The Statistical Mixture Design of Rice Polishing Cylinder

Surapong Bangphan, Sukangkana Lee and Sermkiat Jomjunyong

Abstract—This study presents the application of the mixture design technique in generating the optimal mixture for the rice mill cylinder when using the new materials. The three new materials; Quartz were chosen from three different regions of Thailand in order to compare with the imported materials; Emery. Quartz used in this study are natural stone and found in Thoen district (Lampang province) , Bophloi district (Kanchanaburi province) and from Wiang Pa Pao district (Chiangrai province) respectively.

Design of Experiment (DOE) was used as a tool in order to generate the suitable mixture. All 10 mixtures were generated by the Simplex Centroid Design technique with Special Cubic type. ANOVA and Regression was used for analysis. In this model, three control factors: x_1, x_2 and x_3 represent Quartz no.16, no.18 and Reused Silicon carbide no.18, respectively. The process variables were the temperature (z_1) and the paddy moisture content (z_2). The rice milling tests were conducted on kow dauk mali 105 rice. After milling, the percentage of good rice and the wear rate of polishing cylinder were calculated and analyzed using Regression analysis and Analysis of Variance (ANOVA). The response optimization was quartz from Thoen district. At a significant level $\alpha = 0.05$, the values of Regression coefficient, $R^2_{(adj)}$were 78.62 % And $R^2_{(adj)}$were 70.67 %. The Optimal mixture gave 92.136% good rice and the wear rate of 1.887 g/hr.

***Keywords*—**Abrasive Materials, Rice Polishing Cylinder, Mixture Design, Design of Experiment

I. INTRODUCTION

The quality of milled rice are depends on many factors such as rice strain, the rate of feeding, clearance between a rubber and abrasive cylinder, paddy moisture content which usually are controlled not to be exceed 14% ect. But the most important factor is the type of the abrasives [1]-[2]. Furthermore, one of the major problems encountered is the wear of the polishing stone i.e. stones come off or chip from the cylinder and mix in the milled rice. This seems to be the common problem but for the farmer, wear of stone reduces the cylinder life and can increase milling cost. Also, the polishing cylinders are locally made and the qualities of the cylinder are often not consistent. Furthermore, the mixture of the abrasive cylinder is varied [2]. The major rice polishing technique in Thailand is the abrasive type. The major mixture of polishing cylinder consists of Emery grain, Silicon carbide, Calcined Magnesite and Magnesium chloride solution. The Emery stone is a major abrasive medium containing about 50 wt%. The Emery stones used in Thailand are imported from Europe are dark brown to black in color and have high hardness. However, it was found that the quality of this imported product is descending i.e. hardness values up on the pureness. In addition, good quality Emery stone is becoming rare resulting in progressively cost increasing. It was reported that the imported emery stone were more than 1.25 million US dollar per annual [3]. Therefore, there is an attempt in replacing Emery stone with other materials available in Thailand. Recently, Bangphan and Lee., reported that the Quartz has appropriate abrasive characteristics such as sharp edge, hardness, natural substance ect., therefore, it has a potential for rice polishing cylinder compared with the Emery grain [2]-[3].

The mixture design and analysis is an important methodology for development and optimization of food products [4]-[6]. Mixture designs are also among the most widely used tools for product formulation [7]-[11]. Therefore the purpose of this paper is to generate the suitable mixture from alternative domestic composite materials using Design of Experiment (DOE). This would lead to cost reduction and create more alternative choices for abrasive medium.

II. EXPERIMENTAL PROCEDURE

A. Materials Preparation

Quartz is a natural mineral found in many areas in the Western and the Northern region of Thailand. The chemical formula of Quartz is SiO_2. Quartz contains 46.7 wt %Si and 53.6 wt %O. The Mohr scale hardness of quartz is equal to 7. Quartz used in this experiment has white color. Samples were collected from Bo Phloi district in Kanchanaburi province, Thoen district in Lampang province and from Wiang Pa Pao district in Chiangrai province. Imported silicon carbide was replaced by reused silicon carbide obtained from the Alumina-Silicon carbide plate. Reused silicon carbide contains 50.0 wt %Si and 21.0 wt% C. All replaced materials were mechanically crushed and meshed to sizes. The binder paste or

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magnesium oxychloride cement was a mixture of Calcined magnesite 250 mesh with the magnesium chloride solution 30 Baume [3].

B. Mixture Design

The experimental design was created to determine the conditions when varying the composition of the materials according to a tree component mixture design and process variable. Results of this experimental design are then applied to evaluate the possibility of improving the performances of materials mixtures prepared by the selective quartzes with the binder fraction of the rice polishing cylinder.

