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Research article

The Developing and Testing of Rotary Puddler for Secondary Tillage in Rice Production of Thailand

Phakwipha Sutthiwaree[1], Minli Yang[1,2]

1. College of Engineering, China Agricultural University, Beijing 100083, P.R.China;
2. China Research Center for Agricultural Mechanization Development

E-mail: 1579541710@qq.com

Abstract

Rice is the stable food for Thai people and the main production of Thailand. The double or triple cropeach year is commonly carried out in the central plain of Thailand. Traditional secondary tillage used tines attached to a walking tractor. Itwas low efficiency in double or trip crop areas and took a lot of operation times to get theoptimized tillage condition. The hurry on operationis the cause of low qualitythat effected to the yield decreasing. For improving the soil preparation quality and control operation time, the rotary puddler was designed and developed. The prototype was designed for 20 kW riding type tractor,it has 2.4 meter effective working width. The prototype was tested in Thailand's paddy field condition of irrigated areas in the central plain. Result shown the average effective field capacity, field efficiency, fuel consumption and the puddling index were 0.5 ha/hr, 84.2 percentage, 9.9 liter/ha and 62 percentage respectively. The testing resulted was not effected to the hard pan layer of paddy field as the average soil hardness that measured from cone index shown 7.6 cm. The machinery operation cost was analyzed, the breakeven point was 79 ha a year working area in cause of 11,667 US$ tractor purchased price and 1,167 US$ rotary puddler purchased price. The equipment is advantage and acceptable for promotion and extension to farmer in double or triple crops area in Thailand.

Keyword: secondary tillage, rotary puddler, rice production, Thailand

1 Introduction

Rice is the stable food for Thai people and it is the main crop which provides more than 4,000 million US$ in 2012[1]. Thai's rice market has been 35 % of the world rice market sharing. Rice production was 19% of agricultural gross domestic production. The total cultivated areas are reached up to 13.3 million ha in 2012. The total production is 39.2 million ton[2]. There are 47 % of rice production was exported and 53 % left for domestic consumption. The good quality in land preparation is one of the importance factor can increase rice production. According to the purpose of soil preparation for paddy field[3]; ① fine the soil granules on the surface about 15-20 cm in thickness and maintain the soil hard plan layer,② kill the weed. The hard pan layer is importance for the paddy filed; it is useful for maintaining the nutrient of fertilizer and good management on watering control which directly effect to the yield. The soil preparation on paddy field must operate two step; first step is primary tillage purpose on brake the hard soil, refine the big granule and kill insect, disease and weed which remain from the last crop, second step is puddlering the soil on surface, refine the small particle

compound with the water to be the good condition mud. The soft and fine mud are optimize for transplanting. The equipment for the secondary tillage is importance for this work. The double-triple crops limited in time of soil operation, the existing secondary tillage equipments are not enough efficiency for rice practice in this region. For improve work efficiency on land preparation, respond the farmer's requirements in rush operation time and develop the new technology equipment for land preparation of the paddy field in Thailand. The rotary puddlering attached to the middle size riding type tractor for the secondary tillage in rice production need to develop and test in Thai paddy field condition.

2 Review of literature

The rice production system in Thailand can be divided in two systems. The first one is the rain-fed area which commonly practices on manual transplant or dry broadcast (or direct seeding) which has two series① row dipping type ② sowing type[. The second is the irrigated area which commonly practices on wet broadcast (need to prepare the seedling) or mechanized transplant. The irrigated area is 21 % of total cultivated area which cover about 4.5 million ha. There are 50 % of total cultivated area (21 million ha) is used for the paddy field. The paddy field in the irrigated area commonly practices in wet broadcast planting system or the other name is called "slough water paddy field". The seedling was germinated before planting. Since 1962 the research on new theory of the slough water paddy field has been developed for increasing the yield per area for irrigated paddy field. Due to the multi-cropping in this area, the new theory of slough water paddy field was successful in 2 times a year or 5 times in two years practice. The advantage of the new theory of slough water paddy field is benefit on mechanization, reduce labor cost, reduce operating time and decrease the investment. The good benefit on rice production depend on the good practice on soil preparation, good management on plant protection, good practice on harvest and post harvest operation. The optimize operation time for the paddy field in Thailand followsin Table 1.

