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MEASUREMENT OF WETLAND PENETRATION RESISTANCE AT VARIOUS POINTS OF PRESSURE

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Abstract

Traction performance of a cage wheel for two-wheel tractor depended on its shape, dimension, lugs materials and soil condition. In order to get the optimum design of the cage wheel, relation between tractor, implement and soil condition should be considered carefully. The objective of this research was to determine optimum design parameters of cage wheel for the farm field in North Aceh. A computer program for design analysis and for producing engineering drawing of cage wheels. The computer program was developed and employed for the optimization process and for drawing the design result. As a trial of the program, the optimum design parameters of cage wheel were found to be: 75 cm of wheel diameter; 8 lugs; 19 cm × 10 cm of lug size; and 30° of lug angle. The result of field testing (validation) shown that wheel of a tractor using the design was able to work well and it can produce ground-level of muddy better than the standard wheel.

Keywords: cage wheel, design parameter, wet soil

1 Introduction

Hand tractors have an important role in the soil tillage. This is considering that hand tractors and equipment can be owned by farmers because the price is cheap and easy to operate. The use of agricultural tractors, especially hand tractors in paddy fields in Indonesia, has a positive impact, especially in increasing the capacity, efficiency and comfort of work, increasing employee productivity and income, reducing production costs, improving yield quality and reducing fatigue.

The number of hand tractors in 2015 in Indonesia is about 75 thousand units. The amount will continue to increase considering the national need to work on 8.5 million ha of paddy fields in Indonesia, which is about 532 thousand units (Sugondo, 1999). In the NAD region alone the number of hand-operated tractors is about 1000 units. In order to be accepted and satisfied by farmers, the performance of hand tractors should be improved. The hand tractor must be perfectly capable of plowing, stabilizing, and the dynamics of its perfect balance (Sakai et al., 1998).

In order to be accepted by farmers, the performance of hand and plow tractors should be better than traditional livestock and plowing which is a tool commonly used by farmers. Therefore the machine must be able to plow perfectly, stable, the dynamics of perfect balance, and should be operable with the handlebar need not be held. All this can only be realized by engineers who truly understand the traditional plowing and technology principles of an animal-drawn plow and hand tractor technology (Sakai et al., 1998).

The use of hand tractors often faces obstacles such as the lack of tensile strength that tractors can produce to cultivate land and the value of wheel slip, especially in paddy fields. The amount of tensile that the tractor can provide is generally limited by its traction and ground conditions (Gill and Vandenberg 1968). Traction of tractor wheels depends greatly on the dimensions, shapes, and materials of the wheels used and soil conditions.

Traction generated by the tractor wheel should be able to increase the mobility of the tractor on the saturated soil surface and inundated. The finned cage wheel has proven to be one of the best to work on the condition. The use of a finned cage wheel that has not been optimal can cause operators difficult to work and low tractor work efficiency (Hermawan et al., 1998). To obtain the optimum efficiency of the tractor's work, in designing corrugated cage wheels should consider: 1) the type of tractor used, 2) wheel sizes and 3) the type of plow used (Phongsupasamit 1988).

Tractor wheel design with computer-aided design application is needed in optimizing wheel design parameters and automatic drawing. With this system, the efficiency of time and design accuracy can be improved compared to the manual design process. Therefore, the purpose of this study is to measure the optimal design parameters of tractor cage wheels in accordance with the conditions of rice fields in North Aceh District.

2 Methodology

Soil and validation data were collected at a paddy field in three different sub-districts Aceh Utara and Lhokseumawe namely Tanah Pasir Subdistrict, Blang Mangat Subdistrict and Kuta Makmur Sub-district.

2.1 Research Tools

Equipment used in this research is:

1. Measurement instruments of penetration resistance consisting of; 1) penetrometer frame, 2) SR-2 type penetrometer, 3) lug plate, and 4) meter,
2. Computer units for CAD programming and software (AutoCAD 2002, Autodesk ©1982-2000; Delphi 5.0 Borland® Copyright©1994–2006).

