Probabilistic model simulation in cement process fabrication at Casial Factory

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ABSTRACT: This paper will propose to investigate results obtained from automated measuring process control of temperature in cement fabrication with the simulation modeling by probability distribution functions and conducted at yield goodness of fit results. The simulation’s results enable the comparison with the data obtained by automated real-time project process data which are used in classical analyses of manufacturing process for economical and technical management decision.

KEYWORDS: Distribution, functions, modeling, probability, simulation,

1. INTRODUCTION

Experimental measurements of quantities such as pressure, length, temperature, force will always exhibits some variation if the measurements are repeated a number of times with precise instruments. The data obtained from repeated measurements represents an array of readings, not exact results. A trace-driven process control or simulation using this large data set can be developed, however, there are major drawbacks to such a course of action as the process control or simulation will reproduce solely what has already happened.

2. GENERAL CONSIDERATION ABOUT PROCESS

The Trading Company Casial Deva is concerned with the cement and building materials fabrication, as part of the construction materials industry. In 1998, Casial Company was privatized 51 % of the company’s shares being taken over by the investors of the Lasselsberg Group, Austria and now it is a subsidiary of Heidelberger Zement, Germany.

The clinker represents 80.4% of the cement as a result of the flour (homogenous mixture of limestone, clay and pyrite) partially decarbonizated in the burning installations (kiln furnace). During this phase, specific thermodynamic processes, at a temperature $T_K$ of 1450°C carry out the clinkerization process. The kiln furnace contains the following areas:

I. decarbonization area
II. solid phase reactions area
III. clinkerization area
IV. cooling area

The preheated flour, at a temperature $T_F = 780$-$800°C$, known as the material’s temperature, and partially decarbonized, passes into the kiln furnace during the I-II-III-IV sequence, receiving the heat from the heated gases at $T_G = 1000$-$1050°C$.

The gases go into the heat exchanger, being evacuated at the upper part at the cyclone. Secondary air (7-10%) is pumped into the cooling area (clinker cooler), with a controlled temperature $T_a$. Another input parameter is represented by the coating’s temperature $T_{ma} = 110$-$410°C$, as measure of the heat exchange between inside -outside of the kiln furnace. [Arad]

All these inputs are continuously controlled, aiming to provide a proper output, between the admitted limits, around the clinkerization value. The temperature in the clinkerization area is an output variable $y(t)$ needing to be regulated.
3. PROBABILITY DISTRIBUTION FUNCTION

The problem of collecting and analyzing data confronts all researchers trying to model real world activities. Fitting a statistical distribution to a collecting of sample observations usually approaches the required process inputs for a simulation model.

The Weibull distribution provides a more suitable approach to the statistical analysis of the available data. The Weibull distribution curves are not symmetric, and the distortion in the S-shaped curves is controlled by the Weibull slope parameter $m$.

This distribution function $P(x)$ defined as

$$P(x) = 1 - e^{-((x-x_0)/b)^m}, x < x_0$$

$P(x) = x, x \geq x_0$  

(1)

Where $x_0$, $b$, and $m$ are the three parameters that define this distribution function.

However, to determine the Weibull parameters, $x_0$, $b$, and $m$ requires additional conditioning of the data. [Dally]

4. MATHEMATICAL MODEL AND SIMULATION

The process of the flour burning is a continuous fabrication process with several random variables. In order to determine the process’s model the responses to the pulse or step signals are analyzed. These tasks do not involve only building of the physical model but include the collection and processing of data, numerical regulation, quality improvement of the regulation, optimization and hardware and software implementation. [Landau]

By using an experimental identification technique, it is possible to design a direct identification technology of the dynamic model based on a transfer function. The answer can be simulated on a first degree system according the statistical analysis of the process’s input and output data and the response of the continuous process for an uniraty step input.

The regulation and control of the output parameter, the clinkerization temperature, is essential in order to provide a linear and continuous functioning of the process.

One of the most important aspects of the design and implementation of a regulator is to evaluate the obtained results. It is most important to determine, around a certain temperature, $T_k$, a dynamic model linking the furnace’s temperature with the regulator’s command.

