Automatic Set of the Temperature of Spray Nozzle for Beer Sterilization Machine by Considering Control Energy Consumption

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***Abstract*—Now the temperature setting value of the spray nozzle in sterilization machine of each temperature zone always depends on experience, lacking of real theoretical basis, leading high energy consumption problem during the beer sterilization process. To solve this problem, the thesis according to the theory of thermodynamics establishes mathematical model of the temperature of spray nozzle and beer, and establish the optimization target association model of energy consumption and the setting temperature of spray nozzle firstly; then use the minimum difference value of the beer actual PU and the theoretical, and the minimum energy consumption of sterilization machine as the optimization objective, using the multi-objective genetic algorithm to solve the multi-objective optimization problem, and obtain the optimal target value, realize low energy consumption. The theoretical and experimental results show that the proposed model is correct and can effectively reduce the energy consumption.**

***Keywords*—Sterilization machine; Genetic algorithm; PU; Energy consumption**

I. INTRODUCTION

Sterilization is a common process in the production of beverages. After pasteurization treatment, harmful bacteria in beverages were killed, can make the product can prolong the shelf life. Pasteurization has many different processes: before bottling sterilizing, bottling and sterilizing, rapid high-temperature sterilization, sterilization temperature, fluid heating sterilization, electro thermal sterilization and microwave sterilization and so on. And now has been reported in some literature [1-5] about the process of sterilization for variety of different drinks, at home and abroad. The temperature of sterilization process has great influence on the quality of beer. That if temperature is too high, will cause the beer contains high molecular protein coagulation precipitation, the formation of a trace of floc, and even aggravate the oxygen oxidation on the composition of the beer, the beer producing astringency and aging flavor, while making beer become darker in color, in addition, high temperature will make carbon dioxide release a lot, pressure in the bottle rises sharply, easy to cause burst bottles. And if the sterilization temperature is too low, cannot reach the sterilization effect, which will cause the biological turbidity. So the temperature control of sterilization process is very important. In this paper, we study the beer pasteurization process for tunnel type sterilization, that the bottled beer bottles placed on a conveyor belt, in the transport process of beer after different section by the different temperature of water spray bottle beer gradually at first and then heated gradually cooling. With the increasingly fierce market competition, the beer industry showing to the trend of the development in scale and group, and towards energy-saving, low power consumption and the benefits of development. And with the rapid development of the market economy and the people's living standards improve, which requires sterilization machine in the values of the control accuracy is more and more accurate, and current ordinary type sterilization machine have been unable to meet the requirements [6-8].

The main research of this paper is to ensure that the sterilization of beer is the ideal of the quality of beer to meet the requirements and meet the requirements of energy saving, and finally get the ideal temperature zone of the spray nozzle temperature settings. And beer sterilization process of energy-saving control is a multi input multi output complex industrial process, is a multi variable, nonlinear and large time delay characteristics, the sterilization machine of each temperature zone in the spray nozzle temperature setting value mainly depends on artificial given experience, lack of theoretical guidance and difficult to root according to actual condition change real-time adjustment. Therefore, multi objective optimization method was used to study the temperature setting value of the temperature of the spray nozzle in the energy consumption of the sterilization machine and the temperature zone of the sterilization machine. In normal state, the establishment of tunnel type sterilization machine spray nozzle temperature and temperature of beer model and establish mathematical model between the sterilization machine each spray nozzle temperature and sterilization machine energy consumption, use genetic algorithm for spray nozzle temperature setting to make the setting optimization, so as to ensure the deviation of the actual quality of beer within the

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allowable range, and sterilization machine energy consumption within the allowable range.

