International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014
ISSN 2229-5518

Tractive Performance Testing of Lug Wheel in a Soil Bin

Taufik Rizaldi, Wawan Hermawan, Tineke Mandang, Setyo Pertiwi

Abstract— Tractive performance testing of lug wheel was carried out at Siswadhi Soepardjo Field Laboratory, Department of Mechanical Engineering and Bio-systems, Leuwikopo IPB, Bogor. Tested lug wheel with 42 cm in diameter and varying numbers of lug which were 8, 10, and 12 lugs, respectively. Lug angle was varied from 30°, 35°, and 40°. Lug length and width was 15 and 8 cm, respectively. Wheel rotation was 1013 rps. The results showed that the smallest wheel torque was obtained when a 12 lug-wheel was used with lug angle 30°, while the highest was at 12 lug wheels and lug angle at 40°. The smallest tractive efficiency, about 21.91%, was obtained when a 10 lug-wheel was used with lug angle 40°. The highest efficiency was obtained when the lug wheel has 12 lugs with lug angle 30°, which was about 34.62%. The higher tractive efficiency, the better tractive performance would be achieved.

Index Terms— soil bin, lug wheels, lug angle, torque, tractive efficiency

1 INTRODUCTION

In paddy fields, soil water content is relatively higher than in dry area. Soil tillage activity is sometimes conducted when the field is flooded with water. This condition has been proven difficult for agricultural machinery to cross the field and more likely to apply the agricultural mechanization. Therefore, the movement of tractor in paddy fields must be improved. In agricultural vehicles, wheels are usually used as running device. Additional tools for running device such as lug wheels or floating flippers are provided so that the machinery can be used in paddy fields. Lug wheels are very popular in Southeast Asia countries (Oida 1992).

Hermawan (1998) stated that paddy fields usually contain high or even saturated water content which made tractor operation on the ground is difficult. In conditions like this, lug wheels equipped with traction development is one of the best traction apparatus to use.

Water content on paddy fields are usually very high and sometimes the tractor must be operated in saturated field where the transportation is very difficult. This very soft soil is one of the difficulties of mechanization in paddy cultivation. Of all of the traction-aided equipments which were already tested to improve off-road vehicle movement in wetlands, lug wheels have been proven to be one of the best. Lug wheels are often used in wetland rice crops because of its high floatation and traction. The price is affordable and it is quite easy to fabricate. These two reasons are also the cause why this type is commonly used in fields. Moreover, the tires can be produced much wider than conventional tires (Salokhe et al., 1990).

Many studies had been conducted by the researchers to improve the tractive performance and lug wheel floatation. This study was conducted to find the optimum lug arrangements such as lug spacing, lug angle, and lug size. Watyotha and Salokhe (2001) stated that to improve traction, the variation of design parameters such as lug angle, lug spacing, lug size, lug shape, lug mechanisms, and circumferential angle must be considered. Ciptohadijoyo (1993) stated that high value of traction will improve tractive coefficient and efficiency as well as technically and economically will be more advantageous to use.

A soil bin was used for measuring tractive performance in the laboratory. The condition of measurement was sought to represent the conditions exist in field. The measurement using soil bin in the laboratory was carried out to obtain more uniform lug wheel tractive performance data because the condition was not influenced by environmental factors.

1.1 Soil Characteristics

Soil is composed of solid particles and void filled with water and/or air. When soil receives enough pressure,

- *Taufik Rizaldi is currently pursuing doctoral degree program of Agricultural Engineering, Bogor Agricultural University, Indonesia, PH-081376799866. E-mail: taufikrizaldi_tp@yahoo.co.id*

ISSN 2229-5518

its volume will change. This change is due to external forces from mechanical or natural sources. Soil condition can be determined by specific parameters such as void ratio, porosity, bulk density, and volume density (Mandang and Nishimura 1991).

Soil strength varies systematically according to water content and soil density, which can also change due to soil texture. One of the many technical problems encountered in the application of mechanical devices is low efficiency due to high forces faced by equipments during operation. Soil stickiness is a factor which can reduce tool efficiency. It occurs because of strong adhesion force between soil and tool materials. According to previous studies, the factors such as water content, soil texture, operating speed, and tool materials determine the magnitude of soil stickiness (Mandang and Nishimura 1991).