The mathematical model, in time domain, describing the system's activity in dynamic regime, is the one generated by the first grade system I.

The existence of modern calculation systems, enabling high speed calculations as well as the electronic systems of data acquisition allowed the processing of the experimental data, improved the measurements’ precision and created the possibility of developing devices able to generate sampling signals according to a well established program.

The data obtained from monitoring of the output parameter represent a sample of size 20 from an infinite population of all possible measurements that could have made.

By using the proper software TableCurve (TCWin), the temperature’s variation in the furnace, $T_k$, is approximated with a polynomial function (see Figure 1)

$$Y = a + b \ln x + c(\ln x)^2 + d(\ln x)^3$$

(2)

Where, $y$ is temperature of kiln furnace, and $x$ is the time.

The parameters characterizing the statistical distribution of the output vectors were also determined with this software.

Maximum information can be extracted from this sample by employing statistical methods can be readings on Table 1 and 2.

We obtained confidence interval for predictions, Stunent's t and error.

5. RESULTS

The TableCurve (TCWin) software was used to performe statistical analysis of the input data – as a result was obtained the equation (2) simulating the mathematical model of the process’s output parameter. Among the 44 processed equations, the equation presenting the higher correlation coefficient $r^2 = 0.965$ was selected. (see Figure 1, Table 1).

The variation of the output parameter being comparable with the variation of the furnace’s
coating temperature during the heating process (Figure 2). Once the furnace reached the nominal functioning temperature, the furnace’s internal temperature variation, measured by using a pyrometer, showed a slightly variation around the clinkerization temperature. The temperature variation inside the furnace, during 8 hours, for nominal functioning, is shown in Figure 3.

The output parameter varies according to the slightly variation of the other assessed parameters of the process (temperature of second air $T_a$, temperature of gases $T_G$, temperature of material $T_F$ during the three stages of clinkerization).

Table 3 gives a concise overview of the data inputs $T_a$, $T_G$, $T_F$ (during the three stages of clinkerization) and output temperature $T_K$ for each hour of the monitoring period.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
Hour & $T_a$ & $T_G$ & $T_F$ & $T_K$ \\
\hline
0 &  &  &  &  \\
1 &  &  &  &  \\
2 &  &  &  &  \\
3 &  &  &  &  \\
4 &  &  &  &  \\
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23 &  &  &  &  \\
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\end{tabular}
\end{table}

6. CONCLUSIONS

Statistical methods are extremely important in engineering, since they provide a means for representing large amounts of data in a concise form that is easily interpreted and understood. Usually, the data are represented with a statistical distribution function.

The most significant advantage resulting from the use of a probability distribution function in engineering applications is the ability to predict the occurrence of an event based on a relatively small sample. The effects of sampling error are accounted for by placing confidence limits on the predictions and establishing the associated confidence levels.

It is most important to maintain kiln temperature $T_K$ constant and out of any disruptions, due to economical reasons—meaning the reduction of energy consumption.

The versatility of the numerical computers enables the implementation of the automatic estimation algorithms for the parameters of the discrete model describing the flour burning and cement production.

7. REFERENCES


[Table Curve] Table Curve™ Jandel Scientific AISN Software.
Table 1. Statistical parameters of data

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<th>Parm</th>
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Function min X-Value Function max X-Value
-39518.11572 1.674427e-10 1298.7877758 10.809078282

1st Deriv min X-Value 1st Deriv max X-Value
-6.452473662 18.000000000 7.984762e+08 1.800006e-05

2nd Deriv min X-Value 2nd Deriv max X-Value
-2.05863e+13 3.600009e-05 -0.353166056 17.997864766

r2 Coef Det DF Adj r2 Fit Std Err
0.9651324516 0.9558344387 73.106757952

Source Sum of Squares DF Mean Square F-value
Regr 2367012.4 3 789004.14 147.626
Error 85513.569 16 5344.5981 Total 2452526 19

Table 2. Results of confidence intervals for predictions

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Table 3. Data inputs and output temperature process in eight hours.

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Figure 1. Kiln Pyrometer temperature variation and statistical data processed by TCWin