



PRESS MACHINE PROCESS IMPROVEMENT BY USING DOE METHOD

Mohamad Ikbar A. W.¹, Mazlan A¹, Mohd Amran M. D.¹, Ishamuddin M.¹, Fairul Anwar A. B.¹ and Noor Anim Zanariah Y.²

¹Quality Engineering Department, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology, Persiaran Sinaran Ilmu, Bandar Seri Alam, Johor Bahru, Johor, Malaysia

²Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, UTM Skudai, Johor, Malaysia
E-Mail: mikbar@unikl.edu.my

ABSTRACT

The purpose of this study is to improve the efficiency of press machine for producing finish good product thru design of experiments application. Press process is significant to improve since the output of the palm oil product will be divided into two which are palm oil and palm nuts. The objective of this study is to identify the best parameter setting for reduce broken nuts during press process thru adoption of the design of experiments method. A full factorial design with single replication has been used to study the effects of important parameters which are temperature, cone angle, cone pressure and percentage of water. The measurement of output response is identified as percentage of broken nut. Referring to the company specification, the percentage of broken nuts must not exceed than 7 %. Randomize experiments was conducted based on table generated thru Minitab software. Normal probability test was carried out using Anderson Darling Test and show that the P-value is 0.325. Thus, the data is normal since there is no significance different between the actual data with the ideal data. Referring to effect estimate value for each parameter, factor B (Cone Angle) was not significant. Thus the experiments were converted from 2⁴ to 2³ with two replications. Referring to the ANOVA, all of the factors are significant except the AC interaction since the P-value for each of parameters less than 0.05. From the main plot and interaction plot, the recommended setting for each of parameters were suggested as low level for temperature, low level for cone pressure and high percentage of water. The prediction model was developed thru regression in order to measure effect of output response for any changes on parameters setting. In the future, the experiments can be enhanced using two replications of experiment and Taguchi methods in order to do verification of result.

Keywords: design of experiments, press machine, optimization.

INTRODUCTION

According to the situation in manufacturing sector, the issues of quality and productivity play an important role in order to achieve higher profits but at the same time the product or service meet the customer requirement and satisfaction. The study was carried out at Felda Palm Oil Factory at Felda Palong Timur which situated about 30 kilometer from Gemas. The company faces many problems such as inconsistent performance of the process, in ability to meet customer tight tolerances and the process in the machine is out of specification. In general, there are 17 processes in order to produce two main products which are Kernels and Crude Oil. Press process has been selected as the process to be studied since the process gives a huge impact to overall process and final product. There are two significance measurements for this process which are percentage of broken nuts and Oil Diluted Mass (ODM). These two measurements are dependable each other that make the process complex. Thus, the optimization study is important to enhance the quality and productivity of the product especially to reduce mass of broken nuts.

PRESSING PROCESS

There are two main products that produce by the company. Two of them are the kernel and the oil. The kernels of the fruit are also pressed in mechanical screw presses to recover palm-kernel oil, which is chemically quite different from the oil from the flesh of the fruit.

Palm oil is used in making soaps, candles, and lubricating greases and in processing tinplate and coating iron plates. Palm-kernel oil is used in manufacturing such edible products as margarine, chocolate confections, and pharmaceuticals. The pressing process was very significant because this process will separate two product of palm oil which are crude oil and kernels. Thus, it's very significant to improve the efficiency of the process. Figure-1a and b shows the final products produce by the company:



(a)



(b)

Figure-1. a) Crude Oil b) Kernels.

DESIGN OF EXPERIMENTS

R. A. Fisher in England in the 1920's introduced a very powerful statistical technique on Design of Experiments (DOE). In Fisher's early applications, he wanted to investigate and find out how much water, fertilizer, rain, sunshine and the other 'ingredients' are needed in order to produce the best crop. Henceforth, the technique has been developed for academic applications.

Additionally, the techniques did help a lot in many applications especially in the production floor of industrial sector. At present, Design of Experiments (DOE) has become one of the dominant and powerful tools used to reveal deeply the hidden causes of process variation. These DOE techniques are very useful for surfacing the effect of hidden variables during process design and development stage. Experimental techniques range from randomly introduced uncontrollable factor to carefully controlled factors.