2.2 Measurement of penetration resistance to plate presses

Measurement of penetration resistance is performed by using SR-2 type penetrometer. With the help of the frame, a penetrometer is pressed with different pressure angles (α_p) ranging from 30°, 45°, 60°, 75°, and 90°. At the tip of the penetrometer are a plate of 6 mm thick iron lugs with 3 different sizes (5 × 5) cm^2, (7,5 × 5) cm^2 dan (10 × 5) cm^2. Pressure force is measured at ground depth from 2 cm; 4 cm; 6 cm; 8 cm and 10 cm, where the friction occurring between the penetrometer rod with the buffer is negligible, the way of measurement is presented in Figure 1.

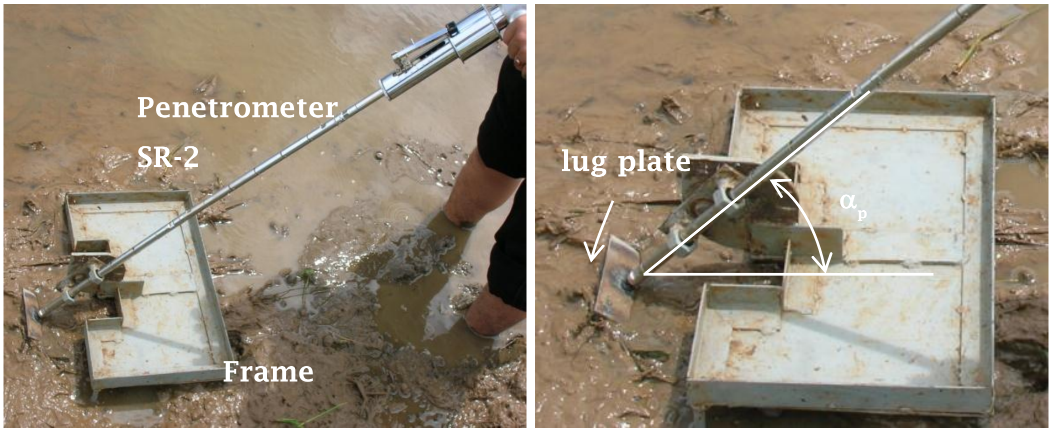


Figure 1 Penetrometer and penetrometer frame, penetration resistance measurement method

Measurement of soil penetration resistance is done on ready-to-plant land. At each location determined 3 different points, and each point is done a measurement of ground resistance with a predetermined angle with the number of repetitions as many as 5 replications. The value of the suppression resistance is calculated by using the following equation:

$$T_p = \frac{F_p}{A} \tag{1}$$

2.3 Optimization of tractor wheel design parameters

The optimized tractor wheel design parameters are wheel diameter, a number of lugs, lug area (length and width of the lug), and lug angle obtained by exhaustive search optimization method based on soil resistance data, tractor construction data, and tensile load. The balance of forces acting on the flipper (Figure 2) is used to determine the cage wheel design parameters. Here is the optimization process step to get the optimum design parameters.