II. GENETIC ALGORITHM SOLVE THE PROBLEM OF ENERGY CONSUMPTION OF STERILIZATION MACHINE

A. Problem description

The beer sterilization process is shown in Fig.1. Beer from the inlet to the experienced numbered 1 to n with ten different water spray heat exchange zone, the first seven district heating and spraying, three regions for spray cooling, and from the point of view of the network characteristic the ten district including three heating and cooling cycles and four heating cycle, the simplified physical model is shown in Figure 1, from product to product a heat exchange zone sequentially numbered the 1 to n. Because of the need of energy saving and water saving, the heat of the heat absorption and heat release temperature can be used for each other, as shown in Figure 1: the structure of the mutual circulation spray between 1 and 2 in the temperature range 9 and 10, and between 8 and 3 of the temperature range. And to precisely control the beer sterilization strength, 4, 5, 6, 7 for independent temperature zones, its main role is the temperature of the wine in the bottle in time to ascend to the target temperature and target temperature keep the time required, the heating zone and the cooling zone the main role is to form a reasonable heating and cooling temperature difference, to prevent sudden rise and sudden drop caused by bottle explosion phenomenon occurs. From the above description, the tunnel type sterilization machine principle can be seen, for the sterilization of beer is mainly to achieve sterilization by regulating the hot water, and the cold water is to protect the beer flavor, ultimately achieve user ideal sterilization, cold and hot water regulating ratio for energy saving is very crucial. User always concerns about two aspects of consideration that one is to achieve the ideal of beer sterilizing degree, and the other is to saving water and energy. In order to achieve energy-saving and water-saving, the article [9] presented research and design of the energy saving type sterilization machine, the machine in the design will be water tank is divided into two parts, which full digestion and absorption on the basis of the German company equipment combined with the domestic situation. But the paper has not considered the effect of the temperature of the spray nozzle on the water saving and energy saving.

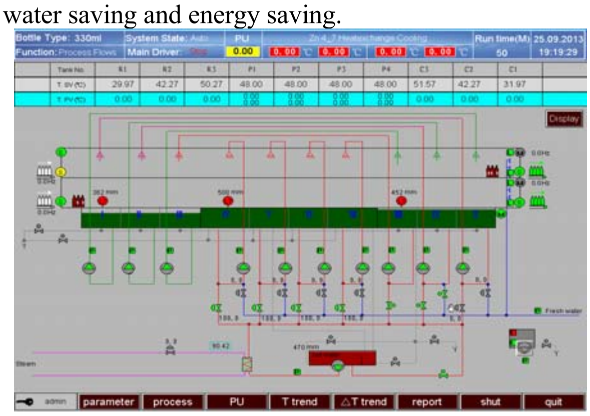

Fig.1.Schematic diagram of the tunnel sterilization machine

In order to meet the expectations of enterprises comprehensive production targets: in the premise of ensuring the quality of beer, the sterilization process energy consumption is minimum that will required establishing the mathematical model between a comprehensive production objectives and various process operation parameters, that to establish correlation model between comprehensive production targets and sterilization machine each temperature region of the spray nozzle temperature. Abase on the established correlation model; through optimization method to obtain the sterilization machine each temperature zone in the spray nozzle temperature optimization target values, and finally set the sterilization machine of each temperature zone temperature setting value as the optimization goal, achieve the companies expect the comprehensive production targets.

B. Mathematical model of beer quality in tunnel type sterilization machine

The most important parameters to effect measure the tunnel type of beer sterilizing machine is the maximum temperature of beer after sterilization, the PU value beer as well as the production of beer, which the maximum temperature of beer and PU value after sterilization machine are the beer quality important parameters. To establish the mathematical model of beer quality, it is necessary to establish the relationship between the temperature of beer, the PU value of beer and the temperature of the spray nozzle of the sterilization machine.

For tunnel type sterilization system can be divided into n solid element, and each solid element includes three systems: (1) air / water system which produced by the spray nozzle, (2) bottle system, (3) water system. As shown in Fig.2[10]. Each system has mass and energy conservation.