Table 1: the optimize operation time for rice production in Thailand condition [2]

Yearly crop	Duration
Single crop	20 August-30 November
Double crop	First crop :20 August-30 November Second crop:20 December-30 March
Triple crop	First crop :20 August-30 November Second crop:20 December-30 March Third crop :20 April – 30 July

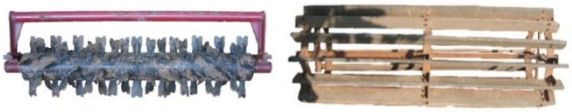
According to the paddy cultivated method, commonly the soil preparation was operation in two steps;

First step, primary tillage commonly uses moldboard plow or rotary attached to the riding or walking tractor. After finished the primary tillage, the soil will left for drying before second tillage. The objective of dry the soil is for killing some weed and some insect.

Second step, secondary tillage commonly uses harrow attached to the riding or walking tractor. After the good condition soil prepared the soil should be leveled.

As the above mention that the processing of soil preparation carries a period of times which is the main problem of the multi-crop planting system in Thailand. During to the soil preparation period, the farmers need to quickly finish the soil preparation due to the irrigation management.

The local secondary tillage equipment had been developed in two types as the follow; ①spike tooth type show as figure.1 (a) ②rolled wheel type show as figure.1(b)



(a) (b)

Picture resource: C. Anuchit. 2005. survey study on rice mechanization of Thailand

Figure1. (a) The local spike tooth type (b) The local rolled wheel type

The irrigated area optimize for multi-crop paddy practice. The good quality of soil preparation must take a lot of time especially in the secondary tillage that commonly practice at least 3 rounds tillage with the local

equipments. The new type of secondary tillage equipments need to be developed for supporting the paddy cultivation in the irrigated area. Works in this area are related to the working time; new technology will release operation time and done on the good quality of soil preparation. The new technology of soil prepared equipment should be developed according to the suitable on Thai paddy field condition and should be a simple structure that can promote to the local manufacturer.

3. Materials and Methods

After the prototype of rotary puddler was designed for 20 kW tractor, The prototype testing was done following the paddy field condition in the central of Thailand. The prototype was tested and collected data for the following analyze reference RNAM Test Code & Procedures for Farm Machinery technical book.

3.1The soil property was measured from the following factor.

The Soil hardness index was measured by the cone penetrometer operated before and after running. The cone penetration force was measured at each 5cm soil depth from 0-50 cm.

The strength of puddling at the soil surface was done by dropping the 3 cm diameter cone in both before and after testing. The strength of puddling was recorded from the depth of the dropped cone.

The puddling index was determined from the ratio of volume of sampling puddle soil before and after running[4]. The puddling index is the percentage of ratio of 48 hours of the precipitate puddlered soil's volumes and total puddlerd soil's volume which sampling was done after testing. The calculation follows the equation (a)

$$PI=\frac{V_t-V_p}{V_t}\times 100 \qquad (a)$$

PI =Puddlering Index (percentage)
V_t = The volume of the sampling before precipitate
V_p = The volume of the sampling after precipitate

3.2 The machinery efficiency was measured from the following factor [5].

The effective field capacity is the time consumed for real work and that lost for other activities such as turning, loading and unloading and adjustment on field crop. The calculation follows equation (b)

$$EFC=\frac{A}{T_p+T_l} \qquad (b)$$

EFC= Effective field capacity (ha/hr)
A = Covered area ha
T_p = Productive time hr
T_l = Non-productive time hr

The working capacity is reciprocal to effective field capacity. The calculation follows equation (c)

$$WC=\frac{1}{EFC} \qquad (c)$$

WC= Working capacity (hr/ha)

The field efficiency gives an indication of the time lost in the field and the failure to utilize the full working width of the machine. The calculation follows equation (d)

$$Ef=\frac{W_e\times V_e\times T_p}{W_t\times V_t\times (T_{p+T_l})} \qquad (d)$$

