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 1450^0 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 = 780-800^0 C, known as the material's temperature, and partially decarbonizated, passes into the kiln furnace during the I-II-III-IV sequence, receiving the heat from the heated gases at T_G = 1000-1050^0 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} = 110-410^0 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 clinckerization 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 approached 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

$$\begin{aligned} P(x) &= 1 - e^{-[(x-x_0)/b]^m}, x \rangle x_0 \\ P(x) &= x, x \langle x_0 \end{aligned} \tag{1}$$

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 continous 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 continuos functionaing 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 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+blnx+c(lnx)2+d(lnx)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 equaition presenting the higher correlation coeficient r2= 0.965 was selected. (see Figure 1, Table 1).
The variation of the output parametere 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 intarnal temperature variation, measured by using a pyrometer, showed a slightly variation around the clinkerization temparature. The temperature' variation inside the furnace, during 8 hours, for nominal functioning, is shown in Figure 3.
The output parameter varies according the slighlty variation of the other assesed parameters of the process (temperature of seondar air T_a, temperaute 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.

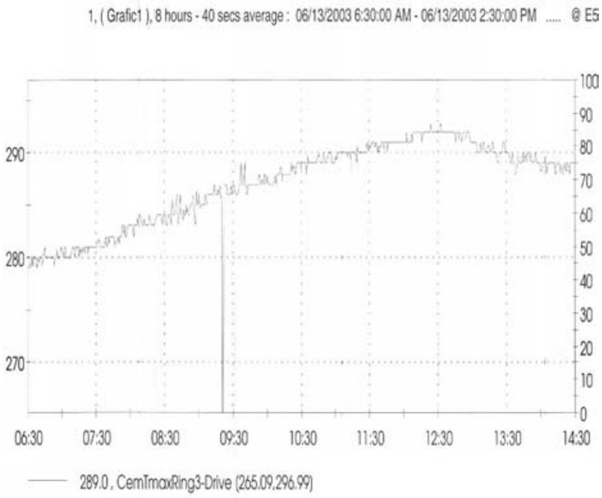

Figure 2. Variation of the coating temperature

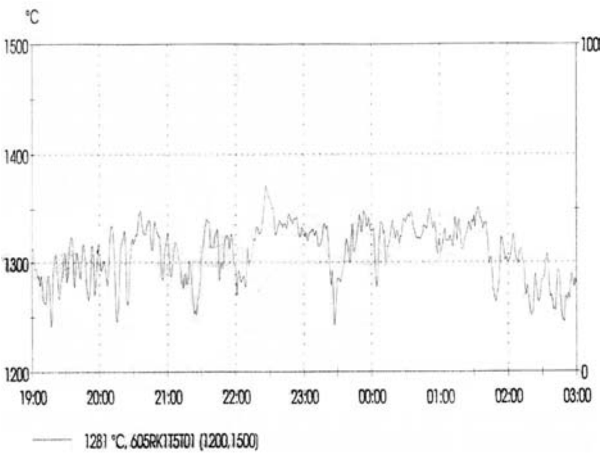

Figure 3. Kiln Pyrometer temperature variation

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 econimical 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

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[Table Curve] Table Curve^{TM} Jandel Scientific AISN Software.

Table 1. Statistical parameters of data

Parm	*Value*	*Std Error*	*t-value*	*99% Confidence Limits*	
a	686.9073826	5.73326678	10.44992005	494.9245309	878.8902343
b	503.5030916	82.55871227	6.09872753	262.3792620	744.6269211
c	-99.0820456	23.61335103	-4.19601798	-168.048015	-30.1160761
d	-1.8704943	0.43449565	-4.30497819	-3.1394973	-0.6014912

Area Xmin-Xmax *Area Precision*
20989.470554 4.895643e-05

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

XY	X Value	Y Value	Y predict	Residual %	Confidence Limits		Prediction Limits	
1	0.00000	0.000003						
2	0.000	50.000						
3	1.0000	729.000	686.907	5.7740	494.924	878.890	399.770	974.043
4	2.0000	923.000	987.681	-7.0077	888.0994.	1087.263	752.083	1223.28
5	3.0000	1083.00	1117.994	3.231291	1030.797	1205.192	887.357	1348.63
6	4.0000	1189.00	1189.510	-0.04293	1104.570	1274.450	959.717	1419.30
7	5.0000	1237.00	1232.815	0.33830	1151.127	1314.503	1004.20	1461.42
8	6.0000	1300.00	1260.211	3.06068	1183.354	1337.067	1337.06	1033.28
9	7.0000	1267.00	1277.716	-0.84578	1206.475	1348.956	1052.62	1502.80
10	8.0000	1296.00	1288.655	0.566715	1222.950	1354.360	1065.25	1512.05
11	9.0000	1315.00	1295.027	1.518849	1233.975	1356.079	1072.95	1517.10
12	10.000	1298.00	1298.108	-0.108057	1240.111	1356.104	1076.85	1519.36
13	11.0001	1395.00	1298.753	6.899405	1241.671	1355.835	1077.73	1519.76
14	2.000	1298.00	1297.557	0.034106	1239.013	1356.101	1076.15	1518.95
15	13.000	1286.00	1294.945	-0.695640	1232.689	1357.202	1072.53	1517.35
16	14.000	1230.00	1291.232	-4.978211	1223.396	1359.068	1067.19	1515.26
17	15.000	1258.00	1286.650	-2.277429	1211.824	1361.475	1060.40	1512.89
18	16.000	1281.00	1281.379	-0.029600	1198.562	1364.195	1052.36	1510.39
19	17.000	1298.00	1275.558	1.728959	1184.068	1367.048	1043.26	1507.85
20	18.000	1247.00	1269.295	-1.787956	1168.680	1369.911	1033.25	1505.33

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

No	T_K [^{0} C]	T_a [^{0} C]	T_{F2} [^{0} C]	T_{G2} [^{0} C]	T_{F3}[^{0} C]	T_{G3}[^{0} C]	T_{F4}[^{0} C]	T_{G4} [^{0} C]
1	1310	960	537	549	7705	722	819	814
2	1320	990	540	552	703	723	817	813
3	1330	940	533	551	908	728	820	815
4	1270	1000	543	557	707	725	819	816
5	1330	1000	537	555	705	727	819	814
6	1335	940	538	550	700	721	820	812
7	1330	920	539	552	710	730	815	813
8	1300	960	540	555	703	725	813	811
9	1280	940	545	553	705	729	818	815

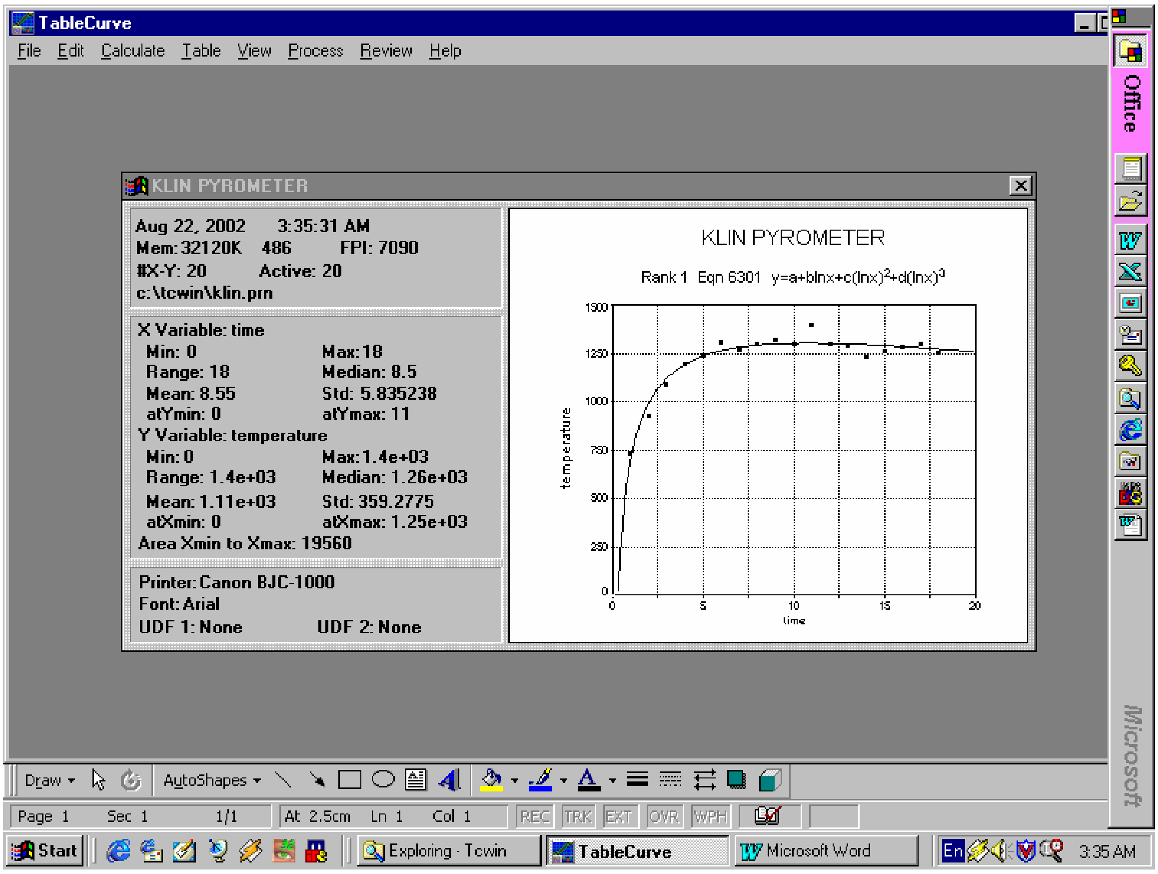

Figure 1. Kiln Pyrometer temperature variation and statistical data processed by TCWin