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ANALYSIS OF THE LOAD-EFFICIENCY GRAPH OF THE BOILER

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Abstract: *The rentability and quality of preserved food (besides the quality of the basic materials, the good recipe and the features of the production belts) are determined by their heat-treatment and its organization. The production process which was not planned carefully can imply quality problems and considerable increase of expenses. To support work organization with computer has not been in practice in Hungary so far. My main objective in case of technologies with an autoclave group is to elaborate a program system based on simulation which could help reduce the direct costs of heat-treatment and improve the quality of products. For this objective it is necessary to carry out further sub-tasks and examinations whose results should be utilized in the system. One of these is to analyse with simulation the load-dependent efficiency graph of gas boiler which provides the necessary amount of steam and then to use the results to find the conditions of optimal operation and to calculate costs reduction arising from it.*
Keywords: *boiler, load-efficiency, heat-treatment*

1. INTRODUCTION

Heat treatment of canned goods and especially of meat products requires large quantities of energy as these products require long treatment at around 120 degree Celsius. Reducing the use of natural resources is an important goal in industrial processes – a few years ago this only meant saving energy, today it includes the paradigm of environment management and the paradigm of sustainable development – the goal is to reduce the energy usage or at least to produce more products without increasing energy usage (Kerekes et al 1996). Although reduction in the use of these resources (water, electricity, heat energy) obviously decreases the cost of manufacturing and increases the economy of manufacturing, it is not trivial to implement in many production plants as the cost of these resources is not calculated or measured at all, thus wasting resources is not visible. Similarly, increased quality and nutrition parameters might also remain undetected.

In the field of heat treatment, general heat loss was an important field around 1970 (Rao et al 1976, Rao et al 1978, Singh 1978). Around 1980, the heat utilization and heat intake ratio were important issues (Bhowmik et al 1985, Sielaff et al 1982, Singh et al 1986). If the insulation is changed on the equipment, the technological processes must be changed in accordance with engineering calculations. Because of the above mentioned reasons, and because of the many parameters and many different processes, modelling and simulation should be combined with engineering calculations.

According to my assumption, the boiler-load which is constant in time guarantees the possible maximum average efficiency, while loads of bigger fluctuation and deviation result in lower average efficiency with the same average load, namely with heat-treatment of products of the same quantity.

2. MATERIALS and METHODS

The diagram (Figure 1) which shows the section with a critical, more intensive change in efficiency of the graph, necessary for the examination, was available in documentation of the boiler of the company which provided me with the data. It has a text complement which says that the efficiency continuously increases over the load of 50% and it reaches 90% at the load of 100%. The efficiency on the vertical ordinate of the figure means that how many percentages of the heat amount calculable from the gas amount utilized to heat up the boiler is found in the heat-energy of the steam coming out of the boiler. It means that in case of lower efficiency, the heat-energy necessary for heat-treatment can be provided only by fuel gas of bigger amount. In the figure on the horizontal ordinate the percentage of the boiler- load shows that how many percentages of the heat amount, which can be maximally guaranteed in the unit of time, and which comes out in the form of steam, the boiler is loaded with.

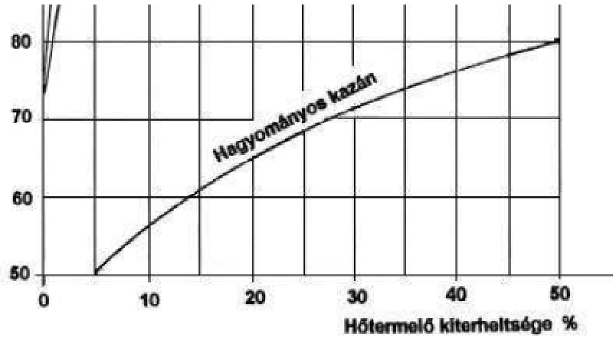

Figure 1 The efficiency of the boiler as a function of loading

It was necessary to simulate boiler-load data of different dispersion with random number generator (Monte Carlo method) in order to be able to analyse the effect of uneven boiler-load on the expenses, on the basis of the results. The essence of the Monte Carlo method is that instead of the measured data we utilize their simulated (generated as random number) value on the input of the computer model, and we evaluate these results instead of the measured effect.

3. RESULTS and DISCUSSION

To get the efficiency automatically for the given load I needed the function of mathematical form which defines the graph. Thus, I aimed to find a function which attaches the efficiency values shown by the chart to the values of [0, 1] interval (corresponds to the [0%, 100%] load domain). I chose the $f(x)=x^n$ power function with exponents between 0 and 1 which adjusts itself to the nature of the graph. It was necessary to dislocate the function downwards (transformation) by 10%, so it is regarded as a parametre to find the precise value. All in all, the function which shows the connection between load and efficiency is the following:

$$y = f(x) = x^n - d, \qquad (1)$$

where: x – load, y – efficiency, n, d – parametres in demand.

I used the Solver complement of the Excel program to find the values of the parametres, applying the smallest squares method. Thus, I had the following function:

$$y = f(x) = x^{0,2} - 0,09. \qquad (2)$$

The chart formed, on the basis of the known data, on efficiency and the function used as its model (Figure 2) showed that there is no need to examine the statistic congruency of the two data series. By means of the function, the efficiency can be calculated to the load of any values.

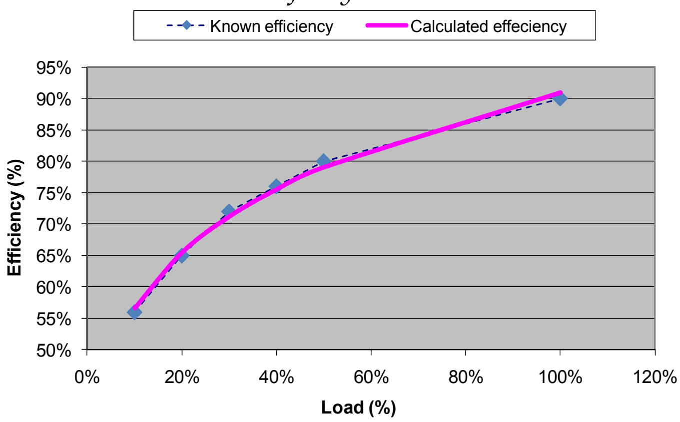

Figure 2. Graphs of known and calculated efficiency as a function of loading

Table 1. Analysis of the boiler efficiency with different loads

Average load	Dispersion of load	Average efficiency	Relative loss of efficiency
70%	70%-70%	84,11%	0,0%
	65%-75%	84,06%	0,1%
	40%-100%	82,66%	1,8%
50%	50%-50%	78,06%	0,0%
	30%-70%	75,83%	2,9%
	20%-80%	75,39%	3,5%
	10%-90%	74,39%	4,9%
30%	30%-30%	69,60%	0,0%
	10%-50%	65,58%	6,1%

During analysis I tried to find out what efficiency of average value the boiler loads of a given average value but of different deviation, dispersion result in (Table 1). It can be calculated from this that the heat-treatment of the given amount of products can be guaranteed by what degree of efficiency and thus, by what gas consumption depending on the evenness of loading. The relative loss of efficiency shows that what loss can be experienced in *percentage with the given average load, as compared to the maximum available efficiency. Dispersion of load means the value domain the boiler load moves in.*

To generalize the data of boiler loads in percentage the average values possible in practice and their approximate dispersion were taken into consideration. The average of the boiler load per year is around 50%. One of the main reasons for uneven load is seasonality when certain products need heat-treatment with a fairly big deviation. Of course, in this case there is no possibility to balance the load. The other, a more important case from the aspect of my research, is when different products are made at the same time which need different loading, and it is not taken into consideration while scheduling the production, as I have experienced in the present practice. In this case, for example, instead of the average load of 50% per shift it is typical that average loads of 30% and 70% can be experienced in successive shifts. Nevertheless, there can be big deviations within a given shift when the heat-treatments in parallel autoclaves are not scheduled.

Consequently, dispersion of loads is on a very large scale but it cannot be regarded as a normal one, for example. For this reason, I generalized a data series of even dispersion between different limits which is typical to the unevenness of loading. I determined the average of the efficiencies arising from it and the relative deviation in relation to the balanced position. This relative loss of efficiency is the loss of gas consumption of the boiler, too.

During examination at each efficiency of 30, 50 and 70% I examined that how much the standard deviation effects the efficiency. The last column of Table 1 shows that how much the relative deviation of efficiency and thus, the costs are from the case which can be maximally attained without the standard deviation, in case of the given average load.

It can be seen from the results that in parallel with the growth of unevenness of load the loss increases, too. With smaller average loads the equalization of load has greater importance since in this case the relative loss can reach 6%. With the load of 50% which can be regarded as the annual average there was almost 5% loss in the worst case which means the additional expenditure of 5 million Fts if the annual gas fee is 100 million Fts.

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