Ef = Field efficiency %
We = Effective working width m
Wt = Theoretical working width m
Ve = Effective operation speed km/hr
Vt = Theoretical operation speed km/hr

The fuel consumption is observed from the used fuel volume before and after testing. The calculation follows equation (e)

$$FC=\frac{V_b-V_a}{A} \qquad (e)$$

FC = The fuel consumption liter/ha
V_b = The used fuel volume before testing liter
V_a =The used fuel volume after testing liter
The data was analyzed by follow the regional network for agricultural machinery [5]. The operation cost analyses was calculated by using the test data and the investigation data.

3.3 The machinery operating cost analysis follows the below equation.

$$OP = AFc + Vc \quad (f)$$

AFc is annual fixed cost which included Depreciation, interest, insurance, tax and repair and maintenance.

$$\text{Depreciation} = \frac{P-S}{N} \quad (g)$$

P = Purchase price US$
S =Salvage price (10% of purchase price)
N = total life in years

$$\text{Interest} = \frac{P+S}{2} \times \frac{r}{100} \quad (h)$$

R = interest rate (%)

$$\text{Insurance} = \frac{P+S}{2} \times \frac{i}{100} \quad (i)$$

$$\text{Tax} = P \times \frac{t}{100} \quad (j)$$

i =insurance rate (%)
t = tax rate (%)

$$\text{Repair and maintenance} = P \times \frac{m}{100} \quad (k)$$

m = repair and maintenance rate %
Vc= Variable cost is include of fuel and lubricating oil or/and electric power, other expendable and labour cost

$$ABP = \frac{AFc}{(Hs-Vc)} \quad (m)$$

ABP = Annual break even point ha/year
Hs = Hire service cost US$/ha

4. Result and Discussion

4.1 The structure design and development

The prototype was designed with 2 main parts; there were the structure part and the power transmission part.
The structure part: The 2.4 m working width prototype was designed for attaching to the 20 kW tractor. The cage wheel blade type was selected for the prototype. The case wheel type is advance for cultivating on the surface of the soil, bury straw and weed. The trapezium shape blade type was used for case wheel shows as figure 1. The blade assembled 5 units of case wheel, each case wheel consisted of 2 blade stands consisted of 4 blades each stand and 2 blades stands which consisted of 5 blades. The assembly of prototype shows as figure 3.

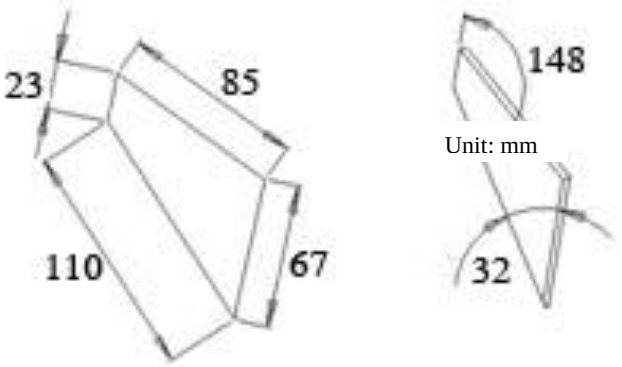
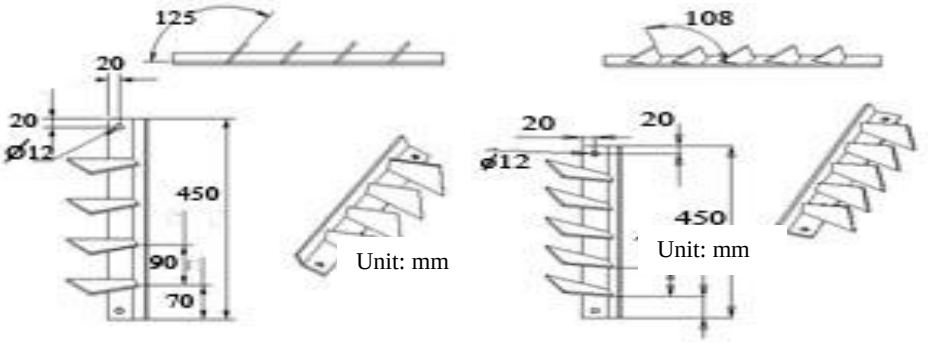


