# USE OF ARTIFICIAL INTELLIGENCE TOOLS FOR CONTROL OF HEATING FURNACE

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**Abstract**

This article is supposed to take into account the usage of business intelligence tools for metallurgical production control systems. Artificial intelligence tools, not only the popular method of data mining, are currently necessary for the control systems, and they are supposed to be used also for any heavy industry, including metallurgy. It is expected that the ratio of usage of fuzzy sets, expert systems and other available means of artificial intelligence, which include also artificial neural networks, will be significantly increased also for metallurgical processes wherever it is feasible and economically acceptable. This article is focused to Neural Networks and their usage for Control of Heating Furnace.

**Keywords:** Artificial Neural Networks, Business Intelligence, Control of Heating Furnace, Data Mining

## 1. INTRODUCTION

Combination of data mining, artificial intelligence (AI) and neural networks with classic mathematical description, including regress and statistical analysis in order to correct a wrong prediction of AI tools, can be seen as beneficial. The failure of certain quantities' impact can be considered as the behaviour weakness of many models [1]. In the range of industrial reheating furnaces the data describing the material reheating process are stored in various kinds of industrial databases. For reconstruction of real state of furnaces an approach based on Turring's machines can be used. The basic ideas will be used for reconstruction of standing material in the furnace and describing this idea could be a goal of this paper.

Monitoring and control systems collect for the purpose of monitoring a number of operational data. These systems construct their databases as easily as possible; each trend is usually stored in a separate table. Data in the tables are stored in two basic principles, either periodically after a preset time interval or after a certain event - change of a variable value. But this leads to redundancy. The solution could be to store each reference variable in a separate table. Many systems use their own mechanisms for storing data that combine both periodic data storage and storage management using a change of value. These data must be pre-processed before deploying data mining [2] and before using them for optimizing the heating control system due the neural network use.

## 2. DATA ACQUISITION AND PRE-TREATMENT OF DATA

From the scanned data it is necessary to select those that are important for further processing and eventually to derive additional data that describe the environment of heated contislab (position, temperature of the furnace environment in a given position). Furthermore, it is necessary to select the appropriate contislabs from the database to determine times of moving the contislab from one position to the next position and assign to these events corresponding flow rates of the heating medium and the temperature.

The next step (using genetic algorithms) is to determine the constants that indicate direct contribution of heat generated by combustion of the heating medium and the contribution, which forms a heat transfer between the furnace lining and the heated contislab. Already mentioned use of genetic algorithms is described in the next chapter [3].

For the prediction of the behaviour of metallurgical production system we can utilize in the first step data mining. Data mining is a general term for different data analysis methods, usually with AI utilization. The data mining process is based on the originally tableted or otherwise arranged information. Finding of the connections mentioned in those data can be considered as the end; they can be then used as a pattern/sample for the future similar or identical situations [4].

If we take into consideration the technological processes of metallurgical production, either from the operational analysis point of view or just technical point of view, we must mention that the omitted parameters can have an impact in the moment of the changed surroundings in which the systems operate or in the moment of model object's change.

It can be said that these systems construct their database tables and even the whole database system as simple as possible. Data in the tables are stored according to two basic principles, either periodically after a pre-set time interval, or after a certain event - change of a variable value. This, however, leads to redundancy and some kinds of non-consistency of the database.

Solution of this issue would be to store each reference variable in a separate table and to store all necessary values. Analysing these problems may be very complicated. Many systems use their own mechanisms for storing data that combine both periodic data storage and storage management using a change of value. For these reasons these data must be pre-processed before deploying data mining techniques. [2]

### 2.1. Database of the reheating furnace control system

For the rotary heart furnace, the positions of material are stored in different tables. The data from these tables are not consistent at all. Some techniques of data mining pre-processing can be used, how it is described in the following text.

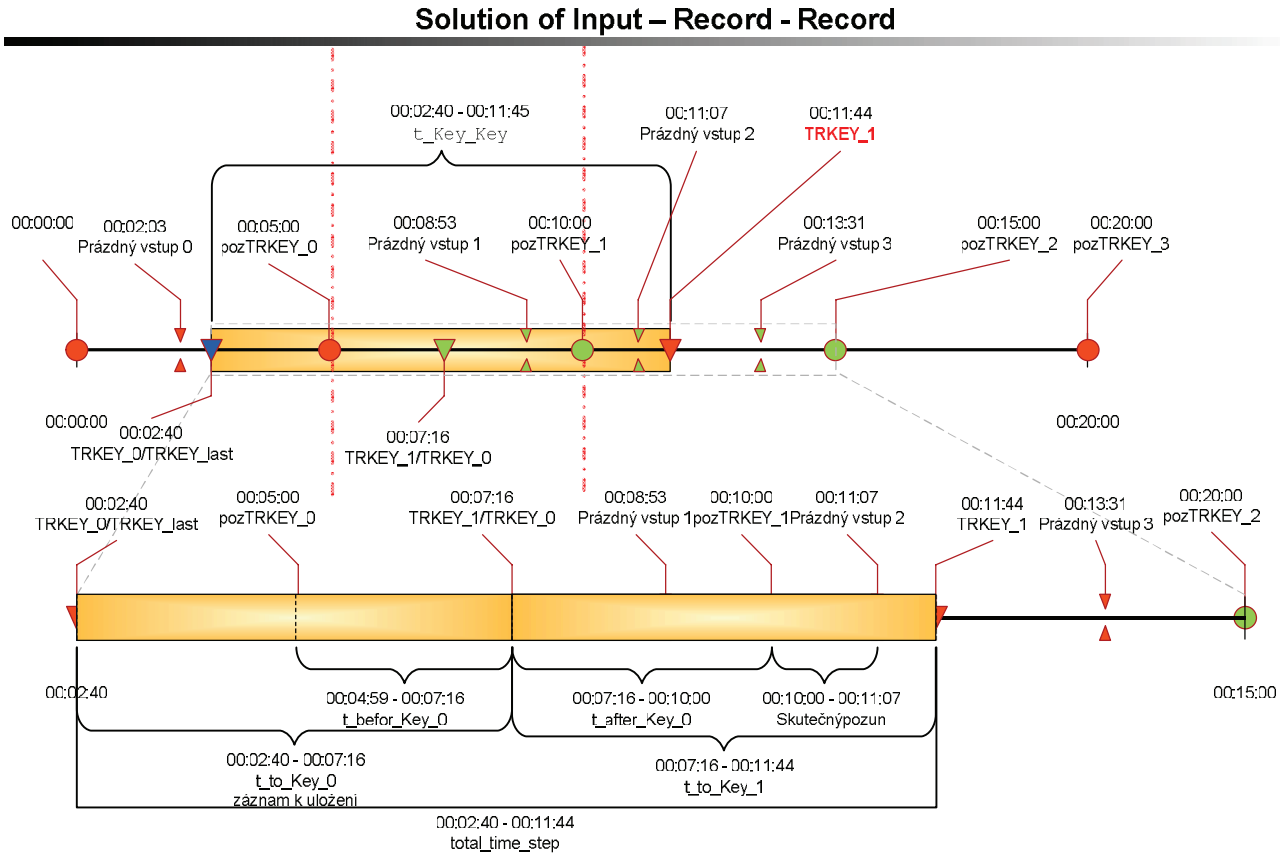


**Figure 1** Timeline of the furnace step. Source: [1]

The record „Position“ keeps the information about current furnace setting; this information is updated each 5 minutes. From those data it is possible to get the information whether any activity in the furnace happened or not. For two following records of bloom positions three possibilities can be identified:

- Movement of material have not happened;
- Material has moved forward;
- Material has moved backward;

The **Figure1** shows the timeline which includes times Position from the record (Position marking milestones round). Moments of furnace rotation (double arrows labelled Empty input) are not part of any record; they can be only assessed from the Position record. A simple triangle is a record entry from record Billets (labelled Input).

## 3. THE USE OF GENETIC ALGORITHMS

Genetic algorithms (GAs) are a powerful search algorithms that performs an exploration of the search space that evolves in analogy to the evolution in nature. The power of GAs consists in only needing objective function evaluations. So derivatives or other auxiliary knowledge are not used. Instead probabilistic transition rules of deterministic rules, and handle a population of candidate solutions (called individuals or chromosomes) that evolves iteratively are used. Each iteration of the algorithm is called generation. The evolution of the species is simulated through a fitness function and some genetic operators such as reproduction, crossover and mutation [5].

The fittest individuals will survive generation after generation while also reproducing and generating offspring's that might be stronger and stronger. At the same time, the weakest individuals disappear from each generation. Individuals must be encoded in some alphabet, like binary strings, real numbers, and vectors and other. In a practical application of genetic algorithms, a population pool of chromosomes has to be installed and they can be randomly set initially. In each cycle of genetic evolution, a subsequent generation is created from the chromosomes in the current population. The cycle of evolution is repeated until a termination criterion is reached. The number of evolution cycles, or a predefined fitness value can set this criterion.

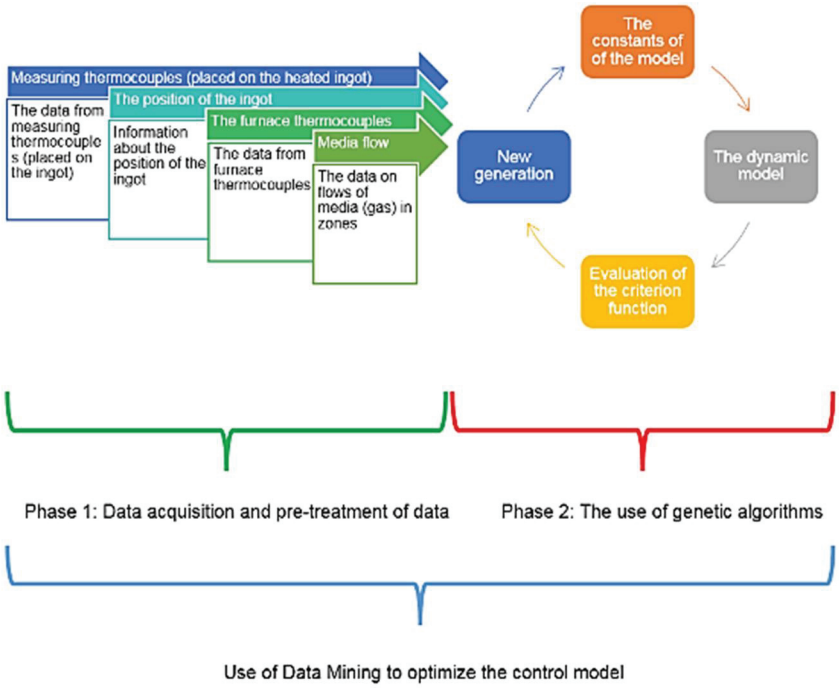


**Figure 2** Data preparation and application of genetic algorithms. Source: (own)

The principle of genetic algorithms is that in the initial phase is generated a default population (generation), each individual of this population is characterized by a specific combination of genes that determine ultimately behavior of examined model. They can therefore be considered as parameters of a general criterion function, which is later used to select the individuals of appropriate generation. Choosing the most appropriate individuals within the meaning of criterion values through crossbreeding methods, respectively mutation, creates a new generation containing the same number of individuals, but with modified genes. These in turn are used to evaluate the criterion function and the process is repeated until the setpoint of the behaviour of the objective function (model) is reached. This shows the cycle on the right side of the figure (see left side of the **Figure 2**) [5].

The result (using genetic algorithms) is the determination of constants which specify the direct contribution of heat generated by combustion of the heating medium and the contribution, which forms a heat transfer between the furnace lining and the heated contislab. This part was solved using genetic algorithms, but without the application of the principles of data mining would genetic algorithms be unable to assign the input data correctly at appropriate times to input the selected dynamic model.

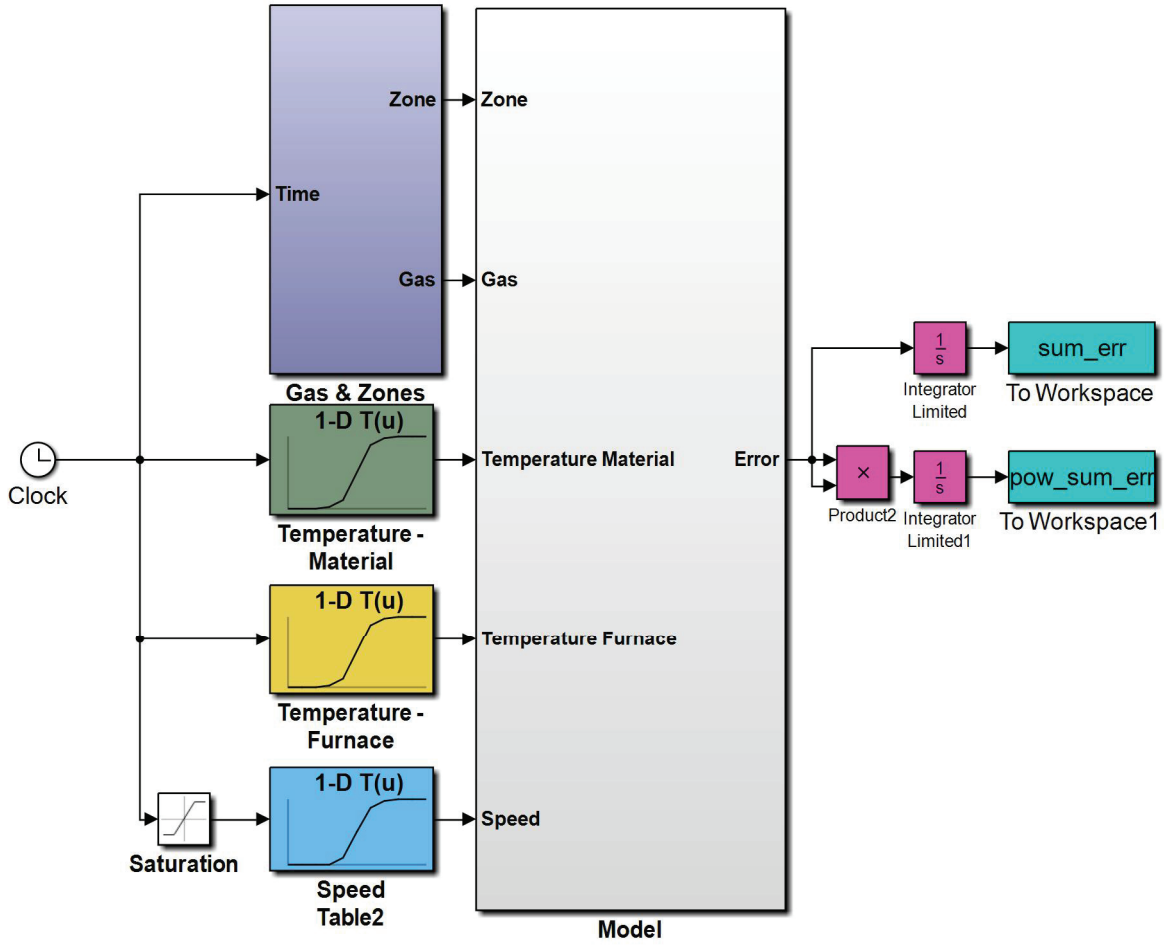


**Figure 3** The structure of model of heating in a heating furnace. Source: (own)

Selected data (see **Figure 3**) about the flows of combustion media in each zone are computed in the block named gas and zones. Furnace temperature is read from table temperature furnace and in block model is compared with temperature of material and the difference between these two values are putted on the port labelled error. From this value are computed square roots and integrated during the whole simulating time. At the end of this simulation the value is stored into the variable named pow_sum_err.

This value means the value of criterion function for next usage in genetic algorithm program. Parameters for block model are set by genetic algorithm. In generally the block model implement the system for solving the heat transfer between the furnace atmosphere and the heated material, the heat generated by combustion of gas and the heated material, and finally transmission determining relation between the quantity of gas in the zone and usable heat [6].

Criterion function is determined as the sum of squared deviations between the modelled temperature of the heated material and the actual measured temperature.

**Figure 4** shows the result which was obtained by procedures outlined above, the curve 5 was obtained by data mining methods. The temperature from the individual thermocouples in the furnace was converted to temperature of furnace environment above the appropriate contislab.

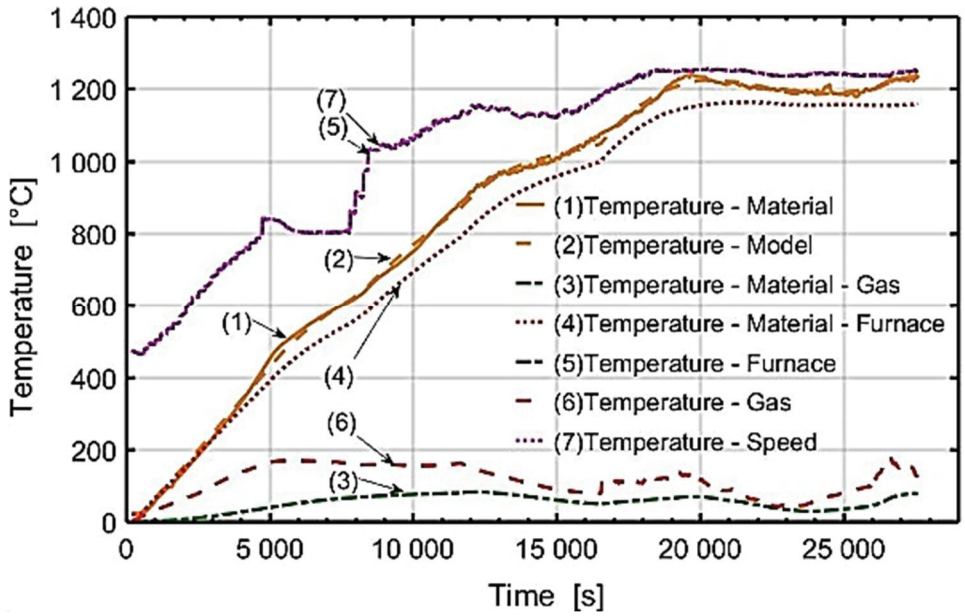


**Figure 4** The temperature curve. Source: [7]

At the time of 20 000 - 25 000 seconds, the temperature at the thermocouple of the contislab is decreasing even when the temperature of the furnace environment above the contislab was almost constant. Therefore, using genetic algorithms sets the parameters of the model, which takes into into consideration not only the temperature of the furnace environment, but also the contribution resulting from the burning of gas in the zone.

## 4. METHODOLOGY OF SIMULATION AND SEARCH MODEL PARAMETERS

To verify the operation of heating furnaces it is very suitable to measure directly on the heated material that is placed in a heating furnace. In the case of the furnace, where the material is shifted on the growth of the furnace, the situation is complicated and measuring is arduous. Therefore, it is usually necessary to think over the location of sensors in the material carefully. The disadvantage is generally spot measurements of the temperature field and it should be counted as a direct and an inverse method for unsteady conduction of heat.

The solution is based on three consecutive steps:

1) Formulation of the dynamic model:
   a. model, which includes only the impact of the furnace temperature,
   b. model that reflects the influence of temperature and of also of heating system of the furnace,
   c. model which in addition also considers the influence of the correction on the speed of movement of the material in the furnace.

2) Use of genetic algorithms to search for parameters of the model.
3) Iterative calculations of the temperature field of the heated ingot by using the corrected temperature of the furnace atmosphere using a dynamic model with pre-set parameters.

In our case, we know the temperature of the body surface, but only at selected points, and the ambient temperature as a time function. Neither is it purely direct one nor purely inverse heat conduction problem. It would be a direct role with appropriate initial conditions in case the temperature field T = f (t, x) on the body surface was described as a function of time and spatial data x f points on the body surface. If we determine the missing parameter of the boundary task, it means an overall heat transfer coefficient, then it is certainly an inverse role. So, if we determine the temperature field in the body on the basis of surface temperature we will deal with the direct task of heat conduction.

To summarize the previous thoughts then, provided we know the initial conditions of the solution, we are able to deal with both a heat conduction problem and an estimation of the global coefficient of the heat transfer from the body to the surroundings by iterative methods, a combination of direct and inverse task of heat convection.

## 5. CONCLUSIONS

The general intention of this paper is to show the possibility of the means of business intelligence, in this case data mining tools and genetic algorithms, in the practical usage, connected with metallurgical production - especially for the control of heating furnace. As the other partial result of this article the fact that in the data mining process one of the most important phases the data preparing for the following processes can be considered. It seems that the simple data filtration only on the basis of certain interval of data validity will bring the expected effect not in all cases. In those events it looks the heuristic models creation as helpful. The expectations are to develop the theses about the available tools as much as possible, to get maximum exploitation and results for their later universal and practical using in the metallurgical processes [9].

From **Figure 3** is evident that offsetting the influence of the current input of the zone progress simulated and measured temperatures are nearly identical. From the results of modelling can be concluded that the concept of combining data mining operational data and use of genetic algorithms for adjusting parameters of the model, which in this case have been 28, brought the expected result. In the future it may be expected that this procedure will be applied to other technologies and their models, in order to create their digital models so that they can be used for subsequent optimization problem with varying the outlined criterion functions [8]. These planned activities should also lead to the fulfilment of certain parts of the program Industry 4.0 in the area of creating a "digital enterprise".

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