1.2 The calculation of wheel slip and tractive efficiency

Wheel slip calculation was carried out by comparing unballasted and ballasted wheel travel speed in every variation of numbers of lug with each lug angle 30°, 35°, and 40° according to the equation below.

$$s = \frac{v_0 - v}{v_0} = \frac{L_0 - L}{L_0} \qquad 1)$$

Liljedahl, et.al (1989) stated that the characteristics of the torque and wheel slip determine the magnitude of tractive performance and tractive efficiency. Comparison of "pull /weight" or "net tractive coefficient" is a term used to define performance level. The term "tractive efficiency" (TE) has been used to define efficiency

Hermawan (2001) developed an equation to measure tractive efficiency, as presented below:

$$\eta_t = \left\{ \frac{P_d V_f}{\omega T_q} \right\} x100 \qquad 2)$$

Where η_t is tractive efficiency (%), P_d is drawbar pull (N), V_f is forward speed (m/s), ω is wheel rotational speed (rad/s), T_q is wheel torque (Nm).

2 RESEARCH METHODS

2.1 Time and place

This study started from January to June 2013. Experiments were performed using laboratory test equipment at Siswadhi Soepardjo Field Laboratory, Department of Mechanical Engineering and Bio-system, Leuwikopo IPB, Bogor.

2.2 Materials and tools

2.2.1 Materials

The main materials used were soil and water. Soil was obtained from paddy field in Siswadhi Soepardjo Field Laboratory, Department of Mechanical Engineering and Bio-system, Leuwikopo IPB.

2.2.2 Tools

Tools used in this research were divided into:

1. Soil bin equipment
   Soil bin with dimension 1800 mm long by 350 mm wide by 300 mm deep was used. Lug wheels had outer diameter of 478 mm. Lug length was 150 mm while its width was 80 mm with varying numbers of lug which were 8, 10, and 12 lugs, respectively. Moving carriage frame, electric motor, reduction gear box (30:1), bearing, rails, sprocket, chains, and loading system.
2. Measuring equipment.
   Strain gage 120 ohm, linear potentiometer, ring transducer, bridge box, stavol 100 volt, strain amplifier (DAS-406B DC Strain Amp) and data logger (minilab 1008).

2.3 Research Procedure

2.3.1 The measurement of torque, drawbar pull, shrinkage, forward speed of lug wheels in soil bin

Soil bin and measuring equipments were constructed by previous researcher, Hermawan (2001). In this study, the tested parameters were torque, drawbar pull, shrinkage, and forward speed in soil bin at 25 cm soil depth.

The tested wheels were mounted on the wheel system frame and driven by electromotor. The diameter was 42 cm and had different numbers of lug which was 8, 10, and 12 lugs, respectively, as well as lug spacing was 16, 13, and 11 cm, respectively. The angle was set at 30^o, 35^o and 40^o, respectively. Wheel system could move freely in the soil due to 4 pairs of bearing. Tested lug wheel rotated and drove the carriage on the upper rail. The average wheel rotation was 1.03 rps or about 1.35 m/s. The horizontal load system was used and designed to obtain drawbar load characteristic as actual as possible. Setting of horizontal load in testing was done by hanging dead weight loading about 16 kg and vertical load from tested wheel weight and other equipments mounted on it about 60 kg.

Parameters measured at testing were: 1) wheel shrinkage 2) torque on wheel shaft 3) drawbar pull 4) wheel forward speed.