The canonical form of a second-order mixture model (special cubic model) for tree components takes the form of the following ''interaction model'' [10–12]. The Scheff'e canonical in equation (1) and process variable equation (2) were used to model the experimental data, in order to fit a mathematical model for the description of the response variables as a function of process variables and mixture components. This approach assumes that measured parameters are additive and therefore departures from linearity can be detected. This assumption was also found in the work of N.Chantarat T. Theodore, and Nilgun. Ferhatosmanoglu., 2006 [12] and C.D. Wood , D.L. Romney, and A.H. Murray., 2000 [13].

$$y = \sum_{i=1}^{q} \beta_i x_i + \sum_{i<} \sum_{j}^{q} \beta_{ij} x_i x_j + \sum_{i<} \sum_{j<}^{q} \sum_{k} \beta_{i\,jk} x_i x_j x_k \tag{1}$$

$$\begin{aligned} y(x_1,\ldots,x_q, z_1,\ldots,z_m = & \sum_{i=1}^{q} \left[\gamma_i^0 + \sum_{i=1}^{m} \gamma_i^l z_l + \sum_{l<} \sum_{n=1}^{m} \gamma_i^n z_l z_n \right] x_i \\ & + \sum_{i<} \sum_{j=1}^{Q} \left[\gamma_{ij}^0 \sum_{l=1}^{m} \gamma_{ij}^l z_l + \sum_{l<} \sum_{n=1}^{m} \gamma_{ij}^n z_l z_n \right] x_i x_j \\ & + \sum_{i<} \sum_{j<} \sum_{k=1}^{q} \left[\gamma_{ijk}^0 + \sum_{l=1}^{m} \gamma_{ijk}^l z_l + \sum_{l<} \sum_{n=1}^{m} \gamma_{ijk}^n z_l z_n \right] x_i x_j x_k + \varepsilon \end{aligned} \tag{2}$$

where y is the studied response (percentage of Good Rice (GR) and Rate of Wear), β_{ij} are the regression parameters and x_1, x_2 and x_3 are the factors of quartz and silicon carbide (reused) in the blends and z_1, z_2 are process variable respectively. This special cubic model can be used for obtaining the response surface to be analyzed in which y represents the response variable; β_0 represents an overall average term; β_1, β_2, and β_3 represent regression coefficients of the tree factor interaction terms (i.e., β_{12} represents the interaction coefficient between factors x_1, and x_2) and ε represents the error term.

These components are measured by their proportion (usually by weight, in this paper use materials and binder ratio,) and the response variables depend only on the component proportions that are present, not their absolute amounts [7]-[11]. Response surface methodology was used to study the simultaneous effect of the influent variables (factors). A mixture experiment is a special type or response surface experiment in which the factors are the components of a mixture and the response is a function of the proportions of each component [3]-[4].

C. Statistical Methods and Software

The analysis and results of the experimental design were studied and interpreted by MINITAB RELEASE 14.00 (PA, USA licensed to Department of Industrial Engineering, Faculty of Engineering, Ubonratchathani University, Ubonratchathani, Thailand) statistical software to estimate the response of the dependent variable. The response curves and contour plots are also generated. After milling, the percentage of good rice and the wear rate of polishing cylinder were calculated and analyzed using Regression analysis and Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

A. Results

During milling of all mixtures, it was found that the longer the contact time between abrasive polishing cylinder and the rubber, the more abrasive efficiency. The analysis of variance are presented in Table I, II, III, IV, V and VI. The application of mixture design in this experiment was complicated and time consuming. Since all of the coefficients have to be interpreted under the restriction that a third factor is varied at the same time as the two which are actively used. The only significant contributions are from the product of x_1 and x_3 and from the product of x_2 and the square of z_1 and z_2. This can be concluded that the surface is nonlinear and there is an interaction between the process variable and three compositions.

B. Discussion

Simplex centroid designs and special cubic models are saturated in the sense that the number of design points is equal to the number of terms in the model. In this case analytical solutions exist for the model coefficients in terms of the response values at the design points [14].

Simplex centroid for each combination of process variables design 80 points for quartz from Thoen district and 40 points for quartz from Bophloi district and Wiang Pa Pao district respectively were performed. In this case analytical solutions exist for the model coefficients in terms of the response values at the design points. As such each coefficient can be given a mechanical interpretation. The estimate of the variance due to pure error was possible. Hence, the adequacy of the fitted model could be checked by comparing the error component due to the model to that one due to experimental error. The test statistic was the F-ratio given by the estimate of the variance due to lack of fit *(MS_{LOF})* and the estimate of the variance due to pure error *(MS_{PE})*. In general, lack of fit of the model is suspected when the computed value of F is significant. As shown in Tables I,II,III, IV,V and VI, the ingredients and process variable of the percentage of good rice (y_1) and the wear rate (y_2) are listed. The parameters of the combined model in Equation (2) were estimated by fitting the 21-term polynomial to the experimental data here reported. For the two variable responses, the estimated residual variance was MS_E = 212.46 and MS_E = 2.023 for y_1 and y_2, respectively. Using the three replicates, the experimental error variance was estimated such as MS_{PE} = 71.76 with 40 *df* for y_1 and MS_{PE} = 0.606 with 40 *df* for y_2 and $\mathrm{MS_E}$ = 0.10 and 0.348 with 11 *df*

