Vacuum pressure
- Filler heat temperature
- Inlet DO
- Seamer valve pressure

Frequency histogram

- Primary CO2 flow rate
- Secondary CO2 flow rate
- Primary CO2 pressure
- Secondary CO2 pressure
- Vacuum flow rate
- Vacuum pressure

FIGURE 4
Examples of monitoring data.

Variation of CO2 Gas Pressure of D Line Filler

(Kg/cm²)

CO2 pressure

Primary CO2 pressure
Secondary CO2 pressure
Vacuum pressure

(Kg/cm²)

Vacuum pressure

Time (hh:mm:ss)

FIGURE 5
Example of pressure monitoring.
Application of the monitoring system to the improvement of the process

The monitoring system can be used not only for monitoring the total oxygen content in each canned beer, but it also has the ability to be used for locating the defective points in the filler and correct them rapidly.

When a can was foaming between the filler and the seamer due to some problem in terms of gas sealing or CO₂ pressure, the beer volume often became low and at the same time the can picked up more oxygen. As the filler speed is very fast, it is quite difficult even for an experienced operator to know which filler head has a problem. A CCD camera that was installed between the filling machine and the seamer, can continuously monitor the surface of every can (fig.11). The data from the surface image can be analyzed against a standard image. If the white area exceeds the specification, the can is judged to be faulty. By this image analysis, it is quite easy to know which filler head is causing the foaming and to adjust or repair it. Fig.12 is one of such samples, which shows that head number 62 has some foaming trouble.

Simple Regression Analysis
16 Monitoring Items Vs TO in Each Can
Pick up 8 items
Multiple Regression Analysis
8 Items Vs TO in Each Can
Further Selection of 5 Items
Establishment of Multiple Regression Equation

FIGURE 6
Process to establish the regression equation simulating total oxygen (TO) in each canned product.

<table>
<thead>
<tr>
<th>Monitoring Item</th>
<th>Regression correlation</th>
<th>Contribution Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.578</td>
<td></td>
</tr>
<tr>
<td>Filler inlet DO</td>
<td>(a₁)</td>
<td>2.597</td>
</tr>
<tr>
<td>Vacuum pressure</td>
<td>(a₂)</td>
<td>0.354</td>
</tr>
<tr>
<td>Primary CO₂ pressure</td>
<td>(a₃)</td>
<td>0.164</td>
</tr>
<tr>
<td>Seamer pressure</td>
<td>(a₄)</td>
<td>0.130</td>
</tr>
<tr>
<td>Secondary CO₂ pressure</td>
<td>(a₅)</td>
<td>0.034</td>
</tr>
<tr>
<td>Vacuum flow rate</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Seamer flow rate</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Primary CO₂ flow rate</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

◆ Multiple Regression Equation
\[ \text{P}_{\text{TO}} = -1.578 + (2.597)a₁ + \ldots \ldots \ldots a₅ \]

FIGURE 7
Result of multiple regression analysis.
**Multiple Regression Equation**

\[ P_{TO} = -1.578 + (2.597)a_1 + \ldots + a_5 \]

**Correlation coefficient**

\[ r = 0.815 \]

**FIGURE 8**
Comparison of simulated value and actual total oxygen in final product.

<table>
<thead>
<tr>
<th>Monitoring Item</th>
<th>Regression correlation</th>
<th>Contribution Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.135</td>
<td></td>
</tr>
<tr>
<td>Filler inlet DO (a_1)</td>
<td>0.734</td>
<td>76.6%</td>
</tr>
<tr>
<td>O_2 content in Filler bowl (a_2)</td>
<td>0.001</td>
<td>17.9%</td>
</tr>
<tr>
<td>Vacuum pressure CO_2 gas (a_3)</td>
<td>0.102</td>
<td>3.8%</td>
</tr>
<tr>
<td>Vacuum flow rate (a_4)</td>
<td>-0.007</td>
<td>1.5%</td>
</tr>
<tr>
<td>Primary CO_2 flow rate (a_5)</td>
<td>0.0001</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

**New Multiple Regression Equation**

\[ P_{TO} = 1.135 + (0.734)a_1 + \ldots + a_5 \]

**FIGURE 9**
Result of repeated multiple regression analysis with new additional items.
New Multiple Regression Equation

\[ P_{TO} = 1.135 + (0.734) a_1 + (0.001) a_2 \ldots a_5 \]

Correlation coefficient \[ r = 0.948 \]

**FIGURE 10**
Comparison of simulated value and actual total oxygen in final product.

**FIGURE 11**
Foaming detection system.
CONCLUSION

We have succeeded in developing a new monitoring system for the can filler which enabled us to simulate the total oxygen content of every can. The correlation coefficient between the simulated value and the actual was 0.948 which was accurate enough for quality assurance. This monitoring system is also useful to find and locate the defective points in the filler and to adjust or repair them rapidly.

QUESTIONS AND ANSWERS

Question: Are your correlations valid for start-ups and beer change-overs or are they valid for steady-stage operations only?
Answer: Our system can be applied to all cases you mentioned. We got higher value of total oxygen content at start-up by simulation and it well agrees with actual value.

Question: How long are filling runs, and how much time usually required to fix faulty filling heads?
Answer: It runs at least 24 hours and we often fill continuously for 48 hours or even 72 hours. It takes only 2 or 3 minutes.

Question: Is it possible to use the new system to reject individual cans?
Answer: Yes, it is possible because the calculating speed is fast enough. However, you have to install the rejecting machine and some new software to connect the machine and simulation computer. Our next challenging project is to establish such system.

Question: What was the cost of installing the system?
Answer: Total development cost was about 250,000 US$ and we spent about 70,000 US$ on sensors and the rest was the development cost of software and the purchasing cost of hardware.

Question: Total oxygen was reduced after installing this system?
Answer: As the fluctuation of total oxygen content of each can was actually reduced and several effective improvement methods could be taken owing to this system, the average total oxygen content of the product was significantly reduced.