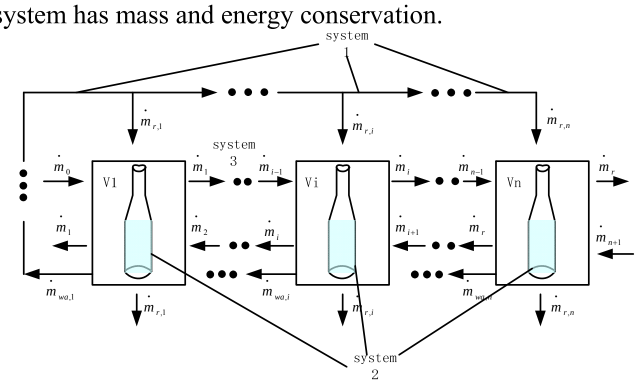

Fig.2. Diagram of the system 1.2.3

(a)Thermodynamic mathematical model of air / water system:

According to Fig.2 and the first law of thermodynamics, the heat conduction equation to the air / water system:

$$\begin{aligned}&\dot{\Phi}_{w,i}+\dot{\Phi}_i+\dot{m}_{r,i}\,c_{wa}(T_{in,wa}-T_i)+\dot{m}_{i-1}\,c_{p,f}T_{i-1}\\&-\dot{m}_{r,i}\,c_{p,f}T_i+\dot{m}_{i+1}\,c_{p,f}T_{i+1}-\dot{m}_i\,c_{p,f}T_i\\&=m_f c_{v,f}\frac{dT_i}{dt}\end{aligned} \tag{1}$$

where $\dot{\Phi}_{w,i}$ and $\dot{\Phi}_i$ are the heat transfer rate between system 1 and the external environment and between system 1 and the mass of bottles (system 2) within the volume element Vi, respectively; $m_{r,i}$ is the water mass flow rate entering the VE through the spray, m_i is the air/water fog mass flow rate from the i VE to next one, m_{i+1} is the air/water fog mass flow rate from the i+1 VE to i VE, and m_{i-1} is the air/water fog mass flow rate from the i-1 VE to i VE. c_{wa}, $c_{p,f}$ and $c_{v,f}$ are the specific heat of the water, of the air/water fog at constant pressure and of the air/water fog at constant volume, respectively; m_f is the mass of air/water fog in the volume element; $T_{in,wa}$ is the inlet water temperature which equal to T_{set}; T_i, T_{i+1}, and T_{i-1} are the temperatures of the air/water fog inside the VE'I', inside the next element, and the previous one, respectively.

The heat transfer rate lost by the VE to the surroundings through the walls is calculated by

$$\dot{\Phi}_{w,i}=U_{w,i}A_{w,i}(T_{\infty}-T_i) \quad (2)$$

Where $U_{w,i}$ is the global heat transfer coefficient between the air/water fog system and the surroundings through the walls and T_∞ is the external ambient temperature.

$$U_{w,i}=\left(\frac{1}{h_\infty}+\frac{\delta_w}{k_w}+\frac{\delta}{k_{ins}}+\frac{1}{h_{int}}\right)^{-1} \quad (3)$$

Where k_w is the thermal conductivity of the wall material, δw is the wall thickness, k_{ins} is the thermal conductivity of the insulation material, δ is the insulation material thickness; h_∞ the convection heat transfer coefficient outside the tunnel walls, and h_{int} the convection heat transfer coefficient between the air/water fog and the walls.

The mass flow rates are evaluated by

$$\dot{m}_{i-1}+\dot{m}_{i+1}=2\dot{m}_i \quad (4)$$

$$\dot{m}_i=\rho_f u_i\frac{A_s}{2} \quad (5)$$

Where ρ_f is the density of the air/water fog and A_s is the vertical cross-section area of the tunnel, defined by the volume occupied by the air/water fog. For i= 1, $m_{i-1}=m_n$; and if i =n, $m_{i+1}=m_1$. u_i, is estimated by a VE analysis using the continuity equation for a two-dimensional domain.

$$u_i\sim\frac{v\Delta x}{H} \quad (6)$$

With v being calculated from $m_{r;i}$, for $v\cong\dot{m}_{r,i}/(\rho_{wa}\Delta xW)$

The heat transfer rate between systems 1 and 2 is given by

$$\dot{\Phi}_i=\alpha_i A_b(T_{b,i}-T_i) \quad (7)$$

Where A_b is the total external surface area of the mass of bottles within a VE, and $T_{b,i}$ is the internal bottle temperature. The convection heat transfer between the air/water fog and the mass of bottles is α_i.

