THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALATI
FASCICLE III, 2022, VOL. 45, NO. 1, ISSN 2344-4738, ISSN-L 1221-454X
ELECTROTECHNICS, ELECTRONICS, AUTOMATIC CONTROL, INFORMATICS
Article DOI: https://doi.org/10.35219/eeaci.2022.2.03

OPTIMIZATION OF AUTOMATIC SPEED CONTROL OF SINTER MACHINE DEPENDING ON SEASON

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Abstract: The paper presents the improvement of the mathematical model that regulates automatic speed control algorithm based on the temperature variation along the sintering bed. Because the sintering process involve complex chemical reaction of the raw material, the environmental condition are important and the algorithm was improved by adding new coefficients extracted from two time periods data-sets. Anyway, because the implementation is possible to be done when the entire process is stopped and sintering machine is on hold, an estimators parameters was proposed to be implemented two times per year, as winter and summer parameters.

Keywords: mathematical modeling, sintering, automation, metallurgy

1. INTRODUCTION

In Steel Plant with Blast Furnace (BF) technologies, the Sinter machine helps to produce around 80% of iron charge for the BF (*steel.gov.in). Sintering process means bringing to a temperature close to melting points, around 1200 Celsius, of the raw materials that lead to a caking of the materials used as fuel for BF (**ec.europa.eu). The sinter process and the components of Sinter Plant are schematically represented in the Fig1.

The most popular conveyor system in steel industry is Dwight Lloyd machine and the sinter is prepared in a constant way (Ruben Usamentiaga, et al., 2013). In manual operation, it is difficult to control the process, due to the BTP (Burning Thru Point), which is more difficult to estimate. As a result, the entire process has much more fluctuations and parameters are not stable, and this has a direct impact in productivity and sinter quality (Xiaohui Fan, et. al., 2010). For this reason, automatic operation is preferable and a mathematical model based on BTP analysis was implemented. After 1 year of operation using this previous mathematical model, an important conclusion was drawn, based on detailed analysis regarding quality of sinter, productivity, different providers of the raw materials used in the process and external parameters. Based on this analysis, the model coefficients were adapted, and the corrected coefficients were included in a new mathematical model. Hence, the automatic control of the conveyor speed has been improved by taking into account the difference between the summer and winter seasons.

The paper presents the improvement of the mathematical model which implements the algorithm for automatic control of conveyor speed based on the temperature variation along the sintering bed. The algorithm was improved by adding new coefficients extracted from two time periods of data-sets.

The paper is organized as follows. In section2, mathematical models are presented, for initial and adapted model. The model simulations are indicated in section 3. Conclusions are pointed out in section 4.

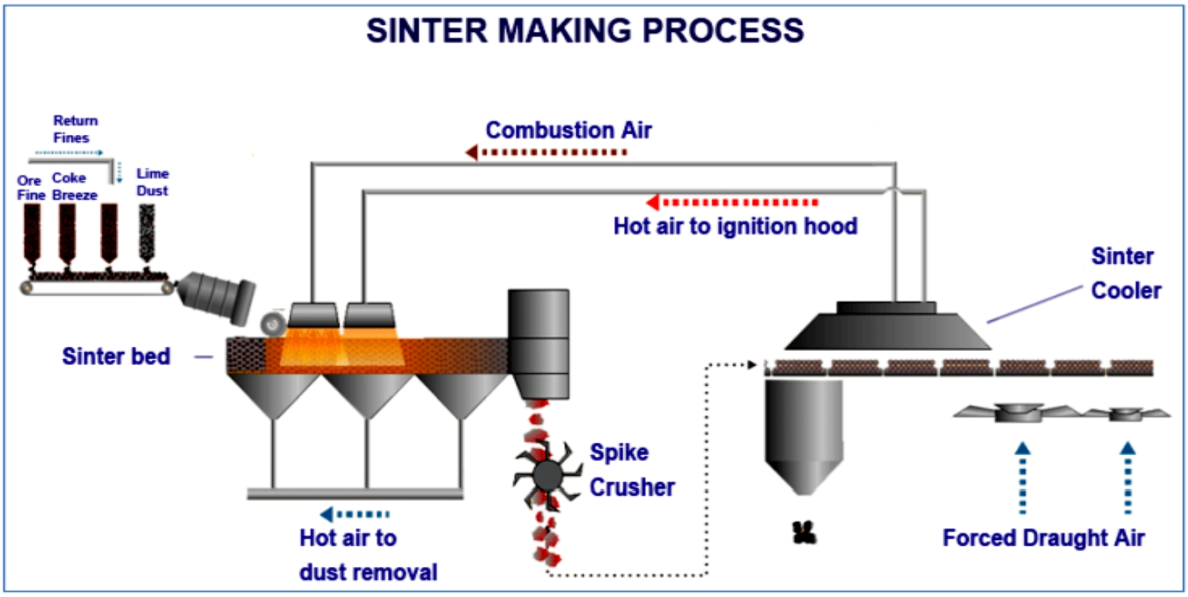

Fig1. Schematic diagram of sinter process

2. PREVIOUS MODEL AND BASE DEFINITION

The BTP is defined as the point at which the residual gas temperature reaches the highest value (Răducan et al., 2020) and the prediction of BTP can be done by integrate the measured temperatures points along the sintering bed, in absence of Gas Analyzer equipment.

The sintering process is a complex one that includes chemical reactions of the raw materials due to the temperature rise that is practically regulated by changing the speed of the sintering bed. Practically, the automation of this process has two main components:

- Transformation of raw material in sinter to feed the BF
- To avoid the occurrence the safety problems that may appear during operation if the temperature rise excessive and risk of fire on the line can appear

The sintering zones are schematically represented on the Fig 2.

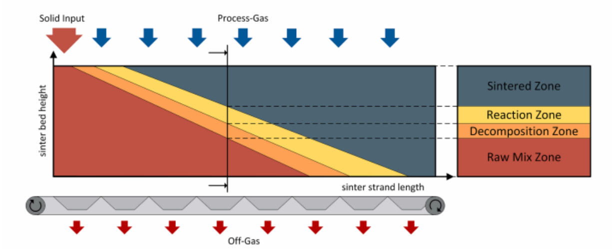

Fig 2. Sintering zone (Johannes, et al., 2022)

The previous mathematical model was described by Răducan et. al. in "Aspects of modeling and speed control of belt conveyors in sintering processes". In modeling process was used 1 month real data and Maple software to find the equation suitable to control the speed of the sinter machine

The difference between manual operation and automatic operation, according to Răducan et. al., was significant and the model was implemented in the local PLC (Programmable Logic Control) to control the process (Răducan et. al., 2020). Also, the need of mathematical model correction from winter to summer was specify, due to the important difference between external conditions as temperatures and level of humidity.

The sinter bed where the mathematical model was implemented can be found in the picture here below.

Fig 3. Sinter bed

3. MODEL SIMULATION WITH TWO PERIODS OF DATA

After more tests and continuous operation of the mathematical algorithm implemented to sinter machine, it was proposed to update the algorithm and made the correction for summer operation and winter operation.

Sintering being a complex process, the degree of humidity and the atmospheric temperature has a great influence in burning time of raw material, means that the sintering bed need velocity need to be adapted taking into consideration at least the external temperature.

In general, sinter machine components include wind boxes that exhaust the gases and air from the combustion layer. The BTP can be estimate to be between two neighboring winds boxes with the maximum temperature rise.

This estimation is the only possible if the gas analyzer is not available or simply, cannot be installed due to the configuration and difficult access in that location of the equipment. For a better exemplification a representative figure with BTP estimated between wind box 13 and wind box 15 it is shown in figure 4.