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for y_1 and MS_E = 1.706 and 4.7314 with 11 *df* for y_2 (for quartz from Bophloi and Wiang Pa Pao) respectively. Having obtained the estimation of the variance due to lack of fit ($MS_{LOF} = MS_E - MS_{PE}$), based on the *LOF* test for response y_2, the combined model shown in Equation (2) was augmented with four terms of the special-cubic polynomial. In fact, the value of the *F*-statistic, for testing the presence of lack of fit of model in Equation (2) was F = 7.09 with a *P*-value of 0.000 for y_1 and F = 8.26 with a *P*-value *of* 0.000 for y_2 (for quartz from Thoen) respectively. And the estimation of the variance due to regression were F = 127.95 and 151.92 with a *P*-value P = 0.000,0.000 for y_1 and F = 6.40 and 3.15 with a *P*-value P = 0.000,0.025 for y_2 (for quartz from Bophloi and Wiang Pa Pao) respectively. This model was maintained. From the analysis of variance table, the R^2 statistics for the two combined models were computed and their values were R^2=0.840, 0.997 and 0.997 with an $R^2_{(adj)}$ = 0.786,0.989 and 0.991 for y_1 respectively , and R^2 = 0.781,0.992 and 0.889 with an $R^2_{(adj)}$ = 0.707,0.795 and 0.607 for y_2 respectively , (from Thoen district in Lampang province, BoPhloi district in Kanchanaburi province and from Wiang Pa Pao district in Chiangrai province) respectively. The coefficient of determination corrected for the number of terms in the equation should be always preferred to R^2 as it gives a more stable measure to the model adequacy.

TABLE I
ANOVA FOR %GR (COMPONENT PROPORTIONS), SAMPLE SOURCE: THOEN

Source	DF	Seq SS	MS	F	P
Regression	20	65983.9	3299.19	15.53	0.000
Component Only					
Linear	2	26559.7	9153.20	43.08	0.000
Quadratic	3	31128.3	8635.39	40.64	0.000
Special Cubic	1	6806.3	6806.26	32.03	0.000
Component* TEMP					
Linear	3	541.0	249.93	1.18	0.326
Quadratic	3	282.4	83.09	0.39	0.760
Special Cubic	1	3.5	3.54	0.02	0.898
Component* MOIS					
Linear	3	398.9	220.33	1.04	0.383
Quadratic	3	262.9	72.40	0.34	0.796
Special Cubic	1	0.9	0.93	0.00	0.948
Residual Error	59	12535.4	212.46		
Lack-of-Fit	19	9664.9	508.68	7.09	0.000
Pure Error	40	2870.5	71.76		
Total	79	78519.2			

The final model was chosen selecting only those coefficients. This lead to the elimination of the x_3z_1 and $x_1x_3z_1z_2$ terms from the model. The final model for quartz from Thoen, Bophloi and Wiang Pa Pao district are given by

$$
\begin{aligned}
\hat{Y} = {} & 17.1(SiO_2(\#16)) + 76.8(SiO_2(\#18)) + 68.2(Sic(\#18)) + (-155.5)(SiO_2(\#16)) * (SiO_2(\#18)) \\
& + 198(SiO_2(\#16)) * (Sic(\#18)) + (-16.9)(SiO_2)(\#18)) * (Sic(\#18)) + 935.7(SiO_2(\#16)) * (SiO_2(\#18)) \\
& * (Sic(\#18)) + (-9.1)(SiO_2(\#16)) * (temp) + (-2.2)(SiO_2(\#18)) * (temp)) + (-1.2)(Sic(\#18)) \\
& * (temp)) + 22.6(SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + 16.8(SiO_2(\#16)) * (Sic(\#18)) \\
& * (temp) + (-1.5)(SiO_2(\#18)) * (Sic(\#18)) * (temp) + (-21.3)(SiO_2(\#16)) + (SiO_2(\#18)) \\
& + (Sic(\#18)) * (temp) + 8.8(SiO_2(\#16)) * (moist) + 0.2(SiO_2(\#18)) * (moist) + 0.0(Sic(\#18)) \\
& * (moist) + (-19.7)(SiO_2(\#16)) * (SiO_2(\#18)) * (moist) + (-17.6)(SiO_2(\#16)) * (Sic(\#18)) \\
& * (moist) + 1.1(SiO_2(\#18)) * (Sic(\#18)) * (moist) + 10.9(SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) \\
& * (moist)
\end{aligned}
\tag{3}
$$