(b)The bottles system

（1）Heat transfer analysis of beer bottle

The first law of thermodynamics states that

$$\dot{\Phi}_p=m_{b,i}c\frac{dT_{b,i}}{dt} \quad (8)$$

Where c is the bottle specific heat as a function of the weight average of the specific heat of the casing material, $m_{b,i}$ is the total mass of the set of bottles in the VE.

(2) Analysis of internal heat transfer beer bottle

Today has a beer bottle, suddenly into the heating tunnel type sterilization machine, beer bottle by the heating effect of the sterilization machine spraying nozzle spray mist environment, the temperature gradually increased from the outer surface of the bottle to beer liquid bottle center with time, and accompanied the energy is gradually transferred to the center of beer bottle. Fig. 3 shows the temperature change of the heating process of beer bottle.

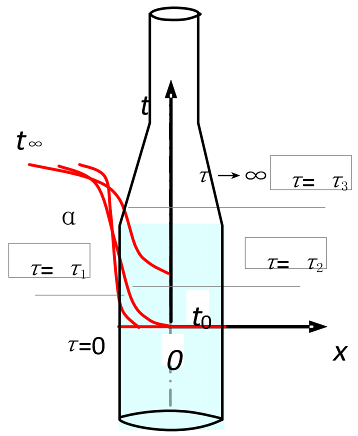

Fig.3. Schematic diagram of heating process of beer bottle

According to the thermodynamic definition when the object system of the external thermal resistance is far greater than that of its thermal resistance, the temperature changes in the environment and the object surface is far greater than body temperature changes, it would be that the temperature distribution of the object is almost uniform. So the thermal resistance of the object can be neglected. And for beer bottles, which are thin, the thermal resistance innet<< the external thermal resistance, and sterilization machine system in heating and cooling process, according to the laws of thermodynamics calculation of non steady heat conduction of a homographic can calculated for the following process. And on the assumption that the volume of beer bottles is V, surface area is A, and the density is ρ, the specific heat is c and initial temperature is $T_{b,i}$, sterilizing machine environment temperature is Ti, heat transfer coefficient as α. At any one time system heat balance relations: heat can change rate with the time ΔE= exchange with the outside world through the surface heat flow $\dot{\Phi}_p$, and heat balance equations are formulated as

$$\frac{\partial T}{\partial\tau}=a\nabla^2 t+\frac{\dot{\Phi}p}{\rho c} \quad (9)$$

Because the internal thermal resistance of the object is far less than the external thermal resistance, so the internal thermal resistance can be ignored, can be considered independent of the temperature and the coordinates, so the temperature of the two - order derivative term $\nabla^2 t$ is zero. And will be converted into:

$$\frac{dT}{d\tau}=\frac{\dot{\Phi}_p}{\rho c} \tag{10}$$

Where $\dot{\Phi}_p$ is generalized heat source. Heat source on the surface of the beer bottle can be regarded as the volume heat source of the object.

$$-\dot{\Phi}_p V = A\alpha(T_{b,i}-T_i) \tag{11}$$

The (11) finishing plug in (10) and with the initial condition $\tau=0$, $T=T_{b,0}$ can be obtained:

$$T_{b,i}=T_i+(T_{b,0}-T_i)e^{(-\frac{\alpha A}{\rho c V}\tau)} \tag{12}$$

$T_{b,0}$ is initial temperature in the formula. It is found that the temperature of the object gradually tends to the environment temperature over time, which is consistent with the law of the cooling process of the object.

(c)Thermodynamic mathematical model of water system

For the water system, the heat conduction formula of the water system can be calculated according to the Fig. 2 and the first law of thermodynamics:

$$\begin{aligned}&\dot{\Phi}_{wt,i}+\dot{m}_{r,i}\,c_{wa}T_i-\dot{m}_{wa,i}\,c_{wa}T_{t,i}+\dot{m}_{wa,i+1}\,c_{wa}T_{t,i+1}\\&=m_{t,i}c_{wa}\frac{dT_{t,i}}{dt}\end{aligned} \tag{13}$$

Where $\dot{\Phi}_{wt,i}=U_{wt,i}A_{wt,i}(T_\infty-T_{t,i})$.