BASIC PRINCIPLES OF DOE

There are three basic principles of experimental design, which are randomization, blocking and replication.

i) Randomization

In a good experiment design, the treatments have to be assigned to the experimental units in such a way that no treatment is consistently favoured by being placed under the best conditions. The process of randomization can do this. The reasons for randomization in an experimental design are to eliminate bias and ensure independence among the observations. Randomization ensures that no treatment is favoured or discriminated against by systematic assignment of units in a design.

ii) Blocking

Blocking is associated with the need to perform experiments in groups of runs. Suppose the raw material for the system comes from a batch process. If it is suspected that, all other factors being the same, different batches will lead to different levels of the experiment's responses, and then blocking would be appropriate.

iii) Replication

Replication means a repetition of the basic experiment. Replication helps to obtain an estimate of the experiment error. This estimation of error becomes a basic unit of measurement for determining whether observed differences in the data are really statistically different. If the sample mean is used to estimate the effect of a factor in the experiment, then replication helps to obtain a more precise estimate of this effect (Douglas, 1991).

APPLICATION OF DESIGN OF EXPERIMENT

DOE (Design of Experiments) provides a powerful means to achieve breakthrough improvements in product quality and process efficiency. From the viewpoint of manufacturing fields, this can reduce the number of required experiments when taking into account the numerous factors affecting experimental results. Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. This information is needed to manage process inputs in order to optimize the output. DOE can show how to carry out the fewest number of experiments while maintaining the most important information.

RUN OF EXPERIMENT

The experiment must be done carefully to get the best data before proceed to analyse it. Before conducting the experiment, a brainstorming had been performed as an integral part in designing the best and effective experiments. It was used to determine the parameters, response and strategy involved in the experiment. At the same time, it ensures that the experiment achieves the objective and satisfied company needs. It means, to conduct a successful experiment, an appropriate and correct strategy needed. The 24 design of experiment was conducted because the four factors have contribution to the result of broken nut based on subject matter expert. The 24 factorial design that is, a design with four factors each two level which can be define as low level and high level. The limitation chance to run the experiment causes the experiment done with single replication. 16 different settings of the machine will be applied to the machine to get the best setting for the machine.

PARAMETER SELECTION

a) Process temperature

The temperature of the process must be control when run the machine. The temperature can give effect to the nut and the crude oil. High temperature can cause the nut easy to break.

b) Cone angle

Cone angle is the angle of the muzzle of the cone. This muzzle will apply the pressure to the fruitlet. At the machine, there are three level value of cone angle. It can



be change with the functional button at the machine to change the setting.

c) Cone pressure

Cone pressure is the pressure applied by the cone to the fruitlet to split the nut and the crude oil. This pressure must be control because high cone pressure can increase the value of broken nut but if the pressure is too low, it will reduce the amount of crude oil.

d) % of Water

At press machine, there is a valve that controls the percentage of water enter the machine system. The function is to avoid the mixture of the nut and the crude oil is not dry. % of broken nut will increase if the % of water is low. But if the % of water is high, the probability the machine will stuck can be increase.

PARAMETER SETTINGS

For the experiment designed, each factor is set at two levels, that is, high level (1) and low level (-1). The selected plastic injection machine runs the process under the profile setting. Each profile setting may consist of more than one reading. The profile setting for each factor is shown in Table-1. The analysis and model fitting for 2k factorial design in this study using coded design variables 1 and -1, and not the design factors in the original unit. Coded variables are very effective for determining the relative size of factor effects. Table-1 shows the parameter settings:

Table-1. Parameter settings for experiment.

Term	Factor	Low Level		High Level	
		Uncoded	Coded	Uncoded	Coded
A	Temperature	75°C	-1	85°C	1
B	Cone angle	105°	-1	135°	1
C	Pressure	30Bar	-1	40Bar	1
D	% water	15	-1	25	1

PILOT RUNS FOR EXPERIMENTS

The total numbers of treatment combination are 16. All of the setting runs with randomization. Randomization is the design technique used to guard against such a lurking nuisance factor. The nuisance factor must be avoid or eliminate to ensure it's not contribute to the experiment.

The output was segregate between the broken nuts and unbroken nuts. The result for output response measured by weighing the broken nut based on sample 1500 gram taken after the experiments conducted.

Table-2. Pilot run for experiments.

