

DESIGN FACTORS AFFECTING LOSSES OF AN AXIAL FLOW CORN SHELLING UNIT

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ABSTRACT

The objective of this research was to study the design factors of the axial-flow corn shelling unit affecting losses and power consumption, which comprised peg tooth clearance (PC), concave rod clearance (CR), and concave clearance (CC). The experiments were conducted based on Response Surface Methodology (RSM) and Central Composite Design (CCRD). The results of this study PC, CR, and CC were found to have significant impact on the shelling unit loss, but not statistically kernel breakage. Increase in PC and CC or decreasing CR had a trend to increase shelling unit loss. Empirical models with R^2 of 0.92, was constructed based on multiple linear models to define the behavior of the shelling unit loss.

Keywords: corn shelling unit; peg tooth clearance; concave rod clearance; concave rod clearance

INTRODUCTION

Corn as an animal is a field crop and very important for Thai animal feed industry, Thailand has productivity of roughly 1.2 million ha of corn plantation, with average yield 4.4 tons per ha and a total yield of over 5.3 million tons (OAE, 2012). Presently, corn shelling is generally done using the corn shelling machine. The use of axial flow threshers should be modified in some of the parts (Tongsawatwong et al., 2003).

Kunjara et al. (1998) conducted an experiment on a sheller with rasp bar sheller and peg-tooth sheller. The both sheller are highly efficient, shelling unit loss and kernel breakage was less than 1.5%. Nevertheless, the rasp bar sheller found the following defects of broken crop remaining on the concave reduced the separating of kernel. The peg-teeth sheller power consumption and shelling drum speed were double that of rasp bar sheller. The both sheller are not corn husker sheller. Changrua. (1999) developed an axial flow shelling unit of corn husker sheller. Efficiency was rather high, but shelling capacity was not good. Corn ears also remained short time in the shelling unit, resulting in less shelling than it should be.

Department of Agriculture. (1996) improved and developed a shelling unit for corn husker sheller. This shelling unit was

modified from a wheat threshing unit. Efficiency is relatively high, but kernel breakage is also high. An axial flow rice thresher was also modified to shell corn. This machine has a high efficiency and cleaning, with little kernel breakage. The axial flow rice thresher has been adjusted to shell corns because it is easy to modify, economical, and can add to the advantages of the axial flow rice thresher (Chuan-udom, 2013).

Moreover, the axial flow shelling unit principle is suitable for Thailand and Asian countries' condition (Chuan-udom, 2011, Singhal and Thierstein, 1987). The threshing unit feature of Thai axial flow rice combine harvester affecting threshing unit losses when harvesting Chainat 1 variety were found to concave rod clearance (RC) affected the threshing unit loss (TL) most, followed by the side concave clearance (SC), concave clearance (CC) and upper concave clearance (UC). The number of spike teeth (NT) or peg tooth clearance (PT), rotor diameter (RD) and height of spike teeth (HT) showed relatively low losses by the threshing units (Chuan-udom and Chinsuwan, 2012). Influencing of threshing unit design of axial flow rice combine harvesters on threshing unit loss when harvesting Thai Hommali rice were found to number of spike teeth (NT) or peg tooth clearance (PT)

affected losses most, followed by the side concave clearance (SC), upper concave clearance (UC) and concave clearance (CC). The concave rod clearance (RC), rotor diameter (RD) and height of spike teeth (HT) showed relatively low losses (Chuan-udom and Chinsuwan, 2011).

In modifying the axial flow threshers to shell corn, the threshing unit is the most important component affecting the thresher's capacity (Chuan-udom, 2013). This research was aimed to study the effects of design factors of the axial flow corn shelling unit on losses.