C. Mathematical model of energy consumption for tunnel type sterilization machine

The beer bottle from into tunnel type sterilization machine in normal operation process then out through ten different spray water temperature heat exchange zone. According to the principle of heat balance, the heat transfer in the heat load is equal to the heat sterilization process, but because of the sterilization process, spray nozzle of hot steam spray to the beer bottle surface, heat by the beer bottle wall afferents to the beer inside, in this process, the heat will exchange with the external environment, that is to say, the total into the sterilization machine internal heat is greater than the heat absorbed by the beer, so there is a (14):

$$\dot{\Phi}_{in,all}=\dot{\Phi}_{out,b}+\dot{\Phi}_\infty=\dot{\Phi}_{out,tot} \tag{14}$$

Where $\dot{\Phi}_{in,all}$ is total enter the heat conduction rate of the sterilization machine, $\dot{\Phi}_{out,b}$ is the heat transfer rate is absorbed by the beer, and $\dot{\Phi}_\infty$ is the heat transfer rate of the external environment is the heat loss.

According to the principle of heat transfer, the total heat transfer rate $\dot{\Phi}_{in,all}$ can be calculated as

$$\begin{aligned}\dot{\Phi}_{in,all}&=\sum_{z=4}^{7}\left[\dot{m}_{rt}\,c_{wa}(T_{in,wa}-T_{t,i=1})\right]_z\\&+\dot{m}_{rt,z=2}\,c_{wa}(T_{in,wa,z=2}-T_{t,i=1,z=9})\\&+\dot{m}_{rt,z=3}\,c_{wa}(T_{in,wa,z=3}-T_{t,i=1,z=8})\end{aligned} \tag{15}$$

Where $\dot{m}_{rt,z}$ is the total spray water mass flow rate for a zone z, $\dot{m}_{rt,z}$ is also a design parameter which is given by

$$\dot{m}_{rt,z}=\sum_{i=1}^{n}(\dot{m}_{r,i})_z \tag{16}$$

Where $\dot{m}_{r,i}$ is spray water mass flow rate in VE i.

The calculated value of each temperature zone is visible in TABLE Ⅰ.

TABLE I. MODELING PARAMETERS OF THE ENERGETIC INTERACTIONS BETWEEN TUNNEL ZONES

Zone	$T_{in,wa}$	$\dot{\Phi}_{in,z}$
1	$T_{in,wa,z=1}=T_{set,i=1,z=10}$	$\dot{\Phi}_{in,1}=0$
2	$T_{in,wa,z=2}=T_{set,i=1,z=9}$	$\dot{\Phi}_{in,2}=\dot{m}_{rt,z=2}\,c_{wa}$
3	$T_{in,wa,z=3}=T_{set,i=1,z=7}$	$\dot{\Phi}_{in,3}=\dot{m}_{rt,z=3}\,c_{wa}$
4	$T_{in,wa,z=4}=T_{set,i=1,z=4}$	$\dot{\Phi}_{in,4}=\dot{m}_{rt,z=4}\,c_{wa}$
5	$T_{in,wa,z=5}=T_{set,i=1,z=5}$	$\dot{\Phi}_{in,5}=\dot{m}_{rt,z=5}\,c_{wa}$
6	$T_{in,wa,z=6}=T_{set,i=1,z=6}$	$\dot{\Phi}_{in,6}=\dot{m}_{rt,z=6}\,c_{wa}$
7	$T_{in,wa,z=7}=T_{set,i=1,z=7}$	$\dot{\Phi}_{in,7}=\dot{m}_{rt,z=7}\,c_{wa}$
8	$T_{in,wa,z=8}=T_{set,i=1,z=3}$	$\dot{\Phi}_{in,8}=0$
9	$T_{in,wa,z=9}=T_{set,i=1,z=2}$	$\dot{\Phi}_{in,9}=0$
10	$T_{in,wa,z=10}=T_{set,i=1,z=1}$	$\dot{\Phi}_{in,10}=0$

The heat transfer rate to the bottles that travel through the tunnel, $\dot{\Phi}_{out,b}$ is given by

$$\dot{\Phi}_{out,b}=m_b c_b\frac{(T_{b,out}-T_{b,in})}{t_{tot}} \tag{17}$$

Where m_b is the mass of the set of bottles in one VE, $T_{b,in}$ and $T_{b,out}$ are the set of bottles temperature when entering and exiting the tunnel, respectively, and t_{tot} is the total travel time of one bottle (or set of bottles) in a particular VE through the whole tunnel.