Std Order	Run Order	A	B	C	D	Broken Nut (g)
15	1	-1	1	1	1	90
3	2	-1	1	-1	-1	68
13	3	-1	-1	1	1	85
7	4	-1	1	1	-1	100
4	5	1	1	-1	-1	85
14	6	1	-1	1	1	106
10	7	1	-1	-1	1	120
2	8	1	-1	-1	-1	91
11	9	-1	1	-1	1	65
16	10	1	1	1	1	116
12	11	1	1	-1	1	124
9	12	-1	-1	-1	1	63
8	13	1	1	1	-1	85
1	14	-1	-1	-1	-1	65
6	15	1	-1	1	-1	80
5	16	-1	-1	1	-1	88

NORMALITY TEST

Normality test usually conducted when a set of data is available for analyse to ensure that the sample of data taken represent the population of data. . From the result gain, the normality test was carried out using Anderson Darling Test and show that the P-value is 0.325 which is greater than 0.05. Thus, the data is normal since there is no significance different between the actual data with the ideal data. Figure-2.0 show the normal probability plot for broken nuts:

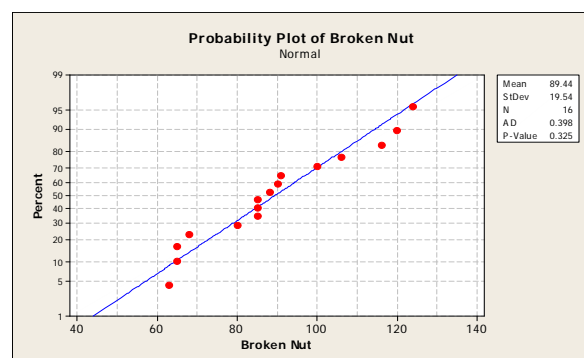


Figure-2. Normal probability plot for broken nuts.

A SINGLE REPLICATION OF THE 2⁴ DESIGN

The experiments conducted using single replication due to resources is limited. The number of replicates that the experimenter can employ may be restricted. The single replicate sometimes called an unreplicated factorial whereby there is no internal estimate of error (or "pure error"). A method can be used to overcome this problem has been introduced by Daniel (1959) who suggests examining a normal probability plot



of the estimates of the effects. The effects are negligible are normally distributed with mean zero and variance will tend to fall along a straight line on data plotted. Figure-2 show the normal probability plot for effect estimates.

Referring to the normal probability plot, there are only three main effects and two interactions are significant which are effects A, C, D, AC and AD. All of the effects that lie along the line are negligible, whereas the large effects are far from the line. Since the B (Cone Angle) is not significant and all interactions involving B are negligible, the parameters can be discarded from the experiments so that the design becomes a 2³ factorial in A, C and D with two replicates.

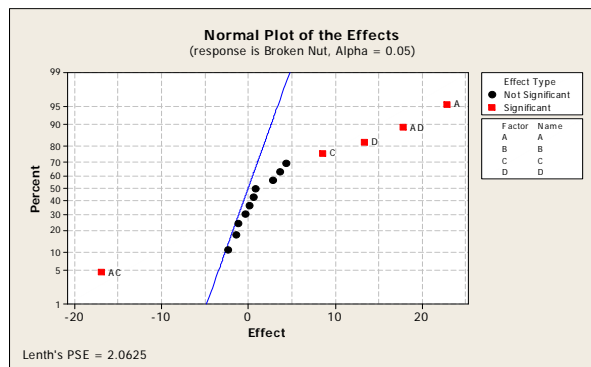


Figure-3. Normal probability plot for effects estimates.

ANALYSIS OF VARIANCE (ANOVA)

The transformation of design projection from 24 to 23 allows verification of the result thru ANOVA. The significant factor which has been identified earlier using normal probability plot for effect estimates can be verified using ANOVA.

Table-3. Table of ANOVA.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	3	3106.19	3106.19	1035.40	46.15	0.000
A	1	2093.06	2093.06	2093.06	93.28	0.000
C	1	297.56	297.56	297.56	13.26	0.007
D	1	715.56	715.56	715.56	31.89	0.000
2-Way Interactions	3	2439.69	2439.69	813.23	36.24	0.000
A*C	1	1139.06	1139.06	1139.06	50.77	0.000
A*D	1	1278.06	1278.06	1278.06	56.96	0.000
C*D	1	22.56	22.56	22.56	1.01	0.345
3-Way Interactions	1	0.56	0.56	0.56	0.03	0.878
A*C*D	1	0.56	0.56	0.56	0.03	0.878
Residual Error	8	179.50	179.50	22.44		
Pure Error	8	179.50	179.50	22.44		
Total	15	5725.94				

Base on the table of ANOVA, the result from normal probability plot is justified with three main effect are significant and two interactions also significant.