MATERIALS AND METHODS

1. Corn Shelling Unit

This study was conducted using the axial flow corn shelling unit, provided by the Agricultural Research Development Agency (Public Organization) in Figure 1. The shelling unit was 0.90 m long, with a diameter towards the end of the peg tooth of 0.30 m, with controllable rotor speed. The axial flow corn shelling unit is spike-tooth cylinder. The concave portion which is under the cylinder, is made of curved steel bar. The guide vane inclination could be adjusted. The chutes for kernels under shelling unit divided into 1-9. Conveyor belt could be controllable feed rate of the materials into the shelling unit.



Fig.1 Corn Shelling Unit

2. Materials and controlling factors

This study was performed with Pioneer B-80 variety. The moisture contents of kernels, husks, and cobs were 12.35 %wb 15.16 %wb

and 15.56 %wb, respectively. The rotor speed was 9.64 m/sec (400 rpm), corn feed rate was 1,500 kg/hr. The experiments were performed in a laboratory.

3. Factors studied and experimental

The important design factors that affected losses of an axial flow corn shelling unit were comprised of PC, CR, and CC, as shown in Table 1. Since there were many factors and degrees, the factorial experiment design necessitated a great quantity of materials and experimental units. Thus, the CCRD design was applied, as shown in Table 2, for it allowed reduction of the use of materials and time for testing (Berger and Maurer, 2002).

Table 1 Independent variable and there factor level.

variable	(-2)	(-1)	(0)	(1)	(2)
PC (mm)	25.4	50.8	76.2	101.6	127.0
CR (mm)	15	20	25	30	35
CC (mm)	10	15	20	25	30

Table 2 Experiments unit according to CCRD for losses of an axial flow corn helling unit.

Expt. no.	PC, mm	CR, mm	CC, mm
1	25.4 (-2)	20 (0)	25 (0)
2	50.8 (-1)	15 (-1)	20 (-1)
3	50.8 (-1)	15 (-1)	30 (+1)
4	50.8 (-1)	25 (+1)	20 (-1)
5	50.8 (-1)	25 (+1)	30 (+1)
6	76.2 (0)	10 (-2)	25 (0)
7	76.2 (0)	30 (+2)	25 (0)
8	76.2 (0)	20 (0)	15 (-2)
9	76.2 (0)	20 (0)	35 (+2)
10	101.6 (+1)	15 (-1)	20 (-1)
11	101.6 (+1)	15 (-1)	30 (+1)
12	101.6 (+1)	25 (+1)	20 (-1)
13	101.6 (+1)	25 (+1)	30 (+1)
14	127.0 (+2)	20 (0)	25 (0)
15	76.2 (0)	20 (0)	25 (0)
16	76.2 (0)	20 (0)	25 (0)
17	76.2 (0)	20 (0)	25 (0)

4. Testing method

The samples taken from husks and cobs outlet was screened until only corn kernel remained and the weight of the kernel, visual analysis of the shelling unit loss (TL). To obtain the percentage of kernel breakage (GB), samples of 2 kg were randomly chosen from the chutes 1-9, GB were separated by hand and the weight of GB was recorded.

5. Data analysis

From the obtained parameters, the terms affecting amount of TL and GB in the construc-

tion of multiple line model. Then the models were applied in analyzing the effects of parameters on the losses based on the Response Surface Methodology (RSM) and Central Composite Design (CCRD), determining the effect of each parameter on the coefficients of determination (R^2) by using Design Expert® Version 7.

6. Indicator values

The indicator values consisted of TL and GB were computed based on the procedure for evaluation of corn shellers (RNAM, 1995).

RESULTS AND DISCUSSION

The effects of peg tooth clearance (PC), concave rod clearance (CR), and concave clearance (CC) on shelling unit losses (TL) and kernel breakage (GB), as shown in Table 3.

Table 3 Effects of PC, CR and CC on TL and GB.