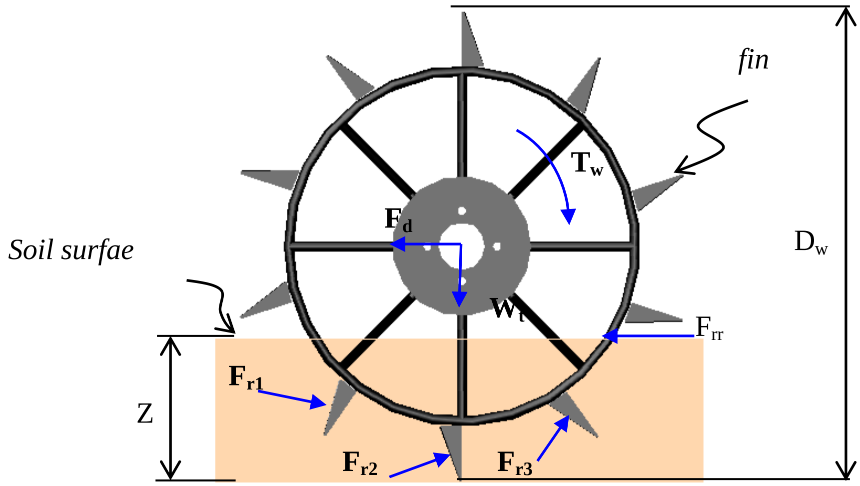


Figure 2 A force scheme that acts on the cage wheel for wheel design parameters

2.3.1 Wheel Diameter

In addition to being determined by the optimum speed of soil tillage (ranging from 0.25 - 1.2 m/sec) with the effect of wheel slip (about 10% - 30%), the wheel size is determined by space constraints on the tractor-implement-land system. The minimum radius (R_w) is determined using the minimum base formation (Figure 3) determined by the following Equation 3.

$$R_w = H_t + H_c + Z \qquad (2)$$

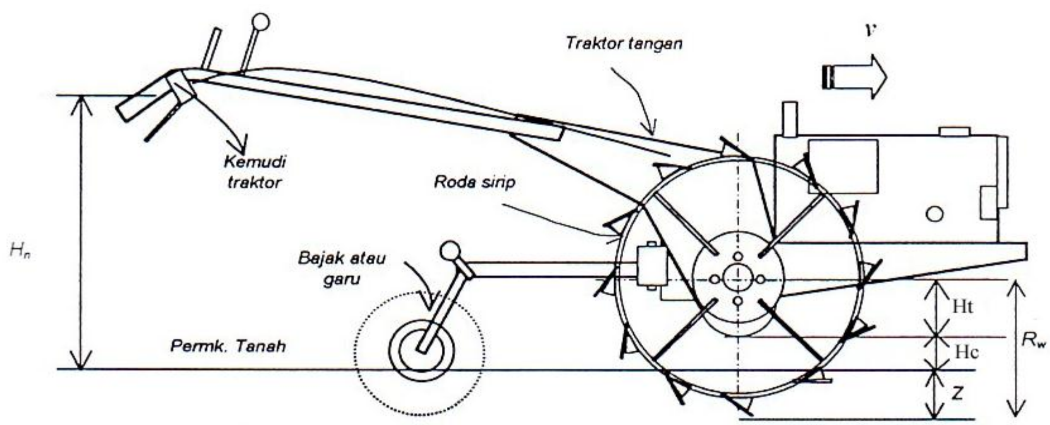


Figure 3 The basic formation of hand tractors in Indonesia

The maximum wheel diameter is based on the wheel-free space available on the tractor by knowing: 1) the center spacing of the wheel axle to the outer edge of the plow, 2) the crank-arm distance to the center of the wheel axle, 3) the distance from the center point of the tractor to the crank arm and 4) the width rotary knife.

2.3.2 Number of lugs

The number of lugs for paddy fields amounts to 8 to 20 pieces. This can be calculated using Equation 5. The maximum number of lugs should be limited because the spacing between the lugs is too narrow will cause the soil and weeds easily trapped between the lugs. The lugs distance (L_s) can be calculated using Equation 3.

$$L_s = \frac{\pi \times D_w}{J_s} \tag{3}$$

2.3.3 Lugs Size

The size of the lugs is determined by the optimization of the wide of the lugs in which the soil reaction force of the lugs is required to overcome the weight of the tractor (vertical direction) and the tensile load and the wheel roll resistance (horizontal direction). In this case, the design must be in accordance with the requirements of Equation 4.

$$F_{rv} > \frac{W_t}{2} \quad \Leftrightarrow \quad F_{rh} > \frac{F_d}{2} + F_{rr} \tag{4}$$

The resultant force of the vertical soil reaction (Equation 7) and the resultant force of the horizontal soil reaction (Equation 8) are obtained by calculating the soil reaction forces in the active wheel lugs acting on the ground.

