THE ROLE OF ENERGY MANAGEMENT FOR THE IMPLEMENTATION OF SUSTAINABLE AND EFFECTIVE HEAT PROCESSES

II. OPTIMAL ENERGY CONTROL OF HEAT PROCESSES IN THE CONDITIONS OF BREWING

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Abstract: In this paper is described the developed by us method for optimal energy control in real production systems. The heat management role for the realization of sustainable and effective heating/cooling processes in the beer production is evaluated. It was made and detailed energy – technology analysis of beer production, guaranteeing flawless and quality production. Adaptive software was developed based on the GAMS programming environment, offering an optimal management solution to energy-related problems in certain production. The specific production criteria are taken into account by formulation a complex multi parametric optimization task. The approach can be applied to other productions (operating or designing) to optimal energy consumption management and energy efficiency.

Keywords: energy management, sustainable heat processes, brewing.

1. INTRODUCTION

In industrial production systems, the realization of sustainable and efficient heat processes is of particular importance in our time. This is extremely important for production processes that are heavily influenced by market requirements, such as the pharmaceutical, food and brewery industries. Managing the energy consumption of these productions is related to the resources reduction needed to carry out the heat processes. Such optimal energy control was considered in 1986 by Vaselenak, J.A., Grossmann I.E [4]. Subsequently, Boyadjiev Ch. B., and others. (1996), [1] and further on by A. Pozna et al. (1998), [3] develop the issues of energy saving.

This work presents the method, developed by us, of optimal energy management in real production system. The role of heat energy management in the realization of sustainable and efficient heating / cooling processes in beer production is appreciated. An interesting development in this direction is the work of the team Monika Dumbliauskaite, Helen Becker, François Maréchal (2010) [2], who propose splitting beer production into two parts.

A detailed technological analysis and monitoring of heating / cooling processes in antibiotic production has been carried out. On the basis of the audit, the application software has been developed (in GAMS's programming environment). An optimal management solution for the problems associated with energy consumption in particular beer production is proposed. Specific features have been taken into account and a complex multiparametric optimization task has been formulated. The developed approach can also be applied to other productions (working or in the design stage) to optimize energy management and energy efficiency.

2. AIM

The aim of this work is to provide optimal energy control of heating processes in conditions of brewing by minimizing energy consumption.

3. PROBLEM DESCRIPTION

There is a detailed technology analysis of conventional beer production, which is focused on management, respectively optimizing heat energy from heating / cooling processes.

The production process is in line with conventional brewing and includes the following steps:

Stage 1: Milling

Stage 2: Mashing - Mashing is carried out after mixing of the malt with water 45°C in apparatus 1 (figure 1.). This process forms a so-called malt mash. A special feature here is that the temperature during the mashing is raised in steps and then kept constant for a while at different mashing rests;

Stage 3: Mash Filtration - During mash filtration, the wort is separated from the spent grains with filter bags. The wort is with temperature of 78°C . From wort subsequently is obtained beer. Filtration is carried out in an apparatus 2 (figure 1.);

Stage 4: Boiling - After mash filtration, the wort is boiled together with hops to add bitterness to the taste of the beer. The boiling takes roughly an hour and the boiler is heated with steam. This stage is carried out in apparatus 3 (figure.1.). After the brewing the wort's temperature is 98°C ;

Stage 5: Hot separation of hops and malt residues - During this stage, is formed a sludge as a result of the boiling. The process is carried out in an apparatus 4 (figure 1.), at temperature $98 - 99^{\circ}\text{C}$;

Stage 6: Cold separation - Cold sludge is formed after cooling the hopped wort. Cooling is carried out in two sections. In the first section, wort is cooled with water with a temperature of 16°C . The second section cools with water with a temperature of 2°C . At the end of the process the wort is with temperature 12°C .

Stage 7: Adding of yeast

Main-alcoholic fermentation performed by yeast;

Post-fermentation and maturation - two interrelated processes that naturally follow the main alcoholic fermentation;

Stage 9: Bottling, packaging and pasteurization

The so called "Calming" of beer is mandatory operation that occurs immediately after its filtration. Then beer is fed for bottling.

The production process of beer is presented as composed of two parts - hot (production of wort Stage 2 - Stage 6) and cold (fermentation, maturing and beer processing Stage 6 - Stage 9).

A comparison is made between a scheme without energy management and the optimized technological scheme proposed by us.

Figure 1 shows the hot part of a scheme without energy control.

Figure 1. Scheme of hot part – without energy management

The energy audit of the technological scheme shown in Figure 1 was carried out. A mathematical description of the heating / cooling systems was also analyzed. Based on this, a new scheme is proposed to bring together these processes in a special section, including a system of specialized reservoirs (Figure 2).

The characteristic feature of the proposed scheme shown in Figure 1 is *the system of specialized reservoirs*. Wort with temperature T_0^P and debit m_n^P enters for cooling in heat exchangers A_1 , A_2 , A_3 , A_4 . The waste water after the heat exchangers is stored in four reservoirs V_{80}^* , V_{45}^* , $V_{Washing}^*$, V_{Waste}^* . The idea of this operation is that the heated water stored in the heat reservoirs is used to carry out the processes for the production and filtration of the malt mash, and also to wash the dishes.

The task of management of the process is limited to the determination of multitude independent variables which to minimize the money spent to conduct processes. Restrictions of the task are related to the technological requirements for carrying out the processes, and also with the demands to the technical equipment for performing coolin. To solve it, the GAMS program environment is used.

Software for managing the heat processes in the production of antibiotics has been developed.

In this type of energy control it is not necessary to observe a certain operation schedule of the apparatus in the workshop. This reduces the amount of wastewater and steam.

Figure 2. Scheme of hot part – with energy management

The management essence output is the use of a minimal resource to carry out the heating processes.

$$\left\{ \begin{array}{l} \text{Find : } X_t \left[\begin{array}{l} m_{in}, \quad \forall n \in (1, N), \forall i \in (1, 5) \\ A_n, m_n^P, t_n, \quad \forall n \in (1, N) \end{array} \right]^T \\ \text{MINIMIZE } \{Cost(X_t)\} \rightarrow (Cost) \\ \text{s.t. : } \{Eq.8 - Eq.14\} \end{array} \right\} \quad (1)$$

Where:

$Cost$ - an energy expenses needed to provide the processes, [lv.]

$$Cost = (E_{45} + E_{80} + E_{Washing}) Cost_{16} + E_2 Cost_2 \quad (2)$$

$$E_{45} = (T_{45} - T_{45}^*) V_{45}^* Cp_{16} + (T_{45} - T_{16})(V_{45} - V_{45}^*) Cp_{16} \quad (3)$$

$$E_{80} = (T_{80} - T_{80}^*) V_{80}^* Cp_{16} + (T_{80} - T_{16})(V_{80} - V_{80}^*) Cp_{16} \quad (4)$$

$$E_{Washing} = (T_{Washing} - T_{Washing}^*) V_{Washing}^* Cp_{16} + (T_{Washing} - T_{16})(V_{Washing} - V_{Washing}^*) Cp_{16} \quad (5)$$

$$E_2 = \sum_{n=1}^{n=5} (Cp_2 m_{5n} t_n (T_{5n} - T_2)) \quad (6)$$

$E_{45}, E_{80}, E_{Washing}, E_2$ - the energy needed to ensure the technological processes, [kJ]

$Cost_{16}$ - Cost per unit of energy consumed for heating water $16^\circ C$ for technological needs, [lv.]

$Cost_2$ - Cost per unit of energy consumed for beer cooling with water $2^\circ C$, [lv.]

This can be achieved by creating conditions for rate maximizing use of waste (second) heat energy. The search variables that can minimize the means used to carry out the heat processes are:

$$\left\{ \begin{array}{l} m_{in}, \quad \forall n \in (1, N), \forall i \in (1, 5) \\ A_n, m_n^P, t_n, \quad \forall n \in (1, N) \end{array} \right\} \quad (7)$$

Task restrictions are related to the technological requirements for carrying out the processes, and also with requirements for the technical equipment for carrying out of the cooling. In this case, the pluralities of task restrictions are:

$$\left. \begin{array}{l} T_{45}^* \leq T_{45} \\ V_{45}^* = V_{45} \end{array} \right\} \quad (8)$$

$$\left. \begin{array}{l} T_{80}^* \leq T_{80} \\ V_{80}^* = V_{80} \end{array} \right\} \quad (9)$$

$$\left. \begin{array}{l} T_{Washing}^* \leq T_{Washing} \\ V_{Washing}^* \leq V_{Washing} \end{array} \right\} \quad (10)$$

$$V_{Beer} = \sum_{n=1}^{n=5} (t_n m_n^P) \quad (11)$$

$$A_i \leq A_i^{MAX}, \forall i \in (1, 5) \quad (12)$$

$$\sum_{n=1}^{n=5} t_n \leq t_{cold} \quad (13)$$

$$T_{5n}^P \leq T_F \quad (14)$$

The presented task is formulated in terms of the mathematical nonlinear programming MNLP and it is solved with programming package GAMS.

As a result of applying the method of energy management in the process of brewing were achieved results presented in the following tables:

Table 1. Energy needed to ensure the technological processes

Resource	Energy needed for a system without applied energy management [kJ]	Energy needed for a system with applied energy management [kJ]
E_2	1432469.724	1432469.724
E_{45}	4131340.000	1.944
E_{80}	9385600.000	2.145
E_{Wash}	5719350.000	2927238.395
Total	20 668 759.72	4 359 712.208

From the table above it is clear that during the implementation of energy control scheme with usage of specialized heat reservoirs (fig.2) the energy needed to obtain water with temperature $45^\circ C$ and water with temperature $80^\circ C$ is minimized.

Table 2. Expenses of energy resource

Expenses	Expenses for a system without applied energy management [lw.]	Expenses for a system with applied energy management [lw.]
$Cost_2$	232.060	232.060
$Cost_{45}$	311.916	1.467841E-4
$Cost_{80}$	708.613	1.619686E-4
$Cost_{Wash}$	431.811	221.006
Total	1684.400	453.067

From table 2 is clear that the optimal process management leads to significant expenses reductions for the used water with temperature $45^{\circ}C$ and $80^{\circ}C$. The overall economy of the energy resources (cooling water and steam) is approximately 3 times the energy consumption in the case without applied energy management. The advantage of this energy management is the elimination of the need to coordinate processes over time. It is not necessary to observe a certain schedule of operating devices.

4. CONCLUSION

The presented study shows the energy - technological study of the heating processes in conventional beer production. Based on the audit, the application software was developed with GAMS programming environment. Some specific features of production are defined and a complex multiparametric optimization task is formulated. The developed approach can also be applied to other industries (operating or designing) in order to optimally manage energy consumption and energy efficiency.

5. REFERENCES

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