Expt. no.	PC, mm	CR, mm	CC, mm	TL (%)	GB (%)
1	25.4	20	25	1.20	0.38
2	50.8	15	20	4.02	0.41
3	50.8	15	30	5.43	0.42
4	50.8	25	20	1.39	0.33
5	50.8	25	30	3.18	0.34
6	76.2	10	25	14.06	0.36
7	76.2	30	25	2.04	0.39
8	76.2	20	15	1.64	0.41
9	76.2	20	35	9.68	0.37
10	101.6	15	20	4.69	0.37
11	101.6	15	30	7.78	0.35
12	101.6	25	20	2.49	0.34
13	101.6	25	30	4.75	0.40
14	127.0	20	25	9.89	0.40
15	76.2	20	25	5.28	0.40
16	76.2	20	25	5.01	0.41
17	76.2	20	25	4.73	0.45

From Table 3, the data was used in analysis of variance for regression equation of design factors affecting TL and GB. Following are the results:

1. Effects of PC, CR and CC on TL

Analysis of optimal model of design factors affecting of shelling unit loss, shown in Table 4. Sequential Model Sum of Squares, select the highest order polynomial where the additional term are significant and the model is not aliased. Model Summary Statistics, focus on the model maximizing the Adjusted R^2 and the Predicted R^2 (Saikew and Chillapat, 2006). The results indicate that linear model was found to have significant and maximizing the Adjusted R^2 and Predicted R^2 .

Table 4 Analysis of optimal model of design factors affecting of shelling unit loss by using CCRD.

Source	SS	df	MS	F	p	
Sequential Model Sum of Squares						
Mean vs Total	447.7	1	447.70			
Linear vs Mean	144.1	3	48.02	12.54	0.00	suggeste
2FI vs Linear	0.62	3	0.21	0.042	0.99	
Quadratic vs 2FI	10.37	3	3.46	0.62	0.62	
Cubic vs Quadratic	24.35	4	6.09	1.26	0.44	aliased
Residual	14.45	3	4.82			
Total	641.5	17	37.74			
Source	Std. Dev.	R^2	Adj. R^2	Pre. R^2	PRESS	
Model Summary Statistics						
Linear	1.96	0.743	0.684	0.497	97.50	suggeste
2FI	2.22	0.746	0.5942	-0.01	195.47	
Quadratic	2.35	0.799	0.5425	-0.64	319.08	
Cubic	2.19	0.925	0.6024	-14.8	3072.2	aliased

Table 5 Analysis of variance design factors affecting of shelling unit loss.

Source	SS	df	MS	F	p	
Model	144.1	3	48.02	12.54	0.000	significant
PC	33.26	1	33.26	8.68	0.011	
CR	72.89	1	72.89	19.03	0.001	
CC	37.92	1	37.92	10.36	0.008	
Residual	49.79	13	3.83			
Lack of Fit	49.64	11	4.51	58.81	0.017	significant
Pure Error	0.15	2	0.077			
Correlatio	193.9	16				
n Total						

From Table 5, design factors affecting of shelling unit loss were analysis of variance. The results indicate that PC, CR, and CC significantly affected on shelling unit loss, with the P-values < 0.05. The regression equation determined the effect of design factors on shelling unit loss as shown in equation (1) with R^2 value equal of 0.92.

$$TL = 2.762 + 0.033PC - 0.202CR + 0.096CC \dots(1)$$

From Equation (1), Response surface plot of shelling unit loss (TL) showing the effect of PC, CR and CC (Figures 3, 4, and 5).

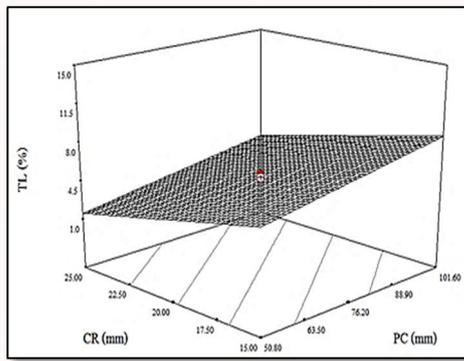


Fig.2 Response surface plot of shelling unit loss (TL) showing the effect of peg tooth clearance (PC) and concave rod clearance (CR), when concave clearance (CC) was 25 mm.

