NUMERICAL COMPUTATION OF THE RESISTANCE FURNACES MASONRY

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Abstract − **The correct dimensioning of the electric furnaces masonry is absolutely necessary for the optimization of the technological process in regard to power consumption and the quality of the products.**
The analytical calculation becomes very difficult when the variation by temperature of the characteristics of the materials used in the masonry is taken into account.
A computer program dedicated to the numerical computation of the resistance furnaces masonry is presented in this paper. The program is written in the Java programming language.

Keywords: *resistance furnace, masonry, numerical computation, optimization.*

1. INTRODUCTION

The resistance furnaces have a special place in the electrothermal equipments category. These furnaces represent the most wide spread solution in the semi-products heat treatments [1, 2].

An important characteristic of the resistance furnaces is the possibility of adjusting the working temperature very accurately, an essential condition for obtaining quality pieces [1, 2].

Designing, construction and rational operation of the resistance furnaces require a thoroughly survey of the factors that influence their energetical and economical indicators.

Among these factors there is also the quality of the furnaces masonry. The correct construction of the masonry and its careful execution at mounting will influence: thermal losses, power consumption, furnace heating time, the quality of thermal processing, operation time, weight, overall size and cost of the furnace.

Consequently, the proper selection of materials and the correct dimensioning of the resistance furnaces masonry are absolutely necessary for optimizing the technological processes regarding the power consumption and the quality of products.

2. NUMERICAL COMPUTATION OF AN ELECTRIC FURNACE MASONRY

To achieve the thermal calculation of a resistance furnace, it is necessary to evaluate the heat flow rate transmitted through the masonry.

The analytical calculation becomes very difficult when the variation with the temperature of the characteristics of the materials used in the masonry construction (especially their thermal conductivity) is taken into account.

If the inner temperatures of the furnace wall (e.g. the temperatures at the contact surface of two successive layers) are not chosen properly, it is necessary to perform an iterative calculation until reaching the desired accuracy.

In this work we propose a numerical computation of the heat flow rate transmitted through the resistance furnaces masonry.

For this purpose, the layers of the furnace wall for which the thermal conductivity is variable with the temperature will be divided in sub-layers of very small thickness, thus to be considered that, in the respective layer limits, the material thermal conductivity is constant. For the wall layers where the thermal conductivity is constant, such a division should not be made.

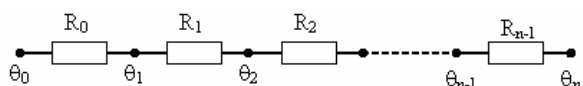The electric model of the resistance furnace will contain „n" non-linear resistances:

Figure 1: The equivalent electric diagram corresponding to the thermal transfer through the resistance furnace masonry.

The interior and exterior surfaces of the furnace enclosure can exchange heat by radiation with objects being at temperatures different from the air inside the enclosure, respectively with the exterior. This is especially relevant for the interior surface, where there is a significant thermal transfer by radiation from the furnace heating elements towards the wall.

The refractory and thermo-insulating materials are solid and opaque, so there is no transfer by convection or radiation into them. Where a transfer by convection or radiation (in air) is taking place, the thermal conduction phenomenon is to be neglected.

For the numerical computation of resistance furnace masonry, a program written in the Java language was developed.

The computations are achieved according to an iterative process. Initially, a linear variation of the temperature in the entire masonry is considered, the extreme temperatures being the ones from interior and exterior. Then the thermal resistances related to the surface unit are computed for each division, and from them results the thermal flow density. With the new temperature distribution are computed the thermal resistances and the process is repeated until the maximum difference between the temperatures calculated at two successive iterations is smaller than a pre-established value (10^{-6} °C).

The main window of the program (Fig. 2) contains two tables, a menu and a status bar.

In the first table the furnace masonry layers and their characteristics can be configured: the thickness g[mm] and the thermal conductivity λ[W/m°C].

The program allows for the study of some complex configurations of the furnace's masonry, with imperfect contact between the layers. In such cases, air layers corresponding to the technological gaps can be defined, described by the thickness g[mm] and the heat transfer coefficient α[W/m²°C].

Through a contextual menu, layers can be added or deleted, their number being practically unlimited.

In the first table are also presented the (extreme) temperatures on each layer (θ_i[°C], θ_0[°C]) and the layer's thermal resistance corresponding to the surface unit (R*1000 [m²°C/W]).

In the second table there are the global variables: the temperatures from the furnace's interior and exterior (θ_{int}[°C], θ_{ext}[°C]) and the heat transfer coefficients (α_{int}[W/m²°C], α_{ext}[W/m²°C]) towards the air from the enclosure's interior and exterior (if needed, the thermal transfer by radiation with objects from the furnace enclosure's interior and exterior can also be taken into consideration).

In the status bar there are the thermal flow density (p_s[W/m²]), or "Error" if the iterative process does not converge.

Computations are made again whenever the input data is modified. In case of a double-click on the column λ, a special editor (Fig. 3) appears where materials can be chosen from a database (encoded in the program), or the coefficients for the dependence of thermal conductivity by temperature, $\lambda(\theta)$ can be entered.

The program allows for saving or loading of the simulation data in files. When the program is closed, data is saved automatically in a special location and at the next start-up it is reloaded from there, so the program gets back automatically to the last simulation.

There is an "undo/redo" type facility, with a buffer of 100. Thus, if undesired modifications have been made, it is possible to revert to the previous values.

When starting the program, another window containing the graphic with the simulation results is also displayed. This window also updates automatically whenever modifications are made in the main window. The program allows for the optimal dimensioning of an electric furnace masonry regarding the density of the heat flow rate transmitted through the masonry and the maximum temperature on the external surface of the furnace.

Nr.	g [mm]	λ [W/m°C]	α [W/m²°C]	θi [°C]	θo [°C]	R*10³ [m²°C/W]
1	250	0.29	0	999.1	742.5	509.907
2	250	0.105	0	742.5	133.5	1209.98
3	10	0.128	0			63.299
4	5	50.93	0			0.101

Contextual menu:
Add layer before — Insert
Add layer after — Shift-Insert
Remove — Delete
Remove All — Shift-Delete

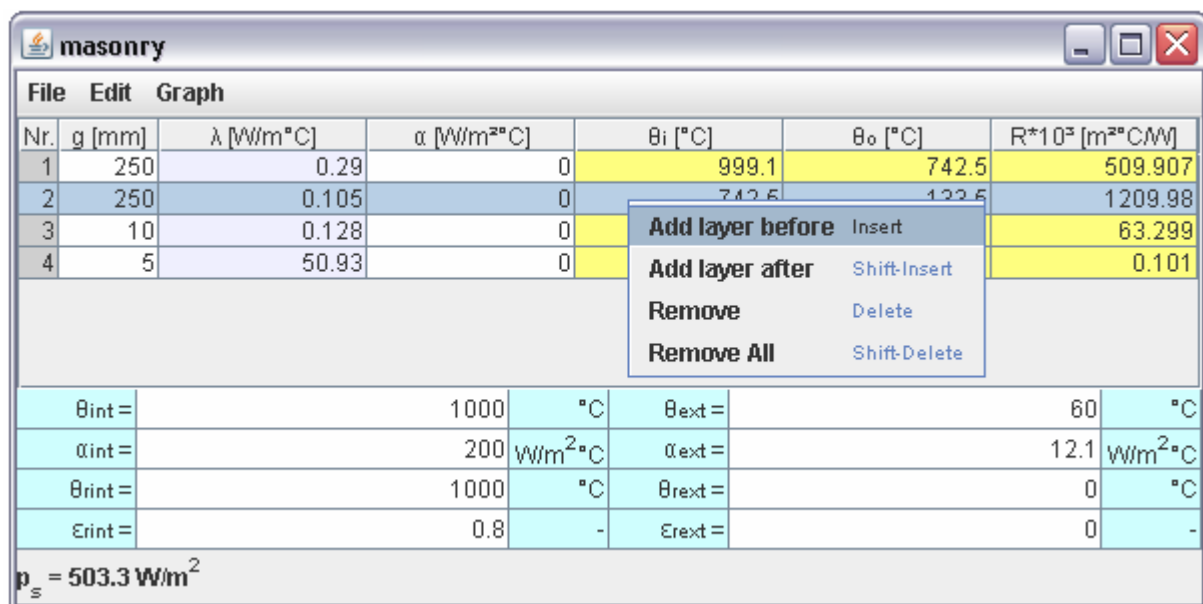| θint =	1000	°C	θext =	60	°C
αint =	200	W/m²·°C	αext =	12.1	W/m²·°C
θrint =	1000	°C	θrext =	0	°C
εrint =	0.8	-	εrext =	0	-

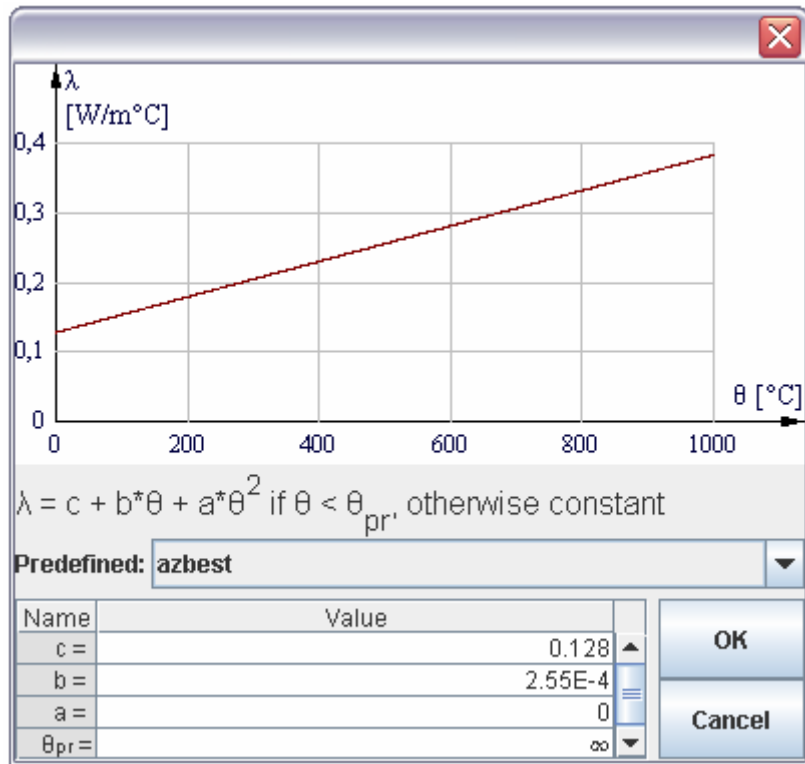$p_s = 503.3$ W/m²

Figure 2: The main window of the program.

Figure 3: The dialog window for choosing or introducing the material characteristics for a layer of the furnace masonry.
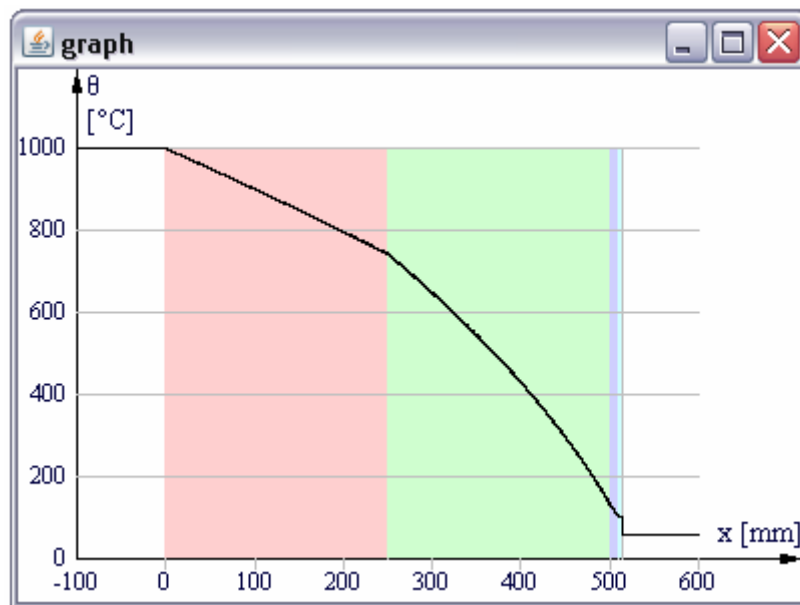

Figure 4: Temperature variation in the resistance furnaces masonry.

4. CONCLUSIONS

The correct dimensioning of the electric furnaces masonry is absolutely necessary concerning the optimization of the technological process.

The analytic calculation becomes very difficult when the variation by temperature of the characteristics of the materials used in the fabrication of the masonry is taken into account.

For the numerical computation of resistance furnace masonry, a computer program was developed, using the Java language.

The program allows for the optimal dimensioning of an electric furnace masonry regarding the density of the heat flow rate transmitted through the masonry and the maximum temperature on the external surface of the furnace.

References

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