$$
\begin{aligned}
\hat{Y} = {} & 1.21(SiO_2(\#16)) + 7.01(SiO_2(\#18)) + 7.12(SiO_2(\#18)) + (-13.4)(SiO_2(\#16) * (SiO_2(\#18)) \\
& (-9.11)(SiO_1(\#16) * (Sic(\#18)) + (-11.84)(SiO_2(\#18)) * Sic(\#18)) + 125.61(SiO_2(\#16)) \\
& * (SiO_2(\#18)) + (-0.60)(SiO_2(\#16))(* temp)) + 0.27(SiO_2(\#18)) * (temp) + (-0.21)(Sic(\#18)) \\
& + 0.85(SiO_2(\#16)) + (SiO_2(\#18)) * (temp) + 2.33(SiO_2(\#16)) + (Sic(\#18)) * (temp) \\
& + (SiO_2(\#18)) * (Sic(\#18)) * (temp) + (-5.36)(SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (temp) \\
& + 0.63(SiO_2(\#16)) * (moist) + 0.05(SiO_2(\#18)) * (moist) + (-0.50)(Sic(\#18)) * (moist) + (-1.65) \\
& (SiO_2(\#16)) * (SiO_2(\#18)) * (moist) + (-0.48)(SiO_2(\#16)) * (Sic(\#18)) * (moist) + 1.16(SiO_2(\#18)) \\
& + (Sic(\#18)) * (moist) + 0.74(SiO_2(\#16) * (SiO_2(\#18)) * (Sic(\#18)) * (moist)
\end{aligned}
\tag{4}
$$

$$
\begin{aligned}
\hat{Y} = {} & 82.1(SiO_2(\#16)) + 87.6(SiO_2(\#18)) + 86.8(Sic(\#18)) + (-1.7)(SiO_2(\#16)) * (SiO_2(\#18)) \\
& + 0.2(SiO_2(\#16)) * (Sic(\#18)) + (-18.7)(SiO_2(\#18)) * (Sic(\#18)) + 41.7(SiO_2(\#16)) * (SiO_2(\#18)) \\
& * (-98.8)(SiO_2(\#16)) * (Sic(\#18)) * (-342.9)(SiO_2(\#16)) * (SiO_2(\#16)) + (SiO_2(\#18)) \\
& * (Sic(\#18)) + 150.9(SiO_2(\#16)) * (SiO_2(\#18)) * (2) + (-0.1)(SiO_2(\#16)) * (moist) + (-0.0) \\
& (SiO_2\#18)) * (moist) + (-0.4)(Sic(\#18)) * (moist) + 0.5(SiO_2(\#16)) * (SiO_2(\#18)) * (moist) \\
& + 1.2(SiO_2(\#18)) * (Sic(\#18)) * (moist) + 1.1(SiO_2(\#18)) * (Sic(\#18)) * (moist) + 2.6(SiO_2(\#16)) \\
& * (SiO_2(\#18)) * (moist) + 7.9(SiO_2(\#16)) * (Sic(\#18)) * (moist) + (-32.2)(SiO_2(\#16)) \\
& * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (moist) + 0.9(SiO_2(\#16)) * (SiO_2(\#18)) * (moist) \\
& + (-0.0)(SiO_2(\#16)) * (temp) + 0.2(SiO_2(\#18)) * (temp) + 0.2(Sic(\#18)) * (temp - 01.2) + (-1.9) \\
& (SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + (-1.2)(SiO_{12}(\#16)) * (Sic(\#18)) * (temp) + (-0.3)(SiO_2(\#18)) \\
& * (Sic(\#18)) * (temp) + (-1.5)(SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + (-0.1)(SiO_2(\#16)) \\
& * (Sic(\#18)) * (temp) + 0.9(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (temp)
\end{aligned}
\tag{5}
$$

$$
\begin{aligned}
\hat{Y} = {} & 11.5(SiO_2(\#16)) + 12.1(SiO_2(\#18)) + 9.6(Sic(\#18)) + 11.0(SiO_2(\#16)) * (SiO_2(\#18)) \\
& + 3.4(SiO_2(\#16)) * (Sic(\#18)) + 7.1(SiO_2(\#18)) * (Sic(\#18)) + (-96.6)(SiO_2(\#16) \\
& * (SiO_2(\#18)) * (-) + 48.1(SiO_2(\#16)) * (Sic(\#18)) * 368.8(SiO_2(\#16)) * (SiO_2(\#16)) \\
& * (SiO_2(\#18)) * (Sic(\#18)) + (-248.5)(SiO_2(\#16)) * (SiO_2(\#18)) * (2) + 0.6(SiO_2(\#16)) \\
& * (moist) + 0.0(SiO_2(\#18)) * (moist) + 0.2(Sic(\#18)) * (moist) + 3.3(SiO_2(\#16)) * (SiO_2(\#18)) \\
& * (moist) + (-4.0)(SiO_2(\#16)) * (Sic(\#18)) * (moist) + 0.1(SiO_2(\#18)) * (Sic(\#18)) * (moist) \\
& + 5.5(SiO_2(\#16)) * (SiO_2(\#18)) * (moist) + (-4.5)(SiO_2(\#16) * (Sic(\#18)) * (moist) \\
& + 28.4(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (moist) + 5.5(SiO_2(\#16)) \\
& * (SiO_2(\#18)) * (2) * (moist) + 0.9(SiO_2(\#16)) * (temp) + 0.0(SiO_2(\#18)) * (temp) + (-0.0) \\
& (Sic(\#18)) * (temp) + (-6.9)(SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + (-0.7)(SiO_2(\#16)) * (Sic(\#18)) \\
& * (temp) + 1.3(SiO_2(\#18)) * (Sic(\#18)) * (temp) + (-12.9)(SiO_2(\#16)) * (SiO_2(\#18)) * (temp) \\
& + 0.5(SiO_2(\#16)) * (Sic(\#18)) * (temp) + 8.0(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) \\
& * (temp)
\end{aligned}
\tag{6}
$$

