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# OPTIMIZATION OF HEAT TRANSFER ON DISTRIBUTOR, DEPENDING ON THE THICKNESS OF POWDER COATING USING SURFACE ANSWER METHOD

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**Abstract**: This paper aims are to presenting the experimental design considerations and exposure response surface method with applications in optimization problem of the continuous casting steel process. Research conducted in experimental data processing was performed using dispersion analysis Minitab.v17 software and optimize the heat transfer from the tundish adjustable according to thickness of covering powder was performed using a program developed in MathCAD14, results been presented both analytical and graphical form.
**Keywords**: optimization, response surface, tundish, covering powder, temperature

## 1. INTRODUCTION

Experimental design [1,2] is currently the most modern tool for optimization problems. It contributes to the achievement of important clarifications on the link between variables, parameter estimation connections, and hypothesis testing, different ways to share practice testing, determining the optimal level of controlled variables and model the behavior of the variation factors.

For optimal management processes is necessary to know the characteristics of mathematical models of these processes. Because of the complexity of processes, establish theoretical models, ideal, there is very difficult, sometimes impossible. For this reason, theoretical models of the processes are replaced by empirical models experimentally obtained. Classic, in the experimental research method still used routinely varying successively one parameter. Thus it is considered a parameter that is varied within a chosen area convenient other parameters being held constant. It establishes the connection between it and considered response, identifying the influence of this parameter range is optimal. With the first parameter kept constant at a value of the optimal found it varies in the same way a second parameter, all other parameters being kept constant at baseline. This connection is also established, identifying the optimum influence. The process is repeated for each parameter until finding ties and influence optimal intervals for all parameters in the study of the process considered.

It is obvious that if a larger number of parameters are taking in the study, the method is expensive, time consuming, energy and materials. In addition, contrary to the result, the global optimum is not achieved because of possible interactions between two or more process parameters which cannot be shown in this way. Also, the classical method, which not requires a rigorous statistical processing, does not allow obtaining with maximum accuracy bonds nor verifying the accuracy of these links or improving them.

The purpose of this paper is to remove deficiencies of the classical method by considering the parameters and process responses as variables subject to random errors and use multiple regression and dispersion analysis of variance from mathematical statistics to support obtaining the optimal parameters. Combining multiple regression, analysis of variance and statistical programming experiences resulted modern experimental research method known as response surface method is applied in this work to optimize heat transfer in continuous casting tundish adjustable in function of thickness of covering powder.

## 2. FORMULATION OF OPTIMIZATION PROBLEM

It is considered continuous casting tundish of trapezoidal shape, with an refractory concrete layer 100mm thick and plastering layer (magnesite material) 50mm thick, with base high dimensions of 6700mm respectively 850mm and those of the bottom base of 6400mm respectively 770mm. Tundish height is 1000mm and working height (height metal bath) is 900mm.

We intend to optimize (minimize) the variation of metal bath temperature from the tundish, in function of thickness of covering powder.

The chemical composition of the covering powder is presented in Table 1 [7].

Table 1. Chemical composition of the covering powder

| Material | $SiO_2$ [%] | $Al_2O3$ [%] | $Fe_2O_3$ [%] | C [%] |
|---|---|---|---|---|
| Accutherm T | 37 | 20 | 7 | 19 |

## 3. CONSIDERATION OF RESPONSE SURFACE METHOD

Response surface method [3] considered the relationship between process parameters and its characteristic responses as surfaces in multidimensional space of variables. In experiments conducted by this method, the independent variables are varied simultaneously, taking a limited number of values in the considered experiment domain, called levels. With this method, though more independent variables are varied simultaneously, their main effects and higher order and interaction works of them can be determined separately. Changing independent variables will automatically lead to a output data modification. The results thus obtained can be used to improve performance of a production process.

In general, the mathematical model of a process or its response function considers indicated physical reality functional link between process parameters k as independent variables $x_1, x_2,...x_k$ and its characteristic as the dependent variable or response $h = f(x_1, x_2,...x_k)$.

We define $y$ as the *response* $y = h + e_{exp}$ with $E(y) = h$, and *dispersion* $(y) = s^2$,

where $e_{exp}$ experimental error is usually considered to be a random variable with zero average and $s^2$ dispersion. Assuming that there is a deterministic relationship $f$ between $h$ and $x_1, x_2,...x_k$ one can write:

$$y = f(x_1, x_2,...x_k) + e_{exp} \tag{1}$$

Second order models best approximates the response surfaces and surfaces named regression surfaces, such that:

$$y = \beta_0 + \sum_{j=1}^{q} \beta_j x_j + \sum_{i<j}\sum \beta_{ij} x_i x_j + \sum_{j=1}^{q} \beta_{jj} x_j^2 + e \tag{2}$$

where $\beta_i$ , $\beta_{ii}$ and $\beta_{ij}$ are constant coefficients to be determined, and $e$ it is error.

Considering the case of a process with two parameters $x_1$ and $x_2$ that can be varied within the limits $x_{1a} \le x_1 \le x_{1b}$ and respectively $x_{2a} \le x_2 \le x_{2b}$, the surface from the independent variables plane represent experimental area and $M$ points of this area is, with different pairs of values coordinate $(x_{1i}, x_{2i})$ parameters, represent the experimental points, because physical pair value of the two parameters provide the process development whose response has a certain value $h_M = f(x_{1m}, x_{2m})$ .

The surface on which responses are related to each data point represents the response surface of the characteristic of process considered.

