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MODELING THE PHENOMENON OF THERMAL TRANSFER IN GAS FURNACES

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ABSTRACT
The paper presents a study concerning the numerical simulation of heat transfer issues by finite element method. The heat transfer occurs in the heating process of the steel billets into combustion ovens. The results obtained by FEA method using ALGOR package are compared with experimental data.

KEYWORDS:
numerical simulation, heat transfer, FEA method

1. INTRODUCTION

Among the technological factors that lead to obtaining plastically deformed high quality products we can mention the way in which the initial semi-finished parts were heated up in the furnaces of the respective workshops.

The optimization of the heating process of the semi-finished parts is closely connected to knowing and mastering of the complex phenomena of thermal transfer that take place inside the furnaces. The control of the heat flow transferred to the metal piece can be achieved if we can get enough accurate information related to the evolution of the temperature range inside the furnace. This information comes, at present, in most cases from direct temperature and, eventually, inflows measurements in the characteristic points of the work area. Usually, these data prove insufficient for an optimization of the thermal process undergone by the piece.

The nature of the real phenomena taking place in the furnace, as well as the particular constructive characteristics of the heating devices do not allow certain measurements that could offer useful information for the optimization of the process under consideration. On the other hand, building industrial-scale experimental devices meant to allow the study of all the real situations arising in practice would be extremely expensive and would not be economically justified.

The considerations given above have lead to the idea of studying the thermal transfer phenomena taking place on steel heating up from a different perspective. This paper intends to approach this problem using as research technique, the numerical simulation.

The aim of this study consists in obtaining a model of numeric simulation, using the finite element approach (FEA), generally valid and applicable to all the particular cases of steel heating in gas furnaces, a model meant to allow the computer-aided study of the optimization of the thermal transfer in those situations, at a low cost (involving only the hard and software to be used) and in a very short time. The results we obtained by simulation are to be validated by experiments.

2. THE STAGE OF OBTAINING THE NUMERICAL MODEL

We intended to create a model of numerical simulation, under non-stationary work conditions, established inside a semi-finished section (bloom, having the dimensions 0,30x0,24x0,27 m) asymmetrically heated in an experimental gas furnace. We took into consideration the complex phenomena of thermal transfer by convection and radiation from the gaseous atmosphere to the surface of the material, respectively the radiation of the inside surface of the furnace masonry towards the metal that is subject to heating.

The specific stages in solving the problem will be described hereinafter:

- ⇨ First, it is important to clearly determine the type of thermal transfer problem under consideration. As we are studying the heating of the semi-finished section along a certain period of time (the total duration is 10 h) inside the experimental installation, this is a problem of thermal transfer under non-stationary work conditions. On the other hand, if we take into consideration both some material temperature dependant thermal-physical properties (thermal conductivity, specific heat) and the complex radiation phenomenon to be used in calculations, we have to use a non-linear analysis of the phenomenon of thermal transfer.
- ⇨ The second step in building the numerical model is to determine the domain of analysis. We decided to determine the distribution of the temperature range inside a body which geometrically represents a parallelepiped, all the three dimensions being finite. In other words, the domain of analysis is a three-dimensional one and therefore we are dealing with a three-dimensional distribution of the thermal range under consideration.
- ⇨ The third step consists in the generation of the geometry of the domain of analysis under consideration.
- ⇨ The next step includes the discretization of the domain of analysis in finite elements, which involves choosing the type of finite element, the characteristic constants, establishing the number of knots for each element and the generation of the discretizing lattice.

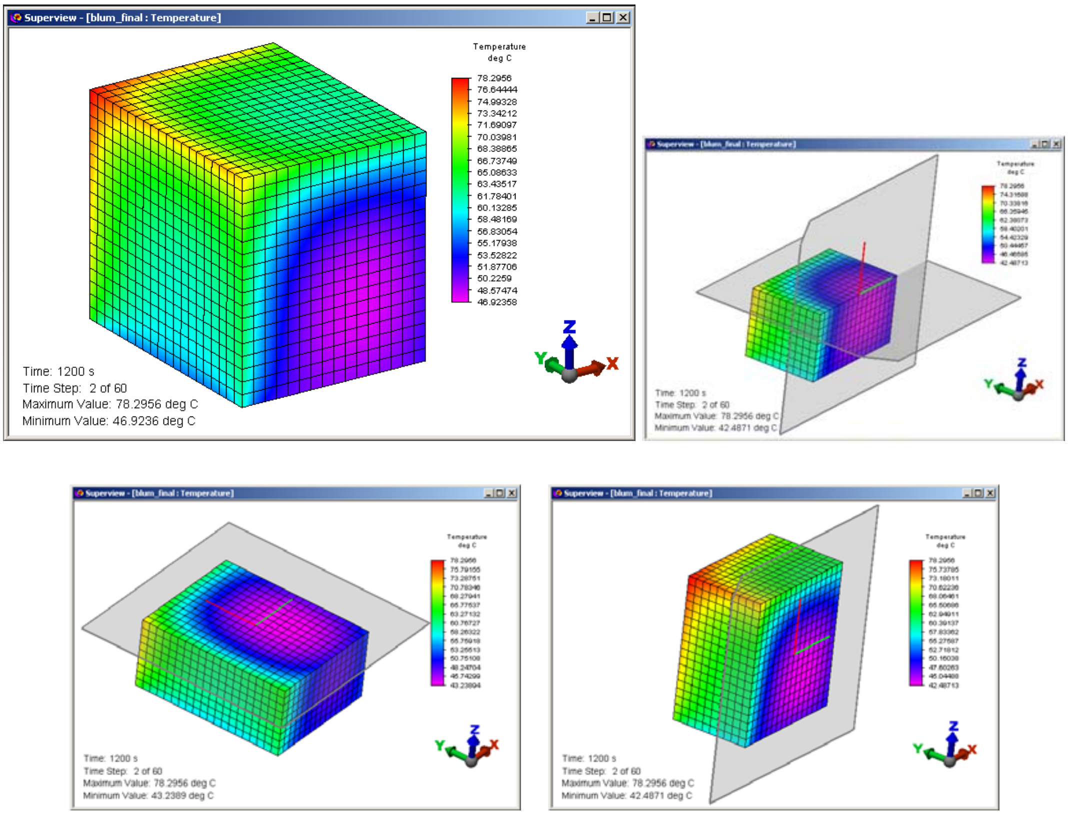
- ⇨ Then we established the thermal-physical properties of the material, considering the steel grade which the experimental semi-finished section has been cast of.
- ⇨ The last step consists in the implementation of the spatial limit and the time limit conditions (or the initial conditions).

The steps listed above belong to the stage of pre-processing the numerical model and give the input data for the program used.

The final stage, called post-processing, includes the running of the program and listing the results obtained under a qualitative and quantitative form.

3. INTRODUCING THE RESULTS

The implementation of the numerical model with finite elements has been done using the professional software package ALGOR. It enables, by means of its SUPERVIEW interface, the *qualitative* visualization of the results obtained after the processing of the input data. The qualitative visualizing of the results implies a color or/and equal heat line (isotherm) mapping of the thermal field under consideration, which allows a global vision at a certain moment of the heating process, or the time evolution of temperatures along the entire domain of analysis.



Time: 1200 s
Time Step: 2 of 60
Maximum Value: 78.2956 deg C
Minimum Value: 46.9236 deg C

Time: 1200 s
Time Step: 2 of 60
Maximum Value: 78.2956 deg C
Minimum Value: 42.4871 deg C

Time: 1200 s
Time Step: 2 of 60
Maximum Value: 78.2956 deg C
Minimum Value: 43.2389 deg C

Time: 1200 s
Time Step: 2 of 60
Maximum Value: 78.2956 deg C
Minimum Value: 42.4871 deg C

Fig.1. The thermal field inside the bloom at time step no. 2

The number of time steps we chose was 60, which means, for a total heating time of 10 hours, a set of 600 s time intervals for which the program calculates the temperatures in the knots of the discretizing lattice. The heating started at room temperature (20 ^{o}C). We further gave the qualitative distribution of the thermal field inside the bloom, after 20 min from the beginning of the heating and at its end.

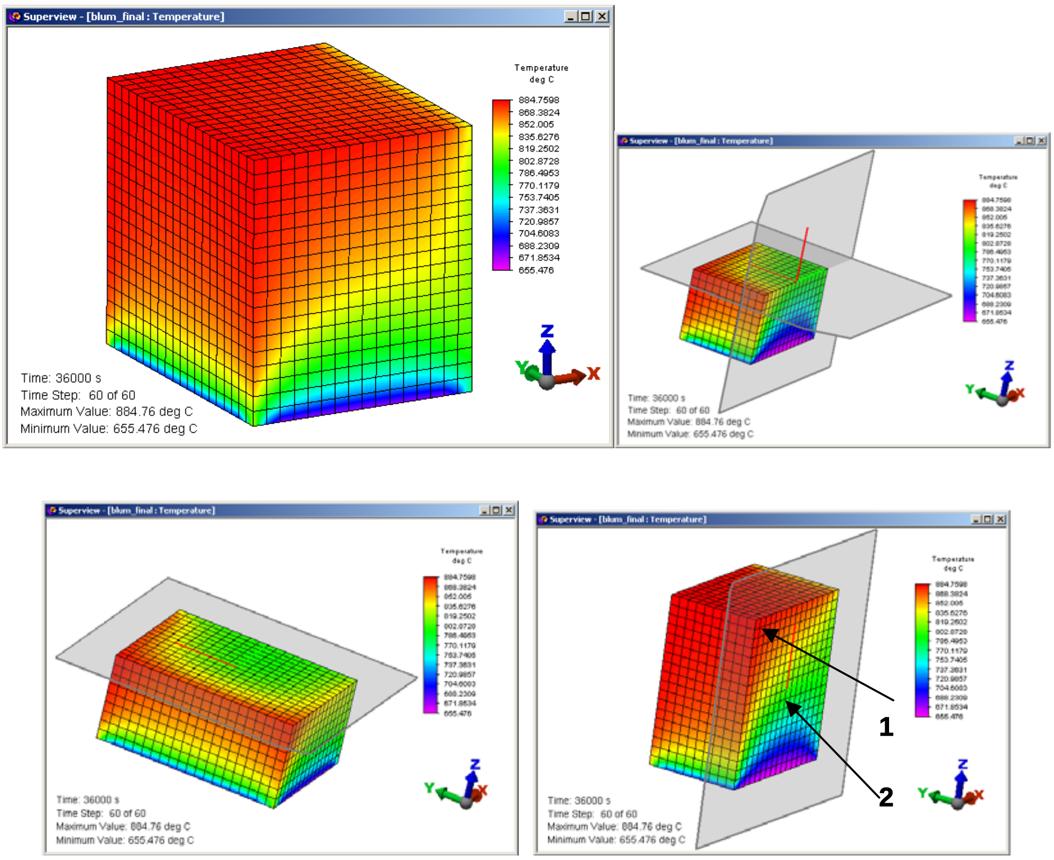


Fig.2. The thermal field inside the bloom at time step no. 60

4. Conclusions

The validation of the numerical simulation model using the method mentioned above implies a comparison between the temperatures obtained by the numerical model built by means of ALGOR package and the values determined experimentally. We further gave a graphical representation of this comparison for two points inside the bloom.

The first, numbered 1 in fig. 2 shows the temperature of the bloom surface (5 mm from the upper left edge of the bloom).

The second, numbered 2 in figure 2, shows the temperature at the center of the bloom.