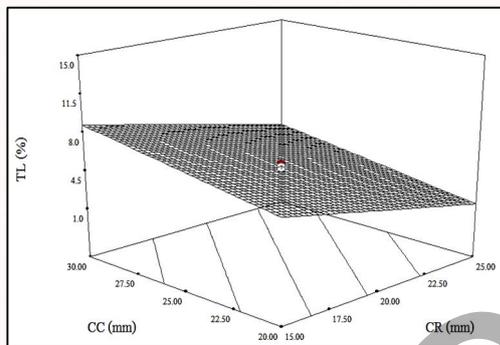


Fig. 3 Response surface plot of shelling unit loss (TL) showing the effect of concave clearance (CC) and concave rod clearance (CR), when peg tooth clearance (PC) was 76.20 mm.

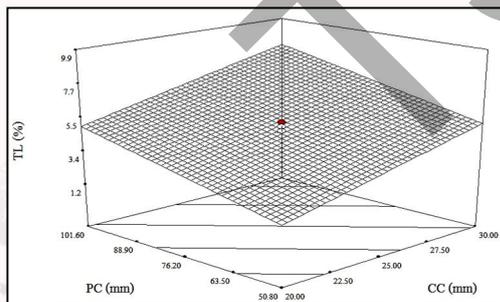


Fig.4 Response surface plot of shelling unit loss (TL) showing the effect of peg tooth clearance (PC), concave clearance (CC), when concave rod clearance (CR) was 20 mm.

From Figures 3 and 4, increase in concave rod clearance (CR) has a trend to reduced shelling unit loss. This correlated to the research by Norris and Wall. (1986), i.e., when concave rod clearance (CR) increased, shelled kernel ease of through the concave, decreasing shelling unit loss (Chinsuwan at al., 2003, Chuan-udom, 2013).

The increase in peg tooth clearance (PC) meant fewer number of spike teeth results in a tendency for shelling unit loss (TL) to increase because reduced shelling (Chuan-udom and Chinsuwan, 2012, Waingwisad at al., 2011), as shown in Figures 3 and 5.

From Figures 4 and 5, increase in concave clearance (CC) has a trend to increased shelling unit loss because the clearance between spike teeth and concave results a trend to reduced shelling (Chuan-udom, 2013, Joshi and Singh, 1980, Rostami at al., 2009, Petkevicius at al., 2008).

2. Effects of PC, CR and CC on GB

From Table 6, analysis of optimal model of design factors affecting of kernel breakage. The results indicate that PC, CR and CC did not affect kernel breakage.

Table 6 Analysis of optimal model of design factors affecting of kernel breakage by using CCRD.

Source	SS	df	MS	F	p
Sequential Model Sum of Squares					
Mean vs Total	2.50	1	2.50		suggeste
Linear vs Mean	4.649	3	1.550	0.11	0.949
2FI vs Linear	4.377	3	1.459	1.11	0.390
Quadratic vs 2FI	4.035	3	1.345	1.03	0.435
Cubic vs Quadratic	5.740	4	1.435	1.27	0.438
Residual	3.380	3	1.127		
Total	2.52	17	0.15		
Source	Std. Dev.	R ²	Adj. R ²	Pre. R ²	PRESS

Model Summary Statistics					
Linear	0.037	0.026	-0.19	-0.56	0.028
2FI	0.036	0.269	-0.17	-1.57	0.046
Quadratic	0.36	0.493	-0.15	-2.75	0.067
Cubic	0.034	0.812	-0.00	-26.2	0.49

CONCLUSION

1. Peg tooth clearance (PC), concave rod clearance (CR), and concave clearance (CC) significantly affected on shelling unit loss, but not on kernel breakage.

2. Increase in peg tooth clearance (PC) and concave clearance (CC) or decrease in concave rod clearance (CR) tends to increase total loss from the shelling unit.

3. The linear model was optimal model of design factors affecting of shelling unit loss (TL) equals to $2.762+0.033PC+0.202CR-0.096CC$ with R^2 of 0.92.

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