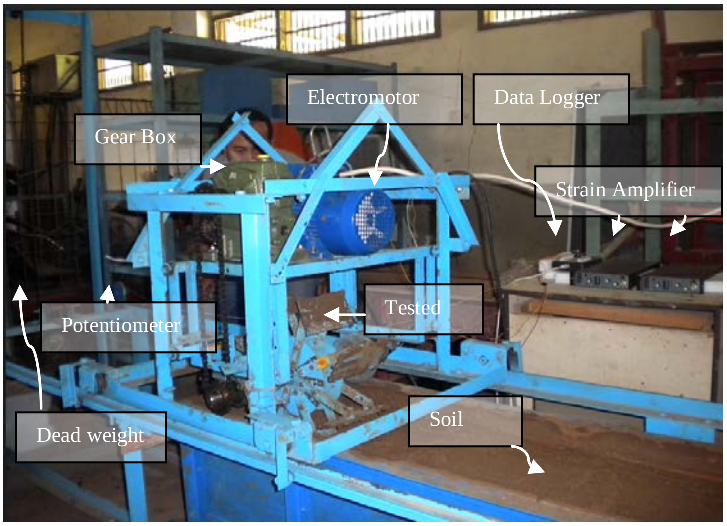

Figure 1 Soil bin equipments for the tractive performance of lug wheels

Forward speed and wheel shrinkage of lug wheel were measured using linear potentiometer sensors installed on the frame while the end of the string tied to the frame of moving wheel system. Torque of tested lug wheel was measured using two strain gages installed across each other on wheel shaft. The pull caused by drawbar was measured with ring transducer installed on the frame and connected to chains from horizontal loading system. In the measurement of torque and forces on drawbar, strain gages of each measuring tools were connected to bridge box which was already connected to strain amplifier. The calibration of each measurement instrument must be done before in accordance with loading direction that would be received. During the test, two units of strain amplifier and bridge box were used and only one unit of data logger was used. All measurement data signals were simultaneously recorded on data logger and the result was in the form of voltage. The data then processed using calibration results value to obtain torque, drawbar pull, shrinkage, and forward speed of lug wheel. The series of activities is shown in Figure 2.

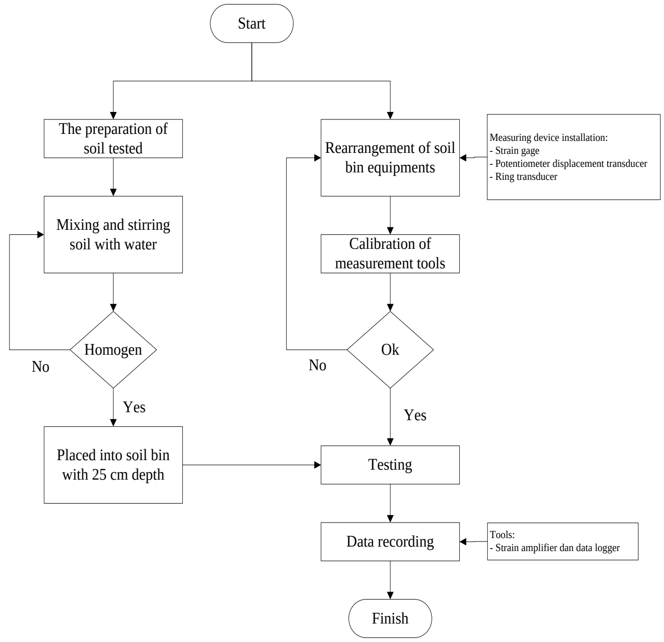

Figure 2 The Diagram of torque, drawbar pull, shrinkage, and forward speed measurement of lug wheel

3 RESULTS and DISCUSSION

3.1 Soil Characteristics

Soil type used in soil bin measurement was obtained by determining soil physical characteristic in laboratory

Table 1 Characteristic data of soil in soil bin, Siswadhi Soepardjo Laboratory (Soil sample was taken from 0-16 cm soil depth)

Characteristics	Soil in Soil Bin
Soil Texture	
• Loam (%)	9.85
• Silt (%)	51.62
• Clay (%)	38.53
Water Content (%)	36
Bulk Density (g/cm^3)	0.86
Porosity (%)	67.46

The tested soil in this study was silt clay loam soil according to USDA standard.

3.2 The measurement of torque, drawbar pull, shrinkage, and forward speed of lug wheels

The results of parameter measurement from wheel testing in soil bin can be seen in Table 2, 3, and 4.

