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Prediction of Moulding Sand Properties Using Multiple Regression Methodology

By

Prof. Rashmi Mishra, Er. Nitin Gupta, Lt. Dr. Durgesh Joshi

Assistant Professor, Department of Mechanical Engineering, Acropolis Technical campus, Near Rala Mandal, Indore - 452020, M.P., India

Asst. Manager, PEB Steel Lloyd I Ltd.,03-B, sector -04, kheda, Pithampur,Indore (M.P.), India

Associate Professor, Department of Industrial and Production Engineering, SGSITS, 23, Park Road, Indore - 452003, M.P., India

rashmimishra_me08@yahoo.co.in , er_nitin22@yahoo.com, djoshi@sgsits.ac.in

ABSTRACT

Optimum formation of the green sand mixture continues to remain a critical problem for the foundry man. In the present work, the research approach start from the study of all possible defects and process parameter selection from various research paper for sand casting process. Out of all available research papers, one was used in the analysis process.

The data so obtained were used to train and test Multiple regression analysis in MINITAB 15 Software for modeling the green sand mould system. In the present work, the five mould properties (GFN, Clay%, Moisture%, Mulling time and Hardness) were fed to the multiple regression analysis as inputs. The Green compressive strength is fed as outputs. Several samples of data were collected; same have been used to carryout the present investigation. The first few samples were used for analysis and the remaining samples were reserved for testing the accuracy of the analysis.

Key Words: Multiple Regression Analysis, Green Compressive Strength.

INTRODUCTION

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced via a sand casting process. Sand Casting is the most important and mostly used casting technique. To perform sand casting we have to form a pattern (a full sized model of the part), enlarged to account for shrinkage and machining allowances in the final casting.

Regression analysis is used to establish relationship between two variables. The response variable *y* is the dependent variable or variable of interest, and the predictor variable *x* is the independent variable. An objective of regression analysis is to develop a regression model, relating *y* to *x* that can be used to predict values of the response variable. The regression was carried out using the MINITAB 15 software.

LITERETURE REVIEW

In this paper Gupta N et. al., (2006) focuses on controlling the important properties of moulds and cores, which can minimize the casting defects, which occurs due to poor ramming of the sand mould, through the design of experiment technique.

This paper is presented by Haq et al., (2008) discuss the use of the Taguchi Method of experimental design in optimizing process parameter for CO_2 casting process. The results revealed that the CO_2 gas, mould hardness no., sand particle size, % of sodium silicate, sand mixing time, pouring time, pouring height, pouring temperature and cooling time of poured metal significantly affect the CO_2 casting process.

Chaing et. al., 2006 presents a systematic methodology to analyze the shrinkage and warpage in an injection-molded part with a thin shell feature during the injection molding process. The systematic experimental design based on the response surface methodology (RSM) is applied to identify the effects of machining parameters on the performance of shrinkage and warpage.

In this paper multi character optimization is done using grey relation analysis based on taguchi method. Raja Babu et al. (2006) used this concept for optimizing the parameter like pressure, time and proportion of sodium silicate considering the multiple characteristics including hardness, green compressive strength, permeability and shatter index.

In this study, response surface (RS) model and an artificial neural network (ANN) are developed to predict surface roughness values error on mold surfaces. In the development of predictive models, cutting parameters of feed, cutting speed, axial–radial depth of cut, and machining tolerance are considered as model variables (Oktem H. et. al., 2005).

Taguchi method of design of experiment and analysis has been adopted to optimize the process parameters and maximum mechanical properties. The investigation has indicated that increase in pouring temperature reduces mechanical properties while increase in die speed increases mechanical properties and density. Thermal conductivity of coating does not have significant effect (Shailesh P. et. al., 2005).

Guharaja S. et. al., (2006) analyses various significant process parameters of the green sand casting process. An attempt has been made to obtain optimal settings of the green sand casting process in order to yield the optimum quality characteristics of the spheroidal graphite (SG) cast iron rigid coupling castings.

Karunakar et al., (2002) used artificial neural networks method for modelling of the cupola furnace parameters. The network could predict the output parameter with about 5 % error.

Nagurbabu et. al., 2007 developed Artificial Neural Network model and a Neuro-Fuzzy model for predicting the properties of clay bonded moulding sand mix. The results of the neuro-fuzzy model were compared with the results obtained from the neural network model. It has been observed that neuro-fuzzy model predicts the properties more accurately as compared to neural network model.

Kumar S. et. al., (2006) implemented DMAIC (Define, Measurement, Analyze, Improve, and Control) based Six Sigma approach to optimize the green sand casting process parameters and have made the process more robust to quality variations. Analysis of various critical process parameters is carried out with the help of Taguchi's method of experimental design. Proposed techniques optimized control factors, resulting in superior quality and stability.

In this work, the effect of machining parameters on the surface roughness is evaluated and optimum machining conditions for maximizing the metal removal rate and minimizing the surface roughness are determined using response surface methodology (Palni kumar K. et al., 2007).

ANALYSIS

Apply Multiple Regression Analysis for Prediction of GCS

The regression analysis for green compressive strength was done using MINITAB 15 software. The multifactor linear regression equation developed is shown in equation 1. In regression equation, X_1 is representing Grain Finess no, X_2 is representing Clay % ,X_3 is representing Moisture %, X_4 is representing Mulling Time and X_5 is representing Hardness where 1.02 is the constant term present in the equation. The standard deviation of random error was found to be S =0.159 and R-Sq of the model was found to be R-Sq = 64.0%. The regression equation is an algebraic representation of the regression line and is used to describe the relationship between the response and predictor variables.

The regression equation for GCS is

$GCS(Y_1)=1.02-0.0327x1+0.0659x2+0.0186x3-0.0151x4+0.0033x5$ eq.......1

The interpretation of the regression equation follows:

1. The slope (b_1=-0.032) is change in GCS when GFN decreases by 1. That is when the GFN decreases by 1 unit, the GCS increases by 0.032 units.

2. The slope ($b_{2=}$0.065) is change in GCS when clay % increases by 1. That is when the clay % increases by 1 unit, the GCS increases by 0.065 units.

3. The slope ($b_{3=}$0.018) is change in GCS when moisture % increases by 1. That is when the moisture % increases by 1 unit, the GCS increases by 0.018 units.

4. The slope (b_4=-0.015) is change in GCS when mulling time decreases by 1. That is when the mulling time decreases by 1 unit, the GCS increases by 0.015 units.

5. The slope ($b_{5=}$0.003) is change in GCS when hardness increases by 1. That is when the hardness increases by 1 unit, the GCS increases by 0.003 units.

6. The constant (intercept) value (b_0=1.020) is the predicted value of GCS when each predictor (Grain Finess no, Clay % , Moisture %, Mulling Time and Hardness) is zero. That is when the predictor is zero, the GCS is 1.020 (kg/sq. cm).

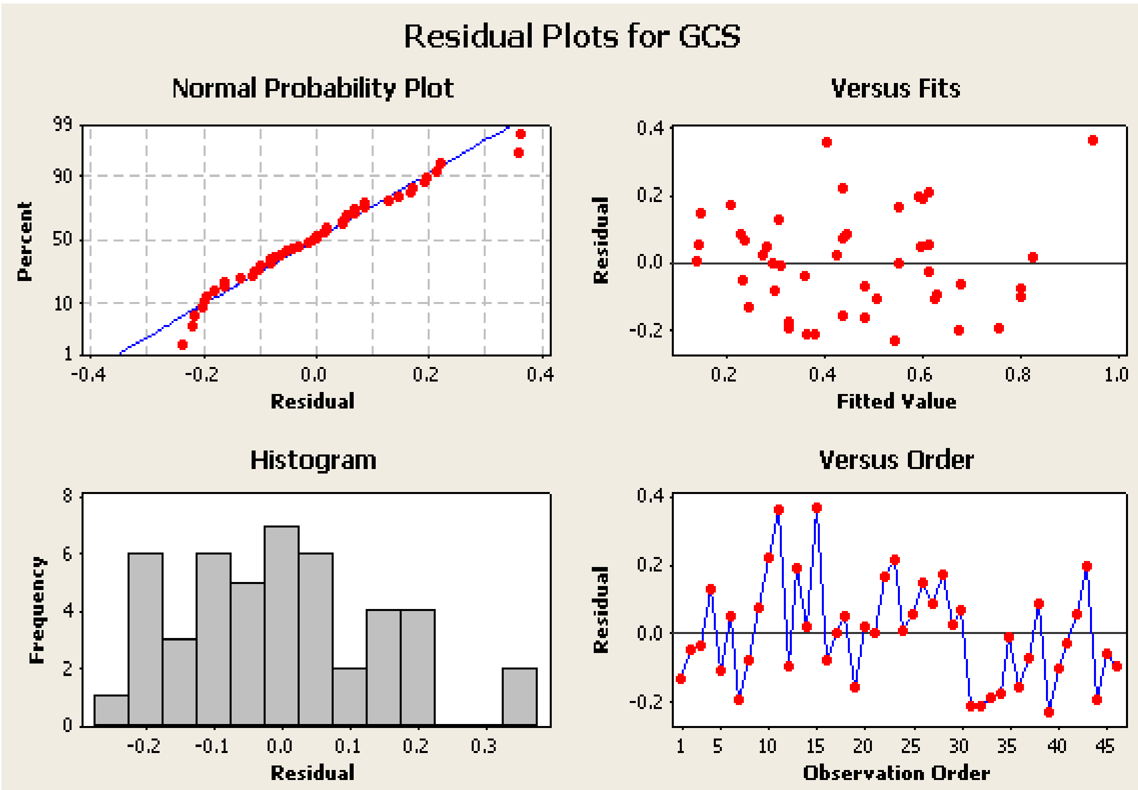

Fig 1: Residual plots for GCS

RESULT

For the optimization of moulding sand parameters according to their effect on the mould quality, the discussion focused on the effects on GCS, on the quality characteristics.

Table 1. Multiple Regression Analysis

S No.	Quality Characteristics	Multiple Regression Analysis	
		R^2 %	Adjusted R^2
1	Green compressive strength	64.0	59.5

After the successful analysis of the Green send mould parameters, the performance of the process parameters was tested with the test data sets. Four different sets of data, which were not included in the experiment, where selected randomly as the test data set.

Table 2. Comparisons between the Actual and Predicted GCS of Moulding Sand-Mix

MULTIPLE REGRESSION ANALYSIS			
Actual Value	**Predicted Value**	**Error**	**%**
Y1	**Y1**		
0.527	0.307	0.219	41.71
0.594	0.762	-0.168	-28.30
1.111	0.932	0.178	16.05
0.302	0.236	0.065	21.81
		0.105	12.82

It may be inferred that Multiple Regression Analysis can predict the Green compressive strength, of moulding sand accurately. Multiple Regression Analysis is very useful and modern technique for the prediction and optimization of manufacturing performances.

CONCLUSION

The data used in multiple regression analysis and response surface methodology in MINITAB 15 Software for modelling the green sand mould system are exhaustively reported in research paper. Out of all available sets, few were not used in the training process. But reserved exclusively for testing.

The coefficient of correlation (R^2), adjusted R^2, and Actual and Predicted values of process parameters of the moulding sand mix is gained by multiple regression analysis. Multiple Regression Analysis has successfully predicted the outputs. Many efforts were required for finding out the optimum process parameters.

This modelling technique may be used by foundries to determine a set of sand Moulding input parameters to yield the desired output properties. The foundries, however, need the appropriate MINITAB software available.

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