The number of active lugs (J_{sa}) is calculated by Equation 5.

$$J_{sa} = Js \times \frac{\cos^{-1}\left(\frac{R_w - Z}{R_w}\right)}{180} \tag{5}$$

Resultant forces (F_{r1}, F_{r2}, F_{r3}, ... F_{rn}) are determined based on the result of measurement of soil penetration. This is obtained based on the regression equations of each of the press angle and the depth of press. Rolling resistance is calculated using Equation 9.

$$F_r = \sum_{j=1}^{i=j_{sa}} (A_s.T_{pi}) \quad (6)$$

$$F_{rv} = F_r \cos\alpha \quad (7)$$

$$F_{rh} = F_r \sin\alpha \quad (8)$$

$$F_{rr} = W_t \, C_{rr} \quad (9)$$

The width of the lugs is determined from the horizontal spacing between lugs (S_{hs}) calculated by Equation 10. In design, width lugs is determined $0.55S_{hs}$. Furthermore, the length of the lugs is determined by dividing the width of the lugs by the width of the lugs.

$$S_{hs} = \frac{(1-S)\cdot\pi\cdot D_w}{J_s} \quad (10)$$

The lugs angle in the optimization process, especially in calculating the soil reaction force in the lugs (Figure 4), the angle formed by the surface of the active lugs is calculated by Equation 11. Angle of α_n is used in calculating the soil reaction in lugs. In the optimization process, then obtained an angle of lugs (γ).

$$\alpha_n = \theta_n - \gamma \quad (11)$$

In this design, there are three optimization conditions used are;

1. Decision variable. The optimized variable consists of; 1) wheel diameter, 2) number of lugs, 3) sinkage, 4) lugs angle and 5) lugs wide.
2. Constraint.
    a. Wheel diameter. [D_w = 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100],
    b. Number of lugs. [J_s = {8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20],
    c. Sinkage. [Z = 10, 12.5, 15],
    d. Lugs angle. [γ = 20, 25, 30, 35, 40, 45, 50, 55, 60],

e. Lugs wide. [A_s = 160, 170, 180, 190, 200, 210, 220],
f. The resultant force vertical of soil should be greater than the tractor weight ($F_{rv} > F_{Bt}$)
g. The resultant of horizontal force should be greater than the plow pull resistance plus the rolling resistance [$F_{rh} > F_{im} + F_{rr}$],