The $\dot{\Phi}_\infty$ (total heat transfer rate lost by the tunnel to the external ambient) is given by

$$\dot{\Phi}_\infty = \sum_{z=1}^{10}\sum_{i=1}^{n}(\dot{Q}_{w,i} + \dot{Q}_{wt,i}) \qquad (18)$$

III. THE MULTI OBJECTIVE OPTIMIZATION MODEL OF ENERGY CONSUMPTION IN THE PROCESS OF BEER STERILIZATION

The mathematical model between the temperature of the spray nozzle and the beer temperature in each temperature zone of the sterilization machine and the mathematical model of sterilization machine energy consumption have been established.

The spray nozzle temperature of each temperature section of the sterilization machine is set by $T_{set,z}$ (z=1,... , 10) have a certain range of values: $[a_i, b_i]$.

Set optimization performance index for

J=L(δ $\dot{\Phi}(T_{set})$,T_{set}), δQ=Q-Qre, in the eqution: $\dot{\Phi}(T_{set})$ is the actual consumption of energy; $\dot{\Phi}_{re}(T_{set})$ is the expected value. Performance index J is function about the deviation between the actual energy consumption and the expected energy consumption value and the input temperature zone of the spray nozzle.

Based on the objective function and the constraint function, the expected energy consumption is 40. By the linear weighted method, the multiple objective function is constructed, and the constraint is added to the objective function in the form of penalty function.

$$\min F(T_{set,z}) = w_1(\dot{\Phi}(T_{set,z}) - \dot{\Phi}_{re}(T_{set,z}))^2 + w_2(PU(T_{set,z}) - PU_{re}(T_{set,z}))^2 + \sum_{z=1}^{10} r_z \max(0, g_z(T_{set,z})) \qquad (19)$$

In (19), the w_1, w_2 for weight coefficient, $w_1 + w_2 = 1$; D for the definition of the domain; r_z is the penalty coefficient, this example is set to 1000000. In addition, the global multi objective function is used to measure the energy consumption and the beer ideal PU value, which is only used to measure the order of magnitude, and its dimension is 1. Using the MATLAB software genetic algorithm toolbox (GADS), the number of population is set to 200, the maximum operating algebra is set to 100, the crossover probability is set to 0.5, the probability of mutation is set to 0.05[11], the weights of w_1 and $w_1$are set to 0.5.

According to the model of the beer temperature and sterilization machine spray nozzle temperature, the test based on genetic algorithm to control the energy consumption of the sterilization machine, and the important parameters of heat transfer are shown in TABLEⅡ.

TABLE II. NUMERICAL VALUES USED IN THE EXPERIMENT

Parameter	Value
PU	10
Coefficient of heat transfer of 1-4 zones and 8-10 zones	117
Coefficient of heat transfer of 5 and 6 zones	115.2
Coefficient of heat transfer of 7 zones	120.6
Weight of beer bottle	0.245kg
Weight of beer	0.33kg
Total height of beer bottle	0.223L
Height of beer bottle neck	0.057L
Outer diameter of beer bottle	0.061m
inter diameter of beer bottle	0.026m
running speed	333.0012mm/min
Machine total long	16.71m
Machine total wide	4.56m

The above models and beer target PU value of 10, after using the genetic algorithm to solve the model to get the sterilization machine of each temperature zone in the spray nozzle temperature setting value as shown in Fig.4. and a base on the genetic algorithm, normal operation of the income under the beer theory of PU value is 10.0329, error only 3.29%. And the energy consumption of the sterilization machine was Q=40 at the temperature of the spray nozzle in each temperature zone of the optimized sterilizing machine.