$$
\begin{aligned}
\hat{Y} = {} & 70.0(SiO_2(\#16)) + 78.3(SiO_2(\#18)) + 78.0(Sic(\#18)) + 47.0(SiO_2(\#16)) * (SiO_2(\#18)) \\
& + 38.0(SiO_2(\#16)) * (Sic(\#18)) + (-49.2)(SiO_2(\#18)) * (Sic(\#18)) + 15.6(SiO_2(\#16)) \\
& * (SiO_2(\#18)) * (-122.5)(SiO_2(\#16)) * (-554.4)(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) \\
& * (Sic(\#18)) + 179.2(SiO_2(\#16)) * (SiO_2(\#18)) * (2) + 0.0(SiO_2(\#16)) \\
& * (moist) + (-0.8)(SiO_2(\#18)) * (moist) + (-0.7)(Sic(\#18)) * (moist) + 6.4(SiO_2(\#16)) \\
& * (SiO_{12}(\#18)) * (moist) + 0.6(SiO_2(\#16)) * (Sic(\#18)) * (moist) + 1.2(SiO_2(\#18)) * \\
& (Sic(\#18)) * (moist) + 4.7(SiO_2(\#16)) * (SiO_2(\#18)) * (moist) + (-10.4)(SiO_2(\#16)) \\
& * (Sic(\#18)) * (moist) + (-22.6)(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) \\
& * (moist) + 6.8(SiO_2(\#16)) * (SiO_2(\#18)) * (2) * (moist) + (-0.2)(SiO_2(\#16)) * (temp) \\
& + (-0.0)(SiO_2(\#18)) * (temp) + (-0.7)(Sic(\#18)) * (temp) + 1.7(SiO_2(\#16)) * (SiO_2(\#18)) * \\
& (temp) + 1.6(SiO_2(\#16)) * (Sic(\#18)) * (temp) + 1.8(SiO_2(\#18)) * (Sic(\#18)) * (temp) + 4.9 \\
& (SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + (-8.9)(SiO_2(\#16)) * (Sic(\#18)) * (temp) \\
& + 13.6(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (temp)
\end{aligned}
\tag{7}
$$

$$
\begin{aligned}
\hat{Y} = {} & 15.22(SiO_2(\#16)) + 9.20(SiO_2(\#18)) + 15.72(Sic(\#18)) + (-2.20)(SiO_2(\#16)) * (SiO_2(\#18)) \\
& + (-30.52)(SiO_2(\#16)) * (Sic(\#18)) + (-9.72)(SiO_2(\#18)) * (Sic(\#18)) + (-16.55)(SiO_2(\#16)) \\
& * (SiO_2(\#18)) * (-0.14)(SiO_2(\#16)) * (Sic(\#18)) * 387.52(SiO_2(\#16)) * (SiO_2(\#16)) \\
& * (SiO_2(\#18)) * (Sic(\#18)) + 61.77(SiO_2(\#16)) * (SiO_2(\#18)) * (2) + 0.38(SiO_2(\#16)) * (moist) \\
& + 2.60(SiO_2(\#18)) * (moist) + 3.74(Sic(\#18)) * (moist) + (-5.13)(SiO_2(\#16)) * (SiO_2(\#18)) * (moist) \\
& + (-5.48)(SiO_2(\#16)) * (Sic(\#18)) * (moist) + (-12.88)(SiO_2(\#18)) * (Sic(\#18)) * (moist) + (-36.25) \\
& (SiO_2(\#16)) * (SiO_2(\#18)) * (moist) + 39.61(SiO_2(\#16)) * (Sic(\#18)) * (moist) + 38.02 \\
& (SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (moist) + (-67.72)(SiO_2(\#16)) * (SiO_2(\#18)) \\
& * (2) * (moist) + 0.47(SiO_2(\#16)) * (temp) + (-0.66)(SiO_2(\#18)) * (temp) + (-0.345)(Sic(\#18)) \\
& * (temp) + 3.52(SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + (-6.90)(SiO_2(\#16)) * (Sic(\#18)) * (temp) + 2.0 \\
& (SiO_2(\#18)) * (Sic(\#18)) * (temp) + (-3.56)(SiO_2(\#16)) * (SiO_2(\#18)) * (temp) + 8.03(SiO_2(\#16)) \\
& * (Sic(\#18)) * (temp) + 90.84(SiO_2(\#16)) * (SiO_2(\#16)) * (SiO_2(\#18)) * (Sic(\#18)) * (termp)
\end{aligned}
\tag{8}
$$

Equations (3) and (4) are the coefficient of the percentage of good rice and wear rate of quartz from Thoen district ,respectively. Equations (5) and (6) are the coefficient of the percentage of good rice and wear rate of quartz from Bophloi district, respectively and Equations (7) and (8) are the coefficient of the percentage of good rice and wear rate of quartz from Wiang Pa Pao district, respectively.