3. Objective. The minimum $F_{rv} - F_{bt}$ and F_{rh} - F_{im}+F_{rr}

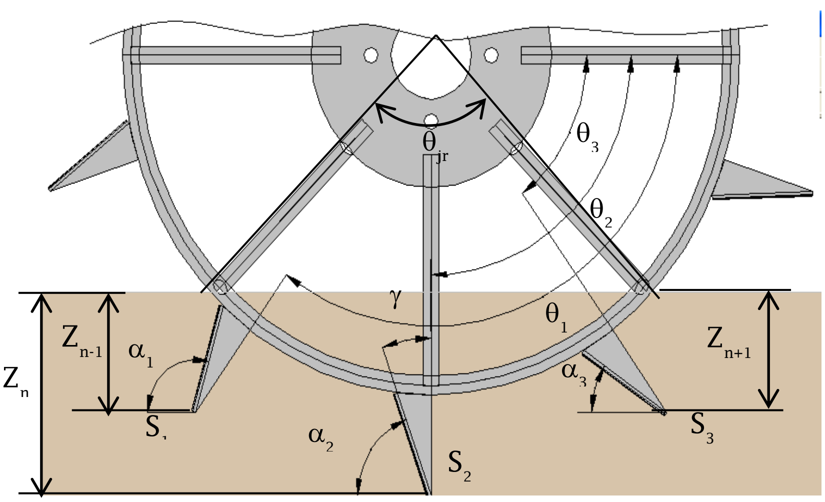
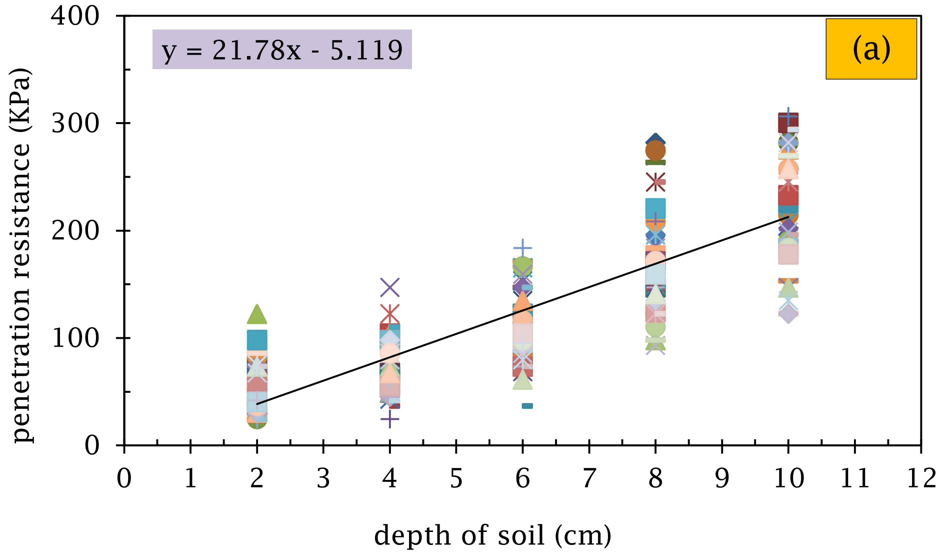
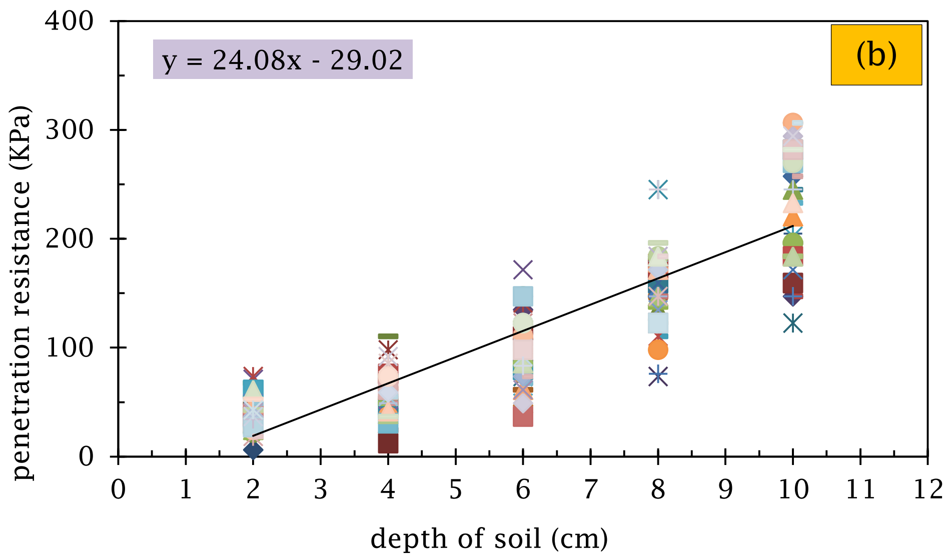


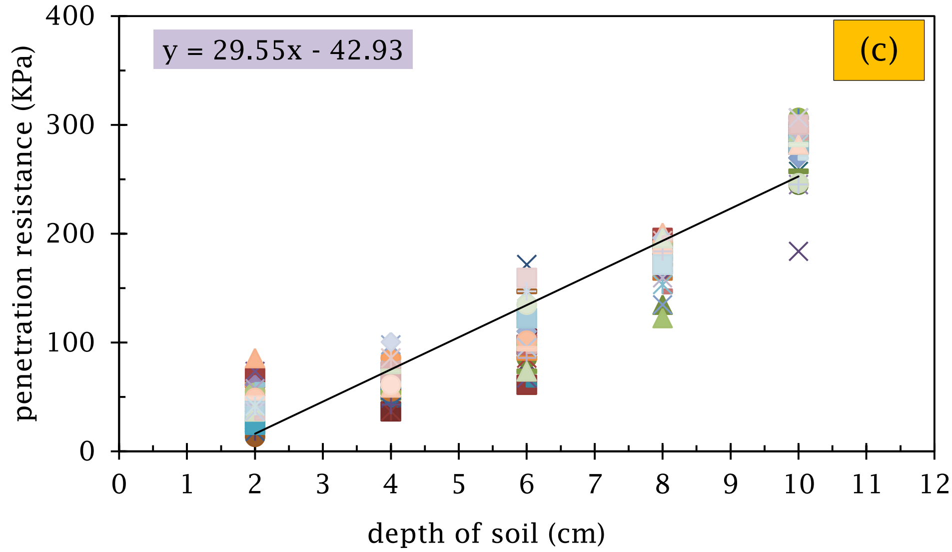
Figure 4 Position scheme and lugs angle of of tractor wheels

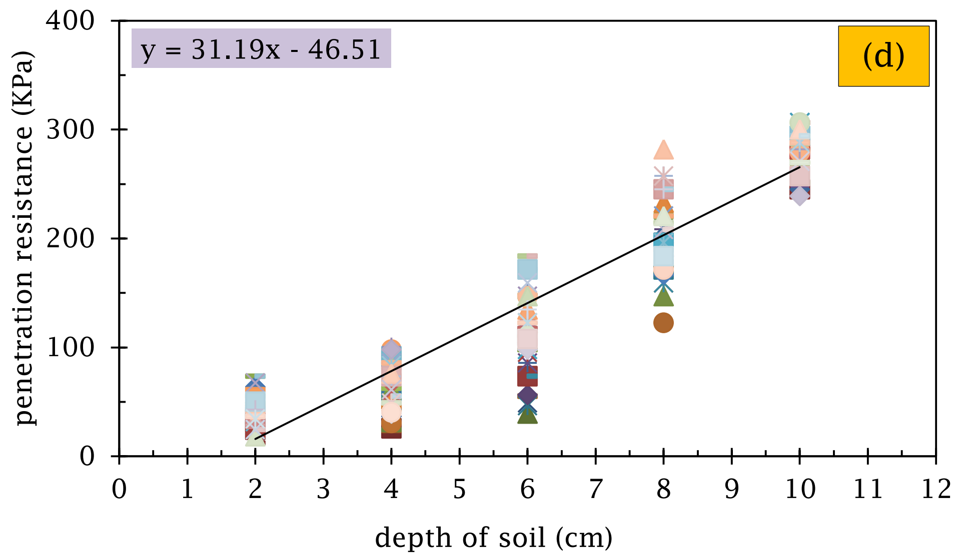
3 Results and Discussion

The measurement of the suppression resistance can be shown in Figure 5. It comprises each pressure angle of 30°, 45°, 60°, 75° and 90°. From the relationship can also be known the regression equation between the depth of the soil and penetration resistance. The regression equation of the graph becomes the input to obtain optimum cage wheel design parameters.


y = 21.78x - 5.119
(a)
penetration resistance (KPa)
depth of soil (cm)
0
100
200
300
400
0
1
2
3
4
5
6
7
8
9
10
11
12


y = 24.08x - 29.02
(b)
penetration resistance (KPa)
depth of soil (cm)
0
100
200
300
400
0
1
2
3
4
5
6
7
8
9
10
11
12


y = 29.55x - 42.93
(c)
penetration resistance (KPa)
depth of soil (cm)
0
100
200
300
400
0
1
2
3
4
5
6
7
8
9
10
11
12


y = 31.19x - 46.51
(d)
penetration resistance (KPa)
depth of soil (cm)
0
100
200
300
400
0
1
2
3
4
5
6
7
8
9
10
11
12