To determine the $\beta$ coefficients of the polynomial model with experimental data, the most appropriate is the method of least squares [4], which provides a minimum dispersion coefficients determined. The method of least squares, Gauss proposed since the early nineteenth century to adjust a function regression of experimental data, is based on the principle of minimizing the sum of squares of differences between variables $h_i$ measured of the response in the corresponding experimental points and corresponding value $y$ calculate using polynomial approximation determined

$$E = \min \sum_{i=1}^{q} (y_i - h_i)^2 \quad (3)$$

## 4. OPTIMIZATION OF HEAT TRANSFER IN THE TUNDISH, ACCORDING TO THE COVERING POWDER THICKNESS USING THE RESPONSE SURFACE METHOD

Experimental data processing was done using analysis of variance Minitab.v17 software and obtained the relation:

$$y = T_0 - T_1 = 87152 - 110{,}8T_s - 8H_p + 0{,}352T_s^2 + 0{,}94H_p^2 + 0{,}008T_sH_p \quad (4)$$

where : $T_0$ – steel temperature from casting ladle at the time to its arrival to the tundish; $T_1$ - steel temperature from tundish, measured after 15min from casting beginning; Hp – the thickness of covering powder; $T_s = T_1$.

The response surface corresponding experimental results is presented in Figure 1.

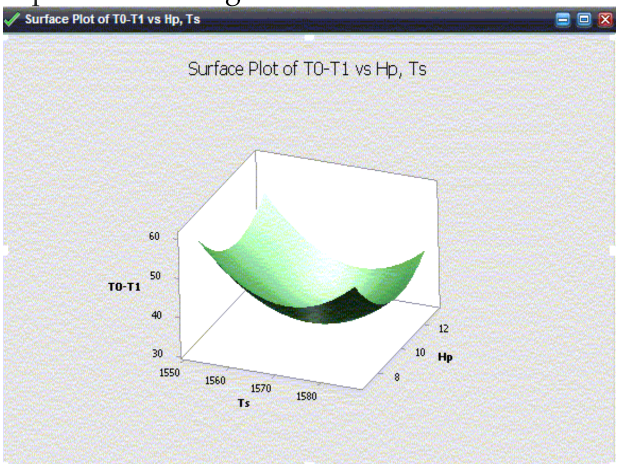


Figure 1. The response surface corresponding experimental results

Table 2. Values of the parameters and values used in the optimization of experimental responses

| No. experiments | $T_0$ [°C] | $T_1$ [°C] | $T_0$-$T_1$ [°C] | $H_p$ [mm] |
|---|---|---|---|---|
| 1. | 1608 | 1562 | 46 | 9 |
| 2. | 1627 | 1587 | 40 | 12 |
| 3. | 1603 | 1565 | 38 | 8 |
| 4. | 1609 | 1552 | 57 | 8 |
| 5. | 1622 | 1581 | 41 | 13 |
| 6. | 1618 | 1568 | 50 | 7 |
| 7. | 1606 | 1562 | 54 | 8 |
| 8. | 1617 | 1570 | 47 | 7 |
| 9. | 1609 | 1567 | 42 | 8 |
| 10. | 1596 | 1554 | 42 | 9 |
| 11. | 1609 | 1572 | 37 | 8 |
| 12. | 1632 | 1584 | 48 | 8 |
| 13. | 1615 | 1573 | 42 | 7 |

Optimum temperature difference $T_0$-$T_1$ that minimizes the response surface is determined by using the following program achieved in MathCAD14 (Figure 2)

$$f(Ts, Hp) := 35.31 - 11.36 \cdot Ts - 4.17 \cdot Hp + 17.06 \cdot Ts^2 + 8.46 \cdot Hp^2 - 0.5 \cdot Ts \cdot Hp$$

$$Ts := 1570$$

$$Hp := 10$$

Given

$$7.5 \le Hp \le 12.5$$

$$1560 \le Ts \le 1580$$

$$Optim := Minimize(f, Ts, Hp) = \begin{pmatrix} 1.56 \times 10^3 \\ 12.5 \end{pmatrix}$$

$$Tsoptim := Optim_0 = 1.56 \times 10^3$$

$$Hpoptim := Optim_1 = 12.5$$

Figure 2. MathCAD14

$$Tsoptim := Optim_0 = 1.56 \times 10^3$$

$$Hpoptim := Optim_1 = 12.5$$

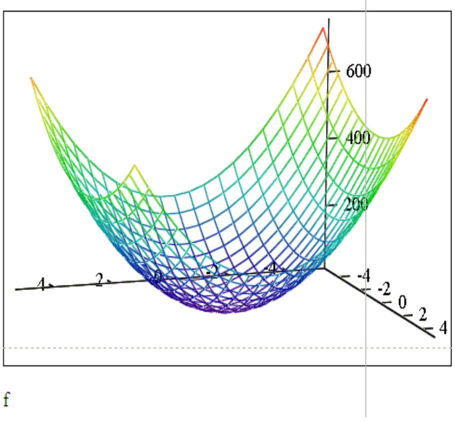


Figure 3. Resulting optimal parameters

Resulting optimal parameters $T_{soptim}$=1560°C and $H_{poptim}$=12.5mm (Figure 3) for which the temperature difference is minimal.

## 5. FINAL RESULTS AND CONCLUSIONS

Using the response surface method was performed an optimization of heat transfer in the tundish, in function of thickness of covering powder coating layer.

The response surface method ensures obtaining the desired final element (optimal model) without errors and also in a lower computation time, independent of hardware resources that make processing data's.

To obtain experimental results in the observations of established design centered, the response surface coefficients were calculated by analysis of variance using Minitab v.17 software and minimize surface response parameters were calculated using a program developed in MathCAD14.

This paper wants to emphasize the importance of experimental design used for optimization problems.

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