TABLE II
ANOVA FOR WEAR (COMPONENT PROPORTIONS), SAMPLE SOURCE: THOEN

Source	DF	Seq SS	MS	F	P
Regression	20	425.458	21.273	10.52	0.000
Component Only					
Linear	2	270.273	100.60	49.74	0.000
Quadratic	3	20.267	34.313	16.96	0.000
Special Cubic	1	122.636	122.63	60.63	0.000
Component* T					
Linear	3	4.043	1.384	0.68	0.565
Quadratic	3	2.339	0.782	0.39	0.763
Special Cubic	1	0.223	0.223	0.11	0.741
Component* MOISTURE					
Linear	3	3.958	1.882	0.93	0.432
Quadratic	3	1.714	0.567	0.28	0.839
Special Cubic	1	0.004	0.004	0.00	0.964
Residual Error	59	119.341	2.023		
Lack-of-Fit	19	95.091	5.005	8.26	0.000
Pure Error	40	24.249	0.606		
Total	79	544.79			

TABLE III
ANOVA FOR % GR (COMPONENT PROPOTIONS) , SAMPLE SOURCE: BOPHLOI

Source	DF	Seq SS	MS	F	P
Regression	28	358.290	12.796	127.95	0.000
Component Only					
Linear	2	101.496	35.259	352.58	0.000
Quadratic	3	88.870	20.020	200.20	0.000
Full Cubic	2	89.110	44.618	446.16	0.000
Special Quart	1	17.433	43.987	439.85	0.000
Full Quartic1	1	56.407	56.406	564.04	0.000
Component* MOISTURE					
Linear	3	1.519	0.276	2.76	0.092
Quadratic	3	0.072	0.123	1.23	0.344
Full Cubic	2	0.930	0.596	5.96	0.018
Special Quart	1	0.430	0.390	3.90	0.074
Full Quartic1	1	0.002	0.002	0.02	0.901
Component*T					
Linear	3	0.951	0.121	1.21	0.351
Quadratic	3	1.030	0.250	2.49	0.114
Full Cubic	2	0.041	0.017	0.17	0.843
Special Quart	1	0.000	0.000	0.00	0.953
Residual Error	11	1.100	0.100		
Total	39	359.390			

TABLE IV
ANOVA FOR WEAR (COMPONENT PROPORTIONS), SAMPLE SOURCE: B.P.

Source	DF	Seq SS	MS	F	P
Regression	28	305.777	10.921	6.40	0.001
Component Only					
Linear	2	44.715	7.154	4.19	0.044
Quadratic	3	51.965	8.332	4.89	0.021
Full Cubic	2	38.281	49.635	29.10	0.000
Special Quart	1	9.653	50.878	29.83	0.000
Full Quartic1	1	134.544	134.54	78.89	0.000
Component* MOISTURE					
Linear	3	6.841	0.508	0.30	0.826
Quadratic	3	5.212	1.777	1.04	0.412
Full Cubic	2	0.650	0.170	0.10	0.906
Special Quart	1	0.476	0.301	0.18	0.682
Full Quartic1	1	0.065	0.065	0.04	0.848
Component* TEMP					
Linear	3	0.507	1.084	0.64	0.607
Quadratic	3	9.911	2.972	1.74	0.216
Full Cubic	2	2.928	1.271	0.74	0.497
Special Quart	1	0.028	0.028	0.02	0.901
Residual Error	11	18.761	1.706		
Total	39	324.538			

TABLE V
ANOVA FOR %GOOD RICE (COMPONENT PROPORTIONS) , SAMPLE SOURCE: W.P.P.

Source	DF	Seq SS	MS	F	P
Regression	28	1480.37	52.870	151.92	0.000
Component Only					
Linear	2	13.03	87.652	251.87	0.000
Quadratic	3	1010.37	394.06	1132.4	0.000
Full Cubic	2	303.06	82.549	237.21	0.000
Special Quart	1	67.82	114.99	330.44	0.000
Full Quartic1	1	69.96	69.958	201.02	0.000
Component* moisture					
Linear	3	3.08	1.529	4.39	0.029
Quadratic	3	7.14	2.294	6.59	0.008
Full Cubic	2	1.44	0.488	1.40	0.287
Special Quart	1	0.12	0.191	0.55	0.474
Full Quartic1	1	0.10	0.101	0.29	0.600
Component* temp					
Linear	3	0.74	0.668	1.92	0.185
Quadratic	3	2.37	0.366	1.05	0.409
Full Cubic	2	1.06	0.569	1.63	0.239
Special Quart	1	0.08	0.079	0.23	0.642
Residual Error	11	3.83	0.348		
Total	39	1484.2			

TABLE VI
ANOVA FOR WEAR (COMPONENT PROPORTIONS) , SAMPLE SOURCE: W.P.P.