MAIN EFFECT PLOT AND INTERACTION PLOT

The main effects plot is used to determine which level (1 / -1) of the factor would affect the response output and to compare the relative strength of the effects. The

main effects of A, C and D are positive. If considered only those main effects, the optimal setting will be low level to minimize the broken nuts. Figure-4 show the main effect plot for each individual's factors.

However, from the table ANOVA indicates that there are two interactions significant, it is always necessary to examine any interactions that are important. Remember that main effects are meaningless when they are involved in significant interactions. Figure-5 show the interaction plot for broken nuts.

Referring to AC (Temperature & Cone Pressure) interaction, the lowest mass of broken nut happen when the process temperature is at low level and the cone pressure is low level. Referring to AD (Temperature & % of water) interaction, the lowest mass of broken nut happen when the process temperature is at low level and the cone pressure is at high level. Therefore, the best parameters setting to reduce the mass of broken nuts would appear to be obtained when A and C are at low level and D at high level.

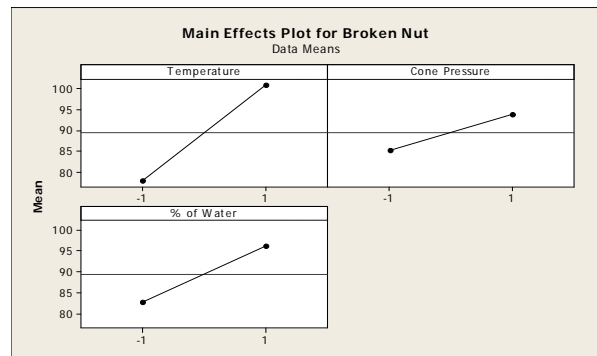


Figure-4. Main effect plot for broken nuts.

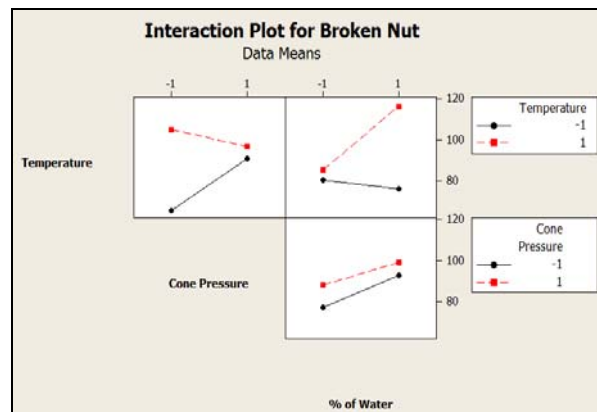


Figure-5. Interaction plot for broken nuts.

REGRESSION ANALYSIS

Regression analysis is used to predict a continuous dependent variable from a number of independent variables. This method can give predictive output response when there are changes on input variables.



The regression equation is

$$\text{Broken Nut} = 89.4 + 6.69 \% \text{ of Water} + 4.31 \text{ Cone Pressure} + 11.4 \text{ Temperature}$$

Predictor	Coef	SE Coef	T
Constant	89.438	3.694	24.21
% of Water	6.688	3.694	1.81
Cone Pressure	4.313	3.694	1.17
Temperature	11.438	3.694	3.10

Based on the regression model, the value of broken nuts is significantly increased when value of temperature is increase.

CONCLUSIONS

In conclusion, the objective of the study was achieved whereby the best parameters setting were identified thru the adoption of DOE. A full factorial with single replication experiments used in this study successfully identifies the significant parameters and optimal setting. The optimal setting are recommended as low level for process temperature, low level for cone pressure and high level for percentage of water while cone angle doesn't reflects too much on output response, mass of broken nuts. The adoption structured experiments was significantly important when there is limitation of the resources and number of experiments can be conducted.

FUTURE RECOMMENDATION

In order to get a better and more accurate result, the replication must be considered. More replication gives more accurate result. The error can be reduced when the replication is increase. Confirmation of experimental material from one batch size is important to minimize the variation in experiment. Use full factorial design is there are no constraints in time and resources. The result obtained through DOE should compare to other engineering approaches to verify the experiment error. We can conclude that the model is good and capable of representing the process with a low amount of error. The result also can be validate by add replication during conduct the experiments in order to have 'pure error' instead of have estimate error. There are also another method for analyzing unreplicated factorial which is Lenth (1989). Hamada and Balakrishnan (1998) has recommended Lenth method since the method has good power to detect significant effects. Lastly, after obtaining the optimal settings and predicted output response, a series confirmation runs need to conduct 'as similar as possible' situation as when the experiment was conducted.

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