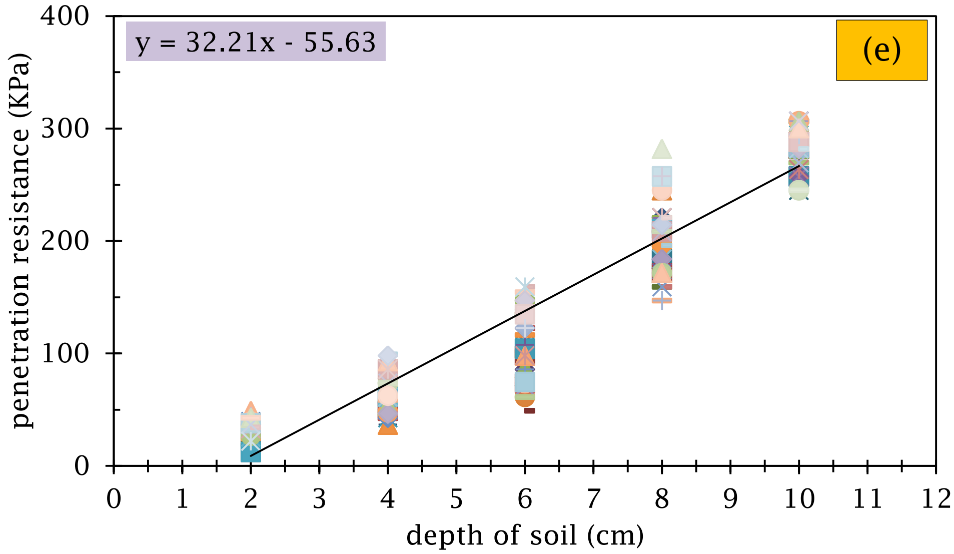


Figure 5 Graph of soil depth vs pressure resistance (a) pressure angle 30˚ (b) pressure angle 45˚ (c) pressure angle 60˚ (d) pressure angle 75˚ (e) pressure angle 90˚

3.1 Field Testing

Field testing (Figure 6) was carried out for two wheel sizes of RBBCAD-1 and RBBCAD-2 wheels with the consideration that RBBCAD-3 wheels have sizes between the RBBCAD-1 and RBBCAD-2 wheels so that by testing RBBCAD-1 and RBBCAD-2, RBBCAD-3 considered to have represented. Functional testing is done by observing the function of the finned cage wheel as a traction tool of a two-wheeled tractor. The following results of observation functional tests as shown in Table 1. The suitability of the wheels with the tractor can be seen in Figure 6. The tractor using the design wheel looks more flat while the standard-wheeled tractor looks a rather upturned front, this is due to the much different wheel sizes.

Table 1 Field observation results

Parameter	Result		
	Good	**Middle**	**Bad**
Conformity wheel size with tractor	√	-	-
Wheel installation	√	-	-
The wheels do not disturb other parts	√	-	-
Wheels can spin	√	-	-
Result of plowing	√	-	-

Figure 6 Comparison of tractor wheels

4 Conclusion

Measurements of soil penetration resistance with the various angle of emphasis have been implemented. The measurement results have been plotted into the graph to obtain the depth pressure regression equation with the penetration resistance of the soil. The next results are used to design an optimal cage wheel. The cage wheels of the design have also been tested in the field. Furthermore, the process of designing a cage wheel using the RBBCAD design program enhances the efficiency of design time and can produce a design with greater strength and accuracy than manual design.

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Nomenclature

T_p	:	Penetration resistance
F_p	:	Force penetration
A	:	Area of a press plate
R_w	:	Minimum radius
H_t	:	Gearbox radius
H_c	:	Ground clearence
Z	:	Sinkage
L_s	:	The lugs distance
D_w	:	Cage wheel diameter
J_s	:	Number of fins
F_{rv}	:	The resultant force of the vertical soil reaction
W_t	:	Traktor weight
F_{rh}	:	The resultant force of the horizontal soil reaction
F_d	:	Draft implement
F_{rr}	:	Force of rolling resistance
J_{sa}	:	The number of active lugs
F_{r1}, F_{r2}, F_{r3}, ... F_{rn}	:	Resultant forces
C_{rr}	:	Coefficient of rolling resistance
S_{hs}	:	The horizontal spacing between lugs
S	:	Slip of cage wheel
α_n	:	Angle used in calculating the soil reaction in lugs
θ_n	:	Angle of active fin to-n
γ	:	Angle of fin