Table 2 The results of parameter measurement in soil bin with 8 lugs

	Angle

	30°	35°	40°
Torque (N.m)	108.79	106.73	107.82
Sinkage (cm)	11.76	11.19	10.08
Drawbar Pull (N)	217.29	217.29	217.29
Speed (m/s)	1.02	0.95	0.91

Table 3 The results of parameter measurement in soil bin with 10 lugs

	Angle		
	30°	35°	40°
Torque (N.m)	133.56	130.24	140.19
Sinkage (cm)	10.8	9.84	8.21
Drawbar Pull (N)	217.29	217.29	217.29
Speed (m/s)	0.98	0.93	0.90

Table 4 The results of parameter measurement in soil bin with 12 lugs

	Angle		
	30°	35°	40°
Torque (N.m)	90.72	92.20	91.23
Sinkage (cm)	8.39	8.09	7.57
Drawbar Pull (N)	217.29	217.29	217.29
Speed (m/s)	0.92	0.88	0.85

From Table 2, 3, and 4 above, it shows the greater angle causes the greater lift force so that shrinkage will be smaller. As for forward speed of lug wheels, it tends to be smaller by increasing of numbers of lug. The increasing numbers of lug will cause smaller area of soil in contact with lugs which creates higher slip.

3.3 Slip measurement and tractive efficiency

Wheel slip can be determined by comparing wheel forward speed both with and without load. Tractive efficiency can be determined by considering the magnitude of torque on wheels, the average wheel rotation which was 1.013 rps, drawbar pull, and wheel forward speed. The results are presented in Table 5 below.

Table 5. The measurement results of slip and tractive efficiency

Descriptions	Slip (%)	Tractive efficiency (%)
Numbers of lug: 8		
Angle: 30°	25	32.00
Angle: 35°	30	30.38
Angle: 40°	33	28.81
Numbers of lug: 10		
Angle: 30°	28	25.05
Angle: 35°	32	24.38
Angle: 40°	33	21.91
Numbers of lug: 12		
Angle: 30°	32	34.62
Angle: 35°	35	32.62
Angle: 40°	37	31.81

According to measurement results as seen in Table 5, it can be concluded that increasing numbers of lugs will increase slip occurrence in the same lug degree. Wheel slip tends to be higher with the increasing numbers of lug. Tractive efficiency will be greater by the increasing of lug angle. Tractive efficiency value is inversely proportional to torque, tractive efficiency will be smaller when the greater torque obtained and vice versa. The most optimum lug angle which will produce maximum tractive efficiency was 30°.

4 CONCLUSSIONS

The highest torque was obtained at 10 lugs with the angle 40° which was 140.19 N.m and the smallest torque was obtained at 12 lugs with the angle 30° which was 90.72 N.m. The highest shrinkage was obtained at 8 lugs with the angle 30° which was about 11.76 cm and the smallest was obtained at 12 lugs with the angle 40° which was about 7.57 cm. The highest forward speed was obtained at 8 lugs with the angle 30° which was 1.02 m/s and the smallest forward speed was obtained at 12 lugs with the angle 40° which was about 0.85 m/s.The average wheel rotation was 1.013 rotations per second. The smallest slip was obtained at 8 lugs with the angle 30° which was about 25% and the highest slip was obtained at 12 lugs with the angle 40° which was about 37%. The smallest tractive efficiency was obtained at 10 lugs with the angle 40° which was about 21.91% and the highest tractive efficiency was at 12 lugs with the angle 30° which was about 34.62%. From the combination of the numbers of lug and lug angle, the best results came from 12 lug wheels and at 30° lug angle.

REFERENCES

[1] Ciptohadijoyo, S. (1993). Upaya peningkatan traksi pada traktor. *Agritech* 10 (1), 16-26.

[2] Hermawan, H., Yamazaki, M., Oida, H. (1998). Experimental analysis of soil reaction on a lug of a movable lug wheel. *Journal of Terramechanics* 35 (2),119-135.

[3] Hermawan, W., Suastawa, I.N., Sudianto, D., 2001. Traction Performance of Movable Lug wheels with spring mechanism and rubber lug. *J. ASSAAS* . 7 , 58-67.

[4] Liljedahl, J.B., Turnquist, P.K., Smