THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX, METALLURGY AND MATERIALS SCIENCE
N°. 2 - 2018, ISSN 1453-083X

MATHEMATICAL MODEL FOR THE OPTIMIZATION OF PREPARATION AND DELIVERY FLOWS AT LBC ADJUSTMENT

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ABSTRACT

In the paper, the mathematical model of the sheet metal rolls handling process was realized in the LBC Adjustment section of Arcelor Mittal S.A. Galati. Mathematical modeling is performed by statistical methods, namely active regression analysis.

The modeling methods by experiment programming are very different because metallurgical processes are varied and complex.

We considered as the main influencing factors (the independent variables) the following parameters of the studied process:

1 - the number of rolls - n (number of rolled steel strips / entered in the section for 8 hours);

2 - the number of cranes - m (number of cranes / conveyor bridges from the LBC fitting section).

For the problem to be solved, the optimized function must have a physical meaning, be numerically expressed and show extreme values.

The objective function for optimizing the flow of rolled steel strips preparation and delivery from the LBC Adjustment section is represented by the storage space with some restrictions.

The best value for the objective function is found out by determining some values for the independent process variables, for which the conditions for obtaining some values imposed on dependent variables on minimum energy consumption Q are met.

KEYWORDS: mathematical modeling, optimization, rolls, storage space

1. Introduction

A basic tool useful both in the conception phase and in the analysis of the processes and operation of the installations is modeling. Determining the optimum for a metallurgical process is the result of combining mathematical modeling with the use of computers by using specialized programs [1].

The development of the specific mathematical apparatus and of the statistical methods has enabled the optimal decision-making issue to be tackled on the one hand as a problem of technical efficiency and, on the other hand, as a problem of high economic efficiency [2].

Mathematical models can be used to reveal optimal conditions, and as an important source of information necessary for optimal management of metallurgical processes [3].

This paper aims to combine the practice of optimization of metallurgical processes with the general techniques for solving extreme problems. All stages of an optimization calculation, from problem formulation to surface response research, are performed to determine optimal conditions in multifactor space [3].

The statistical methods for mathematical modeling suffer two important stages: the first stage, called the preliminary experiment, solves a series of problems mainly related to the selection of process factors and the interactions that may occur, the second stage called the experiment where the model is the real modeling and the statistical analysis of the model [4].

The variation of process factors is appreciated in the preliminary experiment by performing a series of program-based determinations (dispersion analysis, correlation analysis, etc.) that allows the selection of factors that significantly influence and highlights the links between the factors and their contribution to the process [3].

2. Elaboration of the mathematical model of the sheet metal roll handling process in the LBC Adjustment section of Arcelor Mittal S.A. Galati

By using the active experiment, statistical methods are used at all stages of experimental research:

• before the experiment, by determining the number of experiences and the conditions for their realization;

• during the development of the experience by processing the obtained results;

• after the experiment ends with conclusions about future experiences.

The wording of the problem is the first step in solving it. Therefore, there needs to be a precise and clear formulation of the purpose of the work. For the problem to be solved, the optimized function must have a physical meaning, be numerically expressed and show extreme values [4].

Determining factors of influence i.e. independent variables is of great importance in solving optimization problems with experiment programming. Determining the optimal conditions may lose its meaning if one of the factors whose influence on the optimization parameter can be determined is neglected [3].

We considered the main factors influencing (the independent variables) the following parameters of the studied process:

1 - the number of rolls - n (number of rolled steel strips / entered in the section for 8 hours);

2 - the number of cranes - m (number of cranes / conveyor bridges from the LBC fitting section).

Table 1 shows the correspondence between the different levels of the factors expressed in natural values with those expressed in coded values for the two factors used in the studied process.

Table 1. *Correspondence between factor values expressed in natural units and coded units*

Factor	Number of rolls		Number of cranes	
	Natural units, in no. of rolls	**Stock coded**	**Natural units, in no. of cranes**	**Coded values**
Base level	n = 65	$\frac{65-65}{5}=0$	m = 2	$2-2=0$
Interval of variation	$\Delta u_1 = 40$	0	$\Delta u_2 = 8$	0
Higher level	n = 70	$\frac{70-65}{5}=+1$	m = 3	3-2 =1
Lower level	n = 60	$\frac{60-65}{5}=-1$	m = 1	1-2 = -1

For the coded representation of the experiment, the following notations and symbols were used:

Independent variables:

• x_1 - the number of rolls for delivery;

• x_2 - the number of cranes;

Between the natural and the coded values of the factors xi, the following relations exist:

$$x_1 = \frac{n-65}{5}; \quad x_2 = m-2; \qquad (1)$$

Yi values are expressed in natural units. The Yi values for the studied process represent the area occupied by the n rolls in the LBC Adjustment section.

Since the influence of the two factors on the performance of the process (Y) is studied, the experimental matrix shown in Table 2 was performed.

Further, based on the matrix of the complete factorial experiment, the coefficients of the regression equation (the mathematical model) are calculated.

Considering the function Yi as the analytical expression of the first order model, it is of the form [4]:

$$Y_i = c_0 + \sum_{i=1}^{3} c_i \cdot x_i + \sum_{\substack{i=1 \\ j=1 \\ i \neq j}}^{3} c_{ij} x_i x_j \qquad (2)$$

***Table 2.** Experimental matrix of space occupied by rolls*

Nr. Exp.	x_0	x_1	x_2	x_{12}	Y
1	1	1	1	1	191
2	1	1	-1	-1	178
3	1	-1	1	-1	163
4	1	-1	-1	1	136

Equation (2) is written in matrix form as follows:

$$Y = X \cdot C \qquad (3)$$

where: X is the matrix of experimental condition.

$$X = \begin{Vmatrix} x_{01} & x_{11} & x_{21} & \cdots & x_{m1} \\ x_{02} & x_{12} & x_{22} & \cdots & x_{m2} \\ x_{03} & x_{13} & x_{23} & \cdots & x_{m3} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{0n} & x_{1n} & x_{2n} & \cdots & x_{mn} \end{Vmatrix} \qquad (4)$$

n- the number of rolls;
m- number of cranes;
C - the column vector of coefficients ci;
C = [c_0, c_1, ..., c_n] T;
T - the symbol of matrix transposition;
Y - the experimental results matrix.

$$Y = [Y_1, Y_2, ..., Y_n]^T \qquad (5)$$

wherein: Y = [191, 178, 163, 136]

For the experiments performed, the matrix of the experimental conditions at the upper, lower and the basic level has the following form:

$$X = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \qquad (6)$$

For this case, the linear function (6) has the form:

$$Y = b_0 + b_1 \cdot x_1 + b_2 \cdot x_2 + b_{12} \cdot x_1 \cdot x_2 \qquad (7)$$

Multiplying both terms of the matrix equation with the unit matrix to the left

E = [XT X] -1 × XT, resulting:
C = [XT × X] -1 [XT · Y] (8)

expression representing the relation of computation of the coefficients of the regression equation.

Using the values in Table 2, based on the relation (8), we obtain the coefficients of the order I, presented centrally in Table 3.

***Table 3.** Coefficient values of the first order models*

Y_i \ c_i	Y
b_0	668
b_1	70
b_2	44
b_{12}	-14

Therefore, the equation of the first order mathematical model (8) has the form:

Y = 668 + 70x_1 + 44x_2-14x_1 x_2 (9)

By replacing the variables xi with the relations (1) in the equation above we obtain the following equation:

$$Y = -694 + 12.6 \cdot n + 200 \cdot m - 2.8 \cdot n \cdot m \qquad (10)$$

Interpreting the equation (10) shows that the greatest influence on the space occupied by the rolls is exercised by the number of cranes.

The next factor as weight of influence is the number of rolls received from the LBC.

Table 4 presents the values measured and estimated by calculation, using the equation of the mathematical model (10), as well as the data necessary to verify the suitability of the model by calculation.

Following calculations to verify the suitability of the model using the Fischer criterion method as well as the significance of the coefficients, it resulted that the first order mathematical model determined corresponds to the experimental data and can be used in the optimization of the sheet metal roll handling process in the Arcellor LBC Adjustment section Mittal SA Galaţi with minimal costs.

Using the MATLAB version 2016 [5] software and based on the mathematical model obtained, a graphical interface for simulation of the surface occupied by sheet metal rolls was created in the LBC Adjustment section. Figure 1 and Figure 2 show a situation where a simulation of the surface occupied by sheet metal rolls is performed in the LBC Adjustment section.

Figure 1 shows the area covered by rolls ready for delivery when all three conveyors have worked for 8 hours. Figure 2 shows the simulation of the situation when only two conveyors are available during the 8 hours of operation.

Table 4. *Table of measured and calculated values for Y*

Nr. crt.	**Y_1 measured m^2**	**Y_1 Calculated m^2**	**Y_1 measured – Y_1 Calculated m^2**	**$(Y_{1măs} – Y_{1calc})^2$ m^2**
1	191	195	4	16
2	178	182	-4	16
3	163	158	5	25
4	136	120	16	256

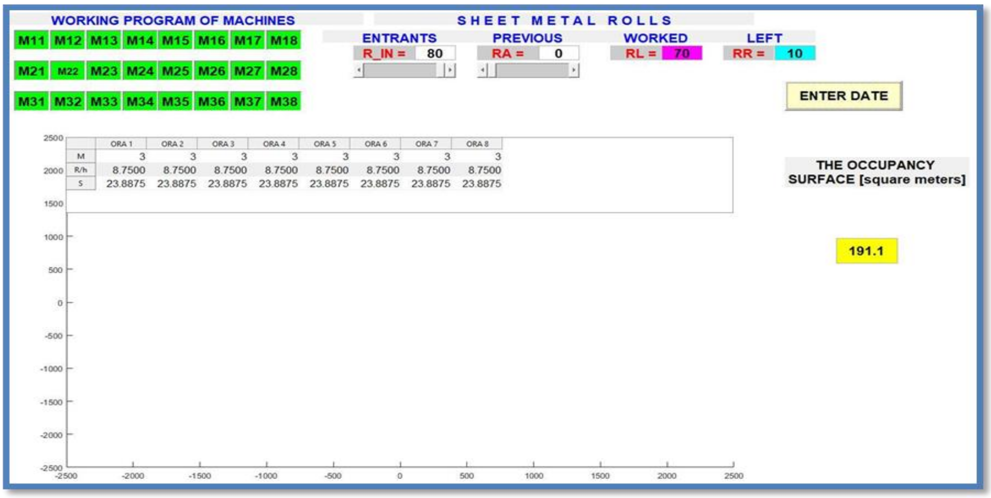

Fig. 1. *Simulation of the area occupied by rolls in the LBC Adjustment section when all three conveyors have worked for 8 hours*

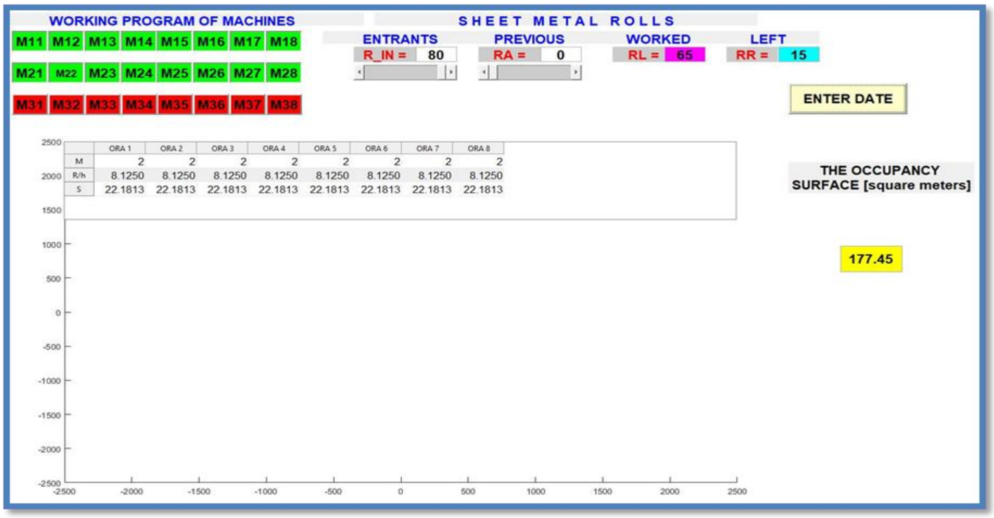

Fig. 2. *Simulation of the area occupied by rolls in the LBC Adjustment section when only two out of the three conveyors have worked for 8 hours*

3. Conclusion

In this paper was achieved the mathematical model of the sheet metal roll handling process in the LBC Adjustment section of Arcelor Mittal S.A. Galati. Mathematical modeling was performed by statistical methods, namely regression analysis by active experiment.

Analyzing the influence of each parameter on the analyzed process, based on the final form of the mathematical model we can say that:

• the greatest influence on the analyzed process is exercised by the term (parameter m) whose coefficient has the highest positive value. This is the number of cranes available.

• the second parameter of the process, namely the number of rolls, has a smaller influence on the process finality because it has a positive coefficient, but which is lower than the other parameter

When the parameter, the number of cranes has a maximum value (m = 3), the area occupied by the number of rolls ready for delivery will be directly proportional to the number of maximum rolls received or entered the process.

When the parameter, the number of rolls has a maximum value (n = 70), the area occupied by the number of rolls is directly proportional to the maximum number of functional cranes in an 8h shift.

The values calculated for the optimized parameter using the mathematical model developed (Y) are very close to the measured values, so the mathematical model presented allows the simulation of the preparation and delivery process rolls at the LBC Adjustment.

Based on the obtained mathematical model, two prediction programs (simulation) of the surface occupied by rollers in the LBC Adjustment section were made using MATLAB software.

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