Figure 1: The blade in case wheel type



(a) 4 blades stand (b) 5 blades stand

Figure 2: The assemble of trapezium shape blade type

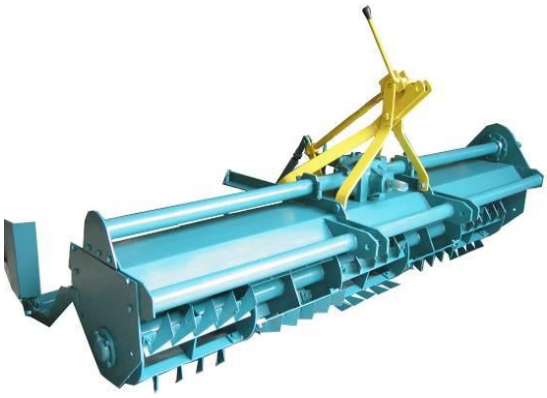


Figure 3: The prototype of puddler

The power transmission part: The power from PTO system was transmitted to 26.1kW gear box. The transmission ratio was 1.46:1, the puddler shaft working speed is 218 rpm. The transmission diagram shows as figure 4.

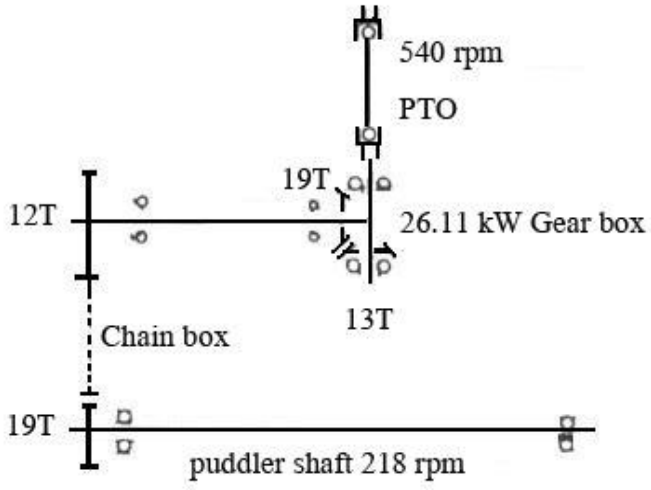


Figure 4 : The puddler transmission system

4.2The field testing analysis

The experiment was done at the central plain in irrigated paddy field. The experimented filed with clay loam and sandy loam was 2 days immersion in water after the primary tillage. The testing result is shown as table 1 and 2.

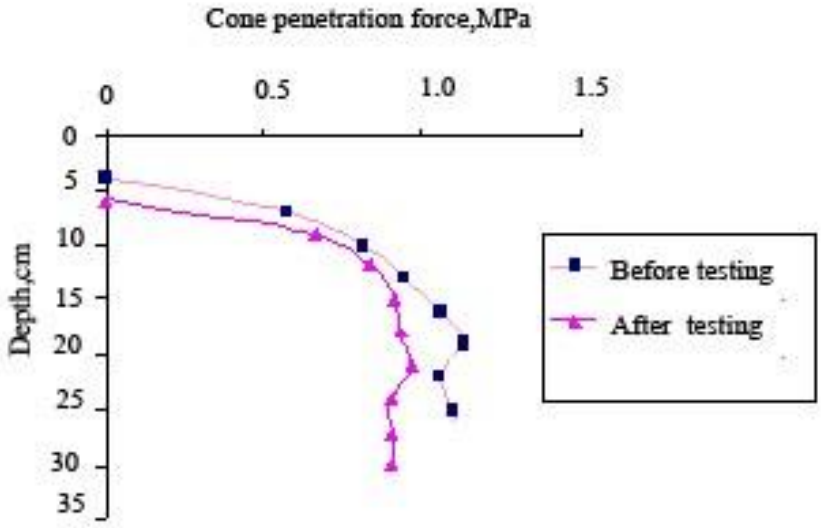


Figure5: The relationship between cone penetrate force and soil depth before and after testing of clay–loam soil