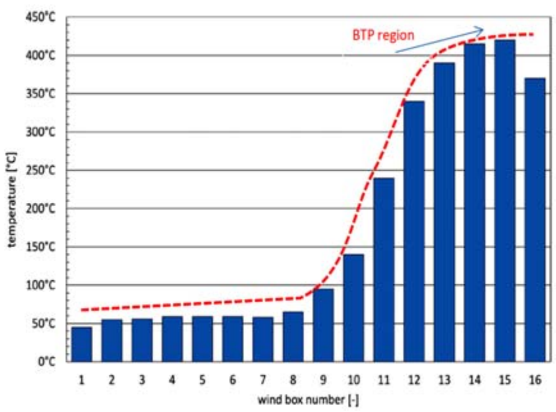

Fig 4. Sinter bed (Johannes, et. al., 2022)

In this study two different periods of data was collected for winter period and summer period, three month each. The distributions of mean temperature per each wind box are highlighted in the figures here below.

From Fig 5 and Fig 6 it can be observed that in summer the sinter bed reach a maximum temperature earlier (box 25) than in winter period (box 29). This means that the mathematical model needs to be adapted with different coefficients for different external condition because this difference has a direct impact in quality of material supplied to BF.

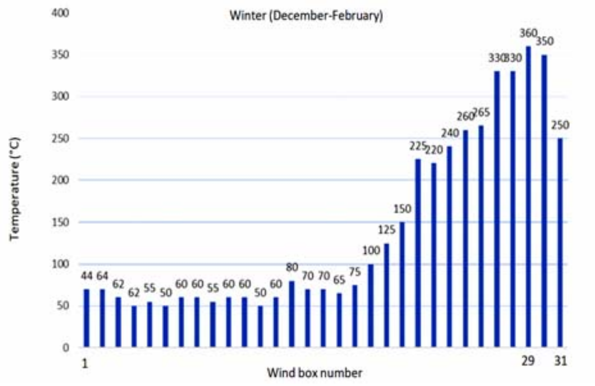

Fig 5. Mean temperature per each wind box in winter

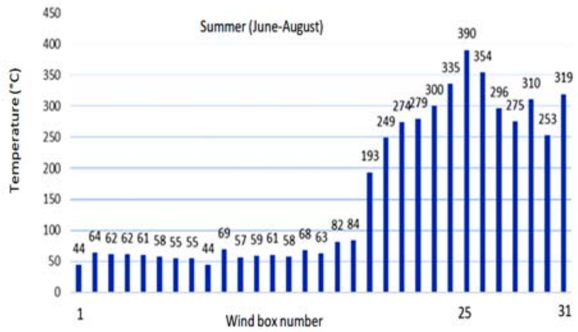

Fig 6. Mean temperature per each wind box in summer

To adapt the model it was used Maple software and Lagrange interpolation function with the new data-sets, as follow:

- Declaration of Lagrange polynomial

```
> polynom_Lagrange := proc (k, x_m, x)
local l_x, i, j, l_j;
 l_x := 0;
 for i from 0 to k do
 l_j := x_m[2, i];
for j from 0 to i-1 do
 l_j := l_j*(x-x_m[1, j])/(x_m[1, i]-x_m[1, j])
end do;
for j from i+1 to k do
l_j := l_j*(x-x_m[1, j])/(x_m[1, i]-x_m[1, j])
end do;
l_x := l_x+l_j end do;
 RETURN(l_x)
end proc
```

- To declare 31 functions for each wind boxes where temperature are recorded by thermocouples, and correlated with the new data-sets.

- Create the vector for Lagrange polynomial interpolation
  > x1 := array(0 .. 30, [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31])

- Read new data-set

```
values_tabel := proc (f, n, x)
local x_y, i; x_y := array(1 .. 2, 0 .. n);
for i from 0 to n do
x_y[1, i] := evalf(x[i]);
x_y[2, i] := evalf(f(x[i]))
end do;
RETURN(x_y) end proc
```

- Calculate Lagrange polynomial

```
> evalf[2](expand(polynom_Lagrange(30, x_m1, x), x))
```

- The results of simulation are, in Fig. 7 for winter data-set, and in Fig 8. for summer data-set.

