USE OF EXPERIMENT PLANNING AND ANALYSIS TECHNIQUES FOR DEFINING THE TECHNICAL PARAMETERS OF THE PRESSING PROCESS

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1. INTRODUCTION

This paper presents a case study of the use of experiment planning and analysis for obtaining more precise information concerning two factors that influence products and manufacturing processes, in addition to reducing the number of tests and cost of experimentation. These techniques enable determining acceptable limit values for ceramic process variables, in order to achieve production values that always lie within the specifications, improve product quality in processing, and enhance final product quality. They also allow identifying the process control parameters that give rise to the greatest problems in relation to quality, and allow adjusting these to minimize such problems. In this study, a single-fire floor tile body prepared by wet milling was used to analyse three factors that could influence control parameters in a ceramic tile manufacturing company: powder particle size distribution, moisture content and pressing pressure. These factors were identified by their significant influence on the results of the analysis. Factorial-type experiment planning was used. This yielded 64 tests with three factors and five replicas for each test, involving a total of some 1600 lab tests. The tests verified the behaviour of the studied single-fired floor tiles with regard to bulk density, drying and firing shrinkage, dry and fired mechanical strength, and water absorption. After the tests had been performed with all the 64 samples, the data were statistically processed by multiple regression analysis, which enabled identifying the factors that most affected the results. This allowed concluding that there were two dominant factors in the process. In this phase, particle size was disregarded in the analysis, as its importance (in the range of variability of the company studied) was minor compared with moisture content and pressing pressure. Multiple regression analysis was then rerun, only considering moisture content and pressure. The results of this new regression analysis were then used to construct a table, using the coefficients of the equation of the straight line obtained through regression analysis with just two factors. The specifications set for each analyzed item were applied to this table. This yielded the limit values which assured that results always lay within the specifications. Using these findings, twenty trials were then performed in the production line. The results show that experiment planning is an effective supporting tool in controlling process variables for quality assurance, and that it is a helpful tool in taking decisions for corrective and/or preventive measures that contribute to improving product quality. This is achieved by establishing the required limit values in order to always keep the results within the permissible tolerance.

2. METHODOLOGY

The study was undertaken according to the following stages:

a) Definition of the body. A single fire floor tile body (BIIb) of the studied company was used.

b) Definition of the parameters: The major parameters in the isocompaction curves (moisture, pressure and particle size) were used.

c) Definition of levels. We considered 4 levels for each variable. This enabled adopting a planning with 3 factors, each with 4 levels. A total of 64 experiments was performed. This exaggerated test procedure was only used in order to verify in practice the theory and methodology used.

Level	Moisture (%)	Pressure (kgf/cm^2)	Particle size fractions
-2	4.5	210	Fine
-1	5.6	240	Intermediate
1	6.7	270	STD
2	7.8	300	Coarse

Particle size fractions	Fine (%)	Inter-mediate (%)	STD (%)	Coarse (%)
500 microns	17.64	20.67	22.20	25.20
250 microns	52.36	61.34	65.90	74.80
150 microns	24.90	14.90	8.70	-
75 microns	4.56	2.74	1.60	-
Above 75 microns	0.57	0.34	0.20	-

- The range of variation in the levels of % moisture and particle sizes corresponds to the possible maximum oscillation limits in the production process of the studied company.

d) Definition of the response variables. In this stage we defined the response variables of the experiments:

Bulk density (g/cm^3)	Firing shrinkage (%)	Dry mechanical strength (%)	Fired mechanical strength (%)	Water absorption (%)
Largest possible with least pressure	Less than 3.05	More than 25	More than 230	Less than 10

e) The adopted procedure indicates the use of a 4^3 factorial experiment matrix;

f) Performance of the experiment: The body was prepared using an industrial spray-dried body with moisture variations of 4.5 and 7.8%. The ranges were obtained through subsequent mixtures of the bodies in the laboratory. The particle size variations in the industrial body were determined by sieving. A hydraulic laboratory press (Gabrielli) was used to make the test specimens.

g) Data processing. The data were processed using two software programs: MINITAB and EXCEL. Since the objective of the work was the identification of the significant parameters and the value limits in accordance with the specification, regression models were constructed for each response variable.

h) Data analysis. After data processing, it was possible to identify the most significant parameters and the relation to the response variables (the studied particle size range did not display a great relevance in the analysis of the studied parameters):

Factor	Bulk density	Dry mechanical strength	Fired mechanical strength	Water absorption	Firing shrinkage
Intersection	1.727497954	-1.92282236	96.8135154	15.19226468	3.621415675
Moisture	0.00943911	1.78174651	10.6364903	-0.311043213	-0.070149498
Pressure	0.000708333	0.21699583	0.71883625	-0.034516667	-0.001408333

i) The results obtained have allowed establishing the values of the two process parameters which satisfy the requirements of the project. These values were used in a final trial of 20 tests in the actual production process. The values found are compatible with the values indicated by the study and confirm the use of the methodology for establishing the parameters of the process for the optimization of process/product results. This leads to the final table:

Moisture (%)	Pressure (kgf/cm^2)	Bulk density (g/cm^3)	Firing shrinkage (%)	Dry mechanical strength (kgf/cm^2)	Fired mechanical strength (kgf/cm^2)	Water absorption (%)
6.0 to 6.29	255 to 263	1.874 to 1.879	2.99 to 3.01	36.5 to 37.8	252.4 to 258.2	8.70 to 8.92

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