Table 1: Result of testing prototype for clay loam soil

Item	Clay Loam	
	Before testing	**After Testing**
Strengthen Soil (cm.)	6.8	8.1
Travelling velocity (km/hr)		2.2
FEC (ha/hr)		0.4
WC(hr/ha)		2.4
Ef (%)		82.6
FC(lite/ha)		10.8
PI (%)		59.0

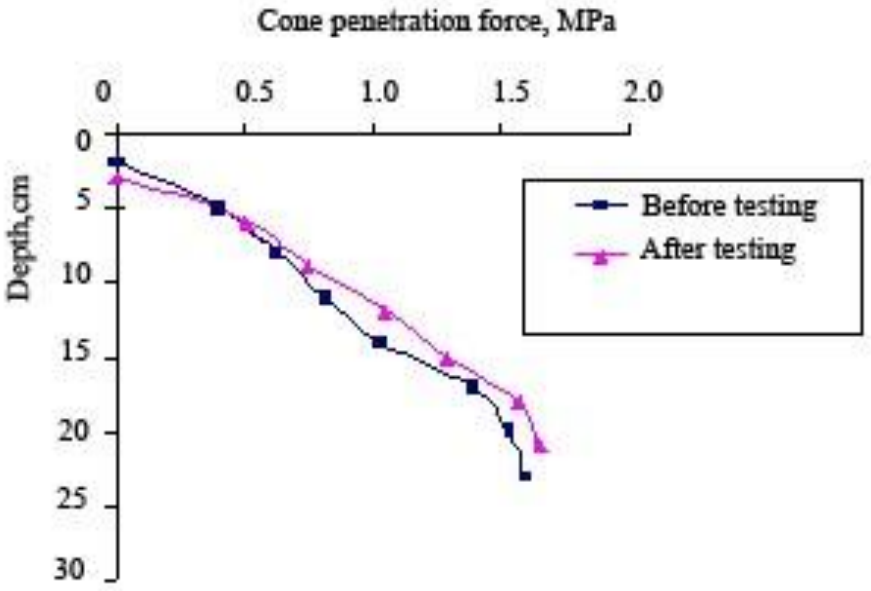


Figure 6: The relationship between cone penetrate meter force and soil depth before and after testing of sandy–loam soil

Table 2: Result of testing prototype for sandy loam soil

Item	Sandy Loam	
	Before testing	After Testing
Soil Strengthen (cm.)	6.9	7.1
Travelling velocity (km/hr)		2.2
FEC (ha/hr)		0.6
WC(hr/ha)		1.8
Ef (%)		85.8
FC(liter/ha)		9.0
PI (%)		64.9

Figures 5 and 6 show that the soil structure was affected from tillage mechanization, it is useful for paddy cultivation where the fineness tilled surface soil and keep the soil hard pan commonly should not lower than 10-15 centimeter that enough for supporting men animal and machine traction force [6]. The soil hardness after testing of clay loam soil and sandy soil were 8.1 and 7.1 centimeter, its mean the machinery do not break the soil hard pan. The clay loam soil field more consumed power than sandy soil field as show 10.8 liter per hectare but the puddlering index of sandy soil was greater than clay loam soil. The equipment had acceptable field efficiency, both type of soil were over than 80 percent.

4.3 The operation cost analysis

The basic data of operation cost analysis follows the table 3. The production cost analyze was shown as figure 7.