Source	DF	Seq SS	MS	F	P
Regression	28	417.06	14.895	3.15	0.025
Component Only					
Linear	2	55.627	52.686	11.14	0.002
Quadratic	3	106.447	53.693	11.35	0.001
Full Cubic	2	31.667	2.029	0.43	0.662
Special Quart	1	84.375	56.180	11.87	0.005
Full Quartic1	1	8.313	8.3131	1.76	0.212
Component* moisture					
Linear	3	29.061	27.876	5.89	0.012
Quadratic	3	53.372	10.224	2.16	0.150
Full Cubic	2	9.120	9.203	1.95	0.189
Special Quart	1	0.204	0.541	0.11	0.742
Full Quartic1	1	9.991	9.991	2.11	0.174
Component* temp					
Linear	3	7.193	1.051	0.22	0.879
Quadratic	3	14.243	4.249	0.90	0.473
Full Cubic	2	3.892	0.445	0.09	0.911
Special Quart	1	3.563	3.563	0.75	0.404
Residual Error	11	52.046	4.731		
Total	39	469.11			

Table VII and Table VIII contains the results and summarize of regression of ANOVA and coefficients for the percentage of good rice and wear rate. The regression coefficients from multiple regression analysis of the sample data in Table I-VI showed that component proportions had significant ($P \leq 0.05$) special cubic effect on forming while effect of other process variables (Temperature and moisture) were not significant ($P \geq 0.05$) an all quartz of minerals in Thailand.

TABLE VII
THE REGRESSION OF ANOVA AND COEFFICIENTS FOR % GR

Source of materials	% GR			
	Regression of ANOVA		Estimated Regression Coefficients	
	F	P	R^2	R^2_{adj}
Bophloi	127.95	0.000	99.69	98.91
Wiang Pa Pao	151.92	0.000	99.74	99.09
Thoen	15.53	0.000	84.04	78.62

TABLE VIII
THE REGRESSION OF ANOVA AND COEFFICIENTS FOR WEAR

Source of materials	Wear Rate			
	Regression of ANOVA		Estimated Regression Coefficients	
	F	P	R^2	R^2_{adj}
Bophloi	6.40	0.000	94.22	79.50
Wiang Pa Pao	3.15	0.000	88.91	60.66
Thoen	10.52	0.000	78.09	70.67

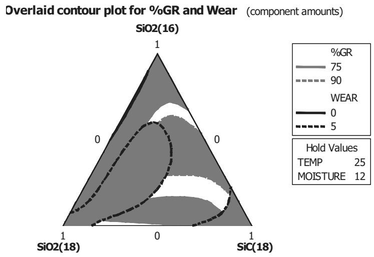

Fig. 1 Overlaid contour plot for %GR and Wear from Thoen District

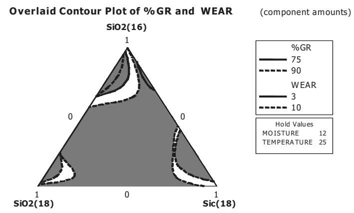

Fig.2 Overlaid contour plot for %GR and Wear from Bophloi District

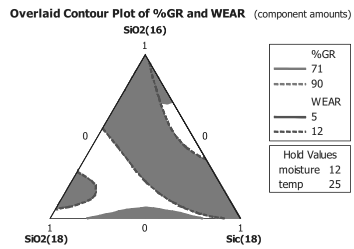

Fig.3 Overlaid contour plot for %GR and Wear from W.P.P. District

Fig.1 to Fig.3 show the overlaid contour plots of the responses, variables for %GR, and WEAR of quartz from Bo Phloi district in Kanchanaburi province, from Thoen district in Lampang province and from Wiang Pa Pao district in Chiangrai province, respectively. The feasible white area shown in each parts of the figure is the region where all response objectives will be satisfied. Furthermore, there is a region for which both the percentage of good rice, and wear rate responses can be simultaneously optimized. Therefore, it is possible to combine both the percentage of good rice and wear rate processes into a rice mills process, one of the original process development objectives. The predicted mean value of each response and the associated standard error of prediction at several points in the triangle. To assess the magnitude of prediction error, and also computed 95% confidence limits on the mean response.

Table IX to Table XI show the response optimization of three new materials. It is shown that the Quartz from Thoen with composition of 0.5wt%SiO_2(16):0.5wt%Sic(18) give highest %GR of 92.136% coupled with the lowest were rate of only 1.887 g/hr.