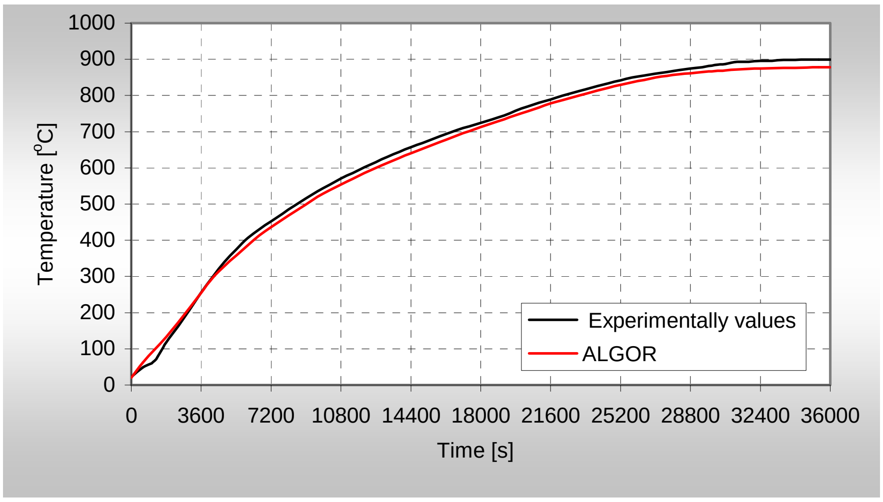


Fig.3. Comparative results related to point 1

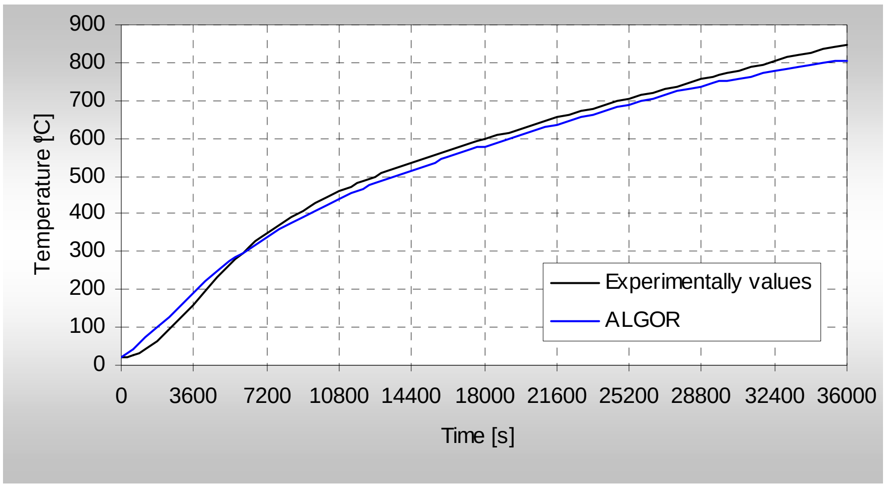


Fig.4. Comparative results related to point 2

An overall view of the dynamics of temperature variation measured experimentally at the two points, shows that the values resulted from the calculations made by ALGOR program at all the five characteristic knots, corresponding to the measurement points, loosely emulate this variation.

On the other hand, at the beginning of the heating period (after about 1…2 h), the values calculated by ALGOR are higher than the experimental ones, and later on the situation is reversed.

The explanation consists in the fact that, in reality, the temperature of the inside masonry surface, considered as thermal radiant surface, increases permanently, during the heating process, reaching a maximum value at its end.

But the numerical model uses for calculations a mean value of masonry temperature, which is the basis of calculation for the radiation heat exchange between the inside masonry surface and the semi-finished product.

Moreover, the radiation from the masonry is higher as temperature is higher. An overestimation of the masonry radiation in the first phase of the heating process (by assigning the inner masonry surface a higher temperature than in reality) is the reason of obtaining higher temperature values by means of the ALGOR program than the experimental ones.

REFERENCES:

[1.] SORIN RAŢIU – *Studiul modelării câmpurilor termice la încălzirea oţelurilor pentru deformare plastică* – Doctoral Thesis, 2004;
[2.] SORIN RAŢIU, *Modern methods of temperature gauging inside the work area of flame-heated ovens*, METALURGIA INTERNAŢIONAL, nr.6, ISSN 1582-2214, pp.43-46, 2004;