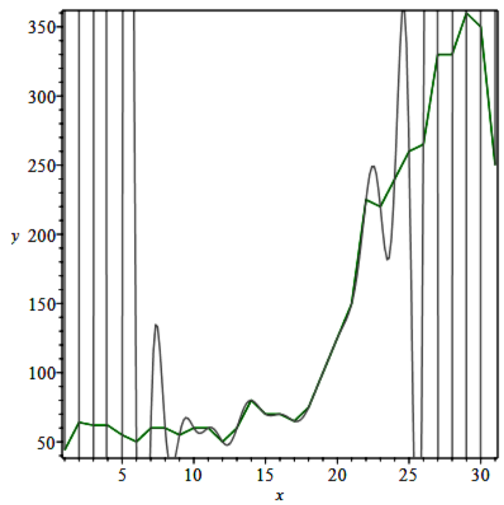

Fig.7 Maple simulation results for winter data-set

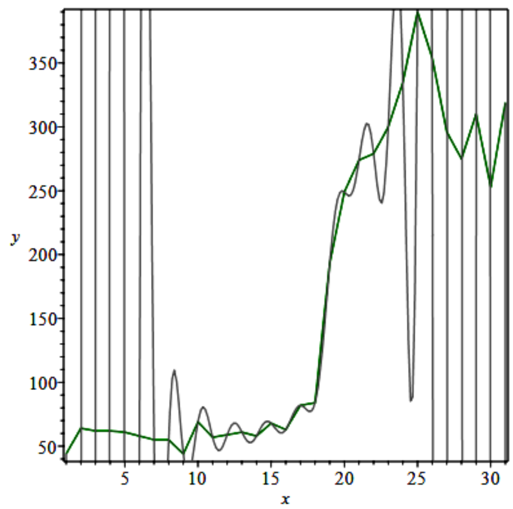

Fig. 8 Maple simulation results for summer data-set

- Calculate the solution for Lagrange polynomial and estimate the BTP for each period.

For winter and summer data-set the software returns the equation with the following coefficients:

- winter

(1)

$$g := 8.958333333x^3 - 758.1250000x^2 + 21370.41667x - 200325.0001$$

- summer

(2)

$$g := -3.500000000x^3 + 247.0000000x^2 - 5774.500000x + 45035.00000$$

The new ecuation was introduced in the PLC that control the siter machine velocity and the results can be examined in the next figure.

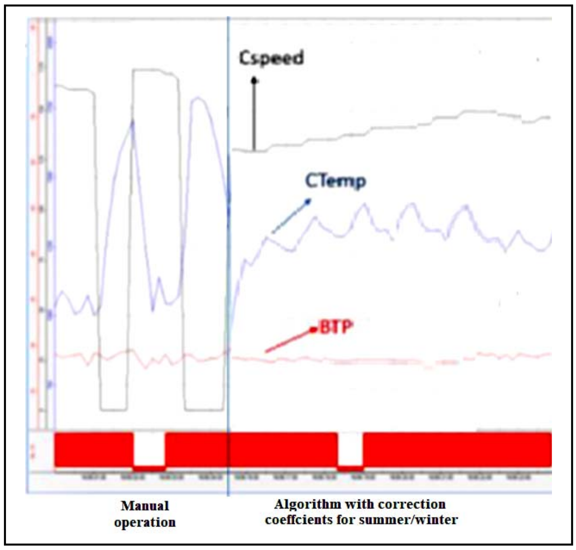

Fig 9. Monitoring system results for the manual operation and mathematical model with correction coefficients

The notation in Fig 9 are:

- Cspeed – velocity of sinter bed
- CTemp – temperature from wind boxe
- BTP – Burn Through Point

4. CONCLUSIONS

Following the results from simulations, the mathematical model was converted in the PLC script and the speed of the sinter machine is controlled with the new coefficients. The velocity of the sinter bed is automatically changed according to the recorded temperature from the wind boxes.

The external temperature, humidity and pressure can have a great impact on the sintering process through process efficiency and production costs of the final raw material for the BF. Between summer and winter there can be temperature difference of 50 degree Celsius and of course the sinter machine speed needs to be adapted.

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