TABLE IX
RESPONSE OPTIMIZATION FROM THOEN

Parameters	Goal	Lower	Target	Upper	Weight	Import
%GR	Max	75	100	100	1.0	10
WEAR	Min	0	0	5	0.5	1
Components						
	SiO_2(16) = 0.5					
	SiO_2(18) = 0.0					
	Sic (18) = 0.5					
Process Variables						
	TEMP		= 27.5			
	MOISTURE		= 13.0			
Predicted Responses						
	%GR		= 92.136, desirability = 0.685			
	WEAR		= 1.887, desirability = 0.789			
Composite Desirability			= 0.694			

TABLE X
RESPONSE OPTIMIZATION SAMPLE SOURCE: BOPHLOI

Parameters	Goal	Lower	Target	Upper	Weight	Import
%GR	Max	79	90	90	1.0	10
WEAR	Min	0	0	15	0.5	1
Components						
	SiO_2(16) = 0.215					
	SiO_2(18) = 0.187					
	Sic (18) = 0.598					
Process Variables						
	TEMP		= 30.06			
	MOISTURE		= 12.99			
Predicted Responses						
	%GR		= 86.990 , desirability = 0.727			
	WEAR		= 11.533 , desirability = 0.932			
Composite Desirability			= 0.744			

TABLE XI
RESPONSE OPTIMIZATION SAMPLE SOURCE: W.P.P.

Parameters	Goal	Lower	Target	Upper	Weight	Import
%GR	Max	71	90	90	1.0	10
WEAR	Min	5	5	12	0.5	1
Components						
	SiO_2(16) = 0.50					
	SiO_2(18) = 0.50					
	Sic (18) = 0.00					
Process Variables						
	TEMP		= 30.00			
	MOISTURE		= 13.00			
Predicted Responses						
	%GR		= 85.904, desirability = 0.784			
	WEAR		= 11.658, desirability = 0.739			
Composite Desirability			= 0.780			

III. CONCLUSION

The mixture experimental design in the study of the effects of the components on some physical properties of a rice polishing cylinder formulation. The combining mixture composition and process variables using experimental design has proved to be appropriate and effective, in particular, in finding processing conditions and subregion yielding blend formulations leading to a product with the characteristics required. Applicability of binder combines calcined magnesite and $MgCl_2.6H_2O$ containing quartz and reused silicon carbide in equal proportion for abrasive rice mills. Under optimal values of process parameters, complete rice mills was found for both the abrasive using binder combines calcined magnesite and $MgCl_2.6H_2O$. This study clearly showed that mixture design was one of the suitable methods to optimize the best operating conditions to maximize the abrasive removing. Graphical response surface and contour plot were used to locate the optimum point. The statistical fitted models and the contour plot of responses, can be used to predict values of responses at any point inside the experimental space and can be successfully used to optimize the rice polishing cylinder.

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REFERENCES

[1] S. Bangphan, S. Lee, "Modeling Material Mixtures to Replace of Rice Polishing Cylinder,"Proceeding of the Conference of Industrial Engineering, IE NETWORK CONFERENCE, 17-19 December 2006.
[2] S. Bangphan, S. Lee and S. Jomjunyong, "Development of the Alternative Composite Material for Rice Polishing Cylinder," APIEMS & CIIE 2007.,Dec.2007, Proceeding 8th Conference. Industrial Engineeris Taiwan, 2007,p.146.
[3] Department of Primary Industries and Mines. online. Available URL:http://www.dmr.go.th/04_News/min_stat/min_stat.htm,June, 2007.
[4] A.I. Khuri, J.A. Cornell (Eds.), "Response Surfaces : Designs and Analysis,"M.Dekker, New York, 1996.
[5] J.A. Cornell(Ed.), "Experiments with Mixtures," Wiley, New York,1981, 1-19,26-27,139-227 and 315-325.
[6] J.A. Cornell (Ed.), " How to Run Mixture Experiments for Product Quality," vol.5, American Society for Quality Control, Wiscosin, 1983, pp.23-5.
[7] R.H. Myers, D.C. Montgomery (Eds.), " Response Surface Methodology : Process and Product Optimization Using Designed Experiments," Wiley, New York, 1995, 535-562 and 570-604.
[8] J.A. Cornell, " Experiments with Mixtures," 2nd ed. New York Wiley, 1990.
[9] D.C., "Montgomery, Design and Analysis of Experiments," 3rd ed. New York Willey,1991.
[10] G.E.P.Box, W.G, "Hunter, and J.S. Hunter, Statistics for Experiments," New York Willey, 1978.
[11] H.Scheffé ,"Experiments with mixtures," Journal of the Royal Statistical Society. Series B (Methodological), Vol. 20, No. 2, pp.344–360,1978.
[12] N.Chantarat, T. Theodore, and Nilgun. Ferhatosmanoglu. , "A combined array approach to minimize expected prediction errors in experimentation involving mixture and process variables," Int. J. Industrial and Systems Engineering, Vol. 1, Nos. 1/2, pp.129–147,2006.
[13] C.D. Wood , D.L. Romney, and A.H. Murray, "The use of in vitro gas Production to investigate feed interaction in the digestibility of supplemented low quality forage-based diets," In: Proceedings of an EAAP Satellite Symposium on the Gas Production Fermentation Wageningen, The Netherlands, 18–19 August 2000, pp. 105–106.
[14] N. Cleber, E. Roy. Borgesa , R. Brunsa , and S. Scarminiob, "Mixture–mixture design for the fingerprint optimization of chromatographic mobile phases and extraction solutions for Camellia sinensis," available, at www.sciencedirect.com,journalhomepage: www.elsevier.com/locate/ aca ,Accepted 27 February 2007.