Table 3: The basic data of operation cost analysis

Item		
20 kW tractor purchase price	11,667	US$
Life time for tractor	10	year
Field effective capacity	0.5 1	ha/hr
Fuel consumption	9.9	lite/ha
Labor cost	14.3	US$
Working hour per day	8	hrs/day
2.4 m. rotary puddler purchase price	1,667	US$
Life time for rotary puddler	8	year
Interest rate	10	percent
Depreciation- tractor	30	percent of purchase price
-rotary puddler	10	
Repair &maintenance rate-tractor	0.5	percent of purchase price/ 100 hours
-rotary puddler	3	
Hire service cost	31	US$/ha

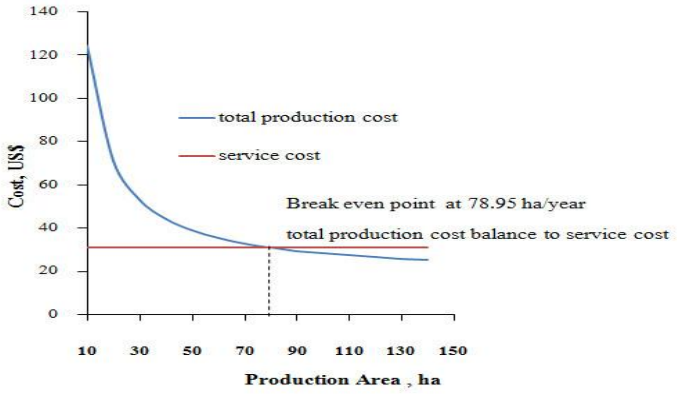


Figure7: The relationship between production cost and production area

The production cost analysis was followed RNAM test codes & procedure for farm machinery. The total operation cost of 20 kW tractor and total variable cost 2.4 meter rotary puddler were 1,066.7 US$ per year and 17.5 US$ per hectare respectively. According to the calculation method the optimum production area for the maximum benefit of mechanization point was 79 hectare per year. According to Thailand's rice cultivation pattern which has three times practice year round, it can be possibility accepted and adopt the rotary puddlerin contract service pattern by 31 US$ per hectare.

5. Conclusions

The prototype of rotary puddler was designed and developed for Thailand's paddy field condition attached to 20 kW tractor. The power of PTO shaft at 540 rpm of tractor was transmitted to 35 hp gear box then transferred to 65 millimeter rotary puddlershaft diameter; it rotates at 218 rpm. The rotary puddler blade was used of 90 units cage wheel type assembled at 45 degree of blade bar. The effective working width was 2.4 meter. The prototype performance testing was done in two conditions of soil in the selected paddy field at the central plain of Thailand where called Rachaburi province. The testing result shown that for clay loam soil the field efficiency, field effectively, fuel consumption and puddlering index were 0.4 ha/hr, 82.9 percentage,10.8 liter/ha and 59 percentage respectively. For sandy soil the field efficiency, field effectively, fuel consumption and puddlering index were 0.6 ha/hr, 1.8hr/ha, 85.8 percentage, 9 liter/ha and 65 percentage respectively. The prototype of rotary puddleris advantage on irrigated paddy field as at the central plain of Thailand, the annual production area should cover at least 79 ha (figure 7). According double or triple crop in this area, the payback period can be done in one year. The prototype is available for promoting and extension to farmer for timely tillage.

References

[1] Thai Rice Exporter Association. (n.d.). Thai rice exporters. Retrieved March 1, 2013, from www.thairiceexperters.or.th/statistic-04.htm.

[2] Official of Agricultural Economic.(n.d.). Retrieved March 1, 2013, from http://www.oae.go.th/.

[3] Claude, C. 1992.Tillage Equipment. In Farm Machinery.pp.56-60.

[4] Sinha, M.P. 1964. A study of the measurement of Puddling and Comparative Performance of Different Implements for Puddling in Rice Cultivation. Food and Agriculture Organization of The United Nations, International Rice Commission, Manila, Philippines. 5 pages.

[5] Kabria S.A.M.S. 1995. RNAM Test Codes&Procedures for Farm Machinery Technical. (series no.12). Bangkok:UNIDO.

[6] Sakai J, Emeritus and Pongsuphasmit S.1998. Reference Book of Two – Wheel Tractors in AGRICULTURAL ENGINEERING HANDBOOK. No. 3, CIGR(English – Thai version). pp.4