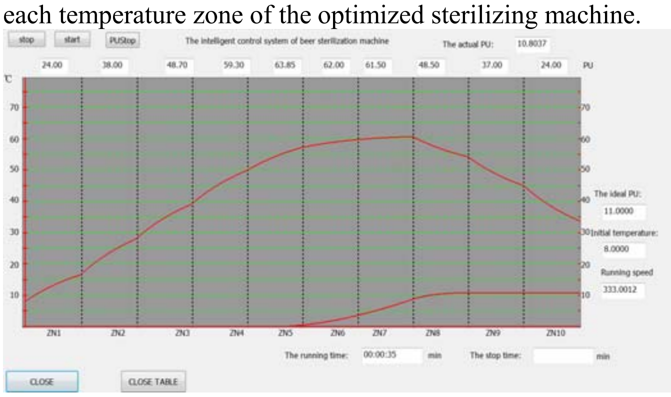

Fig.4. Genetic algorithm to adjust the temperature of the sterilization machine spray nozzle temperature theory model

In order to verify the mathematical model between beer temperature and sterilization machine spray nozzle temperature is correct, and genetic algorithm is used to control the correctness of the sterilization machine energy consumption is opportunity. The experiments include two groups, one group is the sterilization machine spray nozzle temperature setting value abase on the empirical, the other group is using genetic algorithm control the sterilization machine energy consumption to set sterilization machine district spray nozzle temperature setting value. In each experiment, using three beer bottles and each bottle is inserted a real-time recording beer temperature and PU value instruments which shown as in Fig. 5. The acquisition time of the instrument is set for every 30 seconds to collect a beer temperature data, after the beer bottle completely through the sterilization machine, export the instrument records the temperature data and record beer final PU value shown in Fig.6 and Fig. 7.

Fig.5. Diagram of the PU test meter is inserted in the beer bottle.

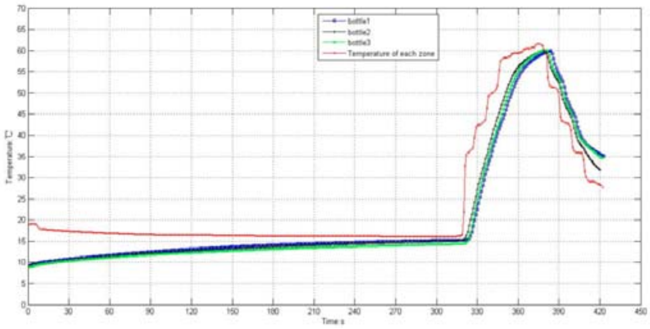

Fig.6. Diagram of no genetic algorithm is used to adjust the set temperature of the spray nozzle of the sterilization machine

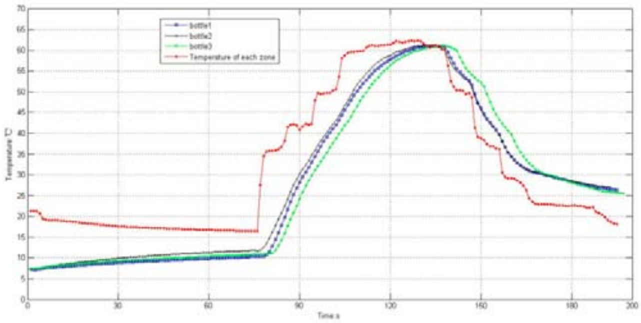

Fig.7. Diagram of genetic algorithm is used to adjust the set temperature of the spray nozzle of the sterilization machine

The results of experiment 1 and experiment 2 are shown in TABLE Ⅲ, and the conclusion that:

①After the genetic algorithm is used to adjust the setting temperature of the spray nozzle, the spray nozzle of the 4-7 zone of the sterilization machine is set with the temperature of the setting temperature of the spray nozzle of the sterilizing machine;

②In Experiment 2, the maximum wine temperature was higher than 60℃, by 60.89;

③In Experiment 2, the PU value of three beers, all more than 8PU;

Compared Fig.6 with Fig.7, it is also can see that the changes of the beer temperature in the process of sterilization of beer bottles are consistent, so the theory and the experiment are the same, it also proves the correctness of the mathematical model of the beer sterilization process.

TABLE III. COMPARISON EXPERIMENT ONE AND EXPERIMENT TWO

	Beer temperat-ure(℃)	**PU**			**Spray nozzle temperature by zone 4-7(℃)**			
		bottle1	bottle2	bottle3	4zone	5zone	6zone	7zone
1	59.96	7.55	8.20	8.24	58.22	58	59.9	61.5
2	60.89	11.77	11.88	13.25	59.3	60.75	62	61.5

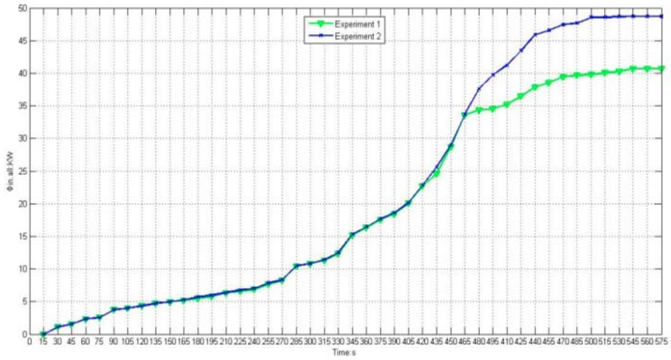

Fig.8. Energy consumption comparison by experiment 1 and 2

During the experiment the energy consumption recording instrument readings every 15 seconds to record, finally finishing the experiment 1 and experiment 2 data on a comparison chart in the Fig.8. And in figure 9 the experimental one is the set spray nozzle temperature by experience, and the experimental two is intelligent setting spray nozzle temperature a base on the genetic algorithm. Seen from the figure the final energy consumption is 48KW in experiment 1, and combined with the established mathematical model of energy consumption and the genetic algorithm, the energy consumption is 41.2KW in experiment 2. Compared to the experimental one, using genetic algorithm to adjust the district spray nozzle set temperature, the sterilization machine energy consumption was reduced by 14.17%. And the final target energy consumption compared to 40KW is 3%. Thus the energy consumption model is correct and using genetic algorithm can effectively reduce the energy consumption of the sterilization machine.

IV. CONCULATIONS

In this paper, the research background of the optimization control of the beer sterilization production process. Using the multi objective genetic algorithm, put forward a control strategy solve the energy consumption of the sterilization machine is, which is based on the setting temperature of the spray nozzle in each temperature zone. Optimization of beer sterilization process is realized. The experimental results show that. Optimal control of energy consumption of beer sterilization process based on multi objective genetic algorithm under the premise of meeting the quality requirements and reduce the energy consumption of the sterilization machine.

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References

[1] Lau, M. H, and J. Tang. "Pasteurization of pickled asparagus using 915 MHz microwaves." Journal of Food Engineering, vol.51.A 4.2002,pp:283–290.

[2] Ibarrola, J. J., et al. "Modelling of a high temperature short time pasteurization process." Food Control, vol.9.A5,1998,pp:267-277.

[3] Bail, A. Le, and G. Cornier. "Improvement of heat transfer during low temperature pasteurization processes." Journal of Food Engineering, vol.27.A4,1996,pp:409–422.

[4] Tucker, G. "A Novel Validation Method: Application of Time-Temperature Integrators to Food Pasteurization Treatments." Food & Bioproducts Processing,vol.77.A3,1999,pp:223–231.

[5] Cygnarowicz-Provost, Miriam, J. C. C. Jr, and R. C. Whiting. "Computer control of a steam surface pasteurization process." Journal of Food Engineering, vol.25.A1,1995,pp:131-139.

[6] J.R.A Pollock. Beer consumption market situation. Beer Science, A3, 1991,pp:120-125.

[7] Yan Jia-wei, "The international market for beer." Food and Fermentation Industry,A2,1991.

[8] Du Lv-jun, "China's beer industry development trend and outlook." Beer Technology,A3,2005.

[9] Jiang Wei-quan. "Research and application of energy-saving sterilization machine". South China University of Technology, 2010

[10] Dilay E, Vargas J V C, Amico S C, et al. "Modeling, simulation and optimization of a beer pasteurization tunnel". Journal of Food Engineering, vol.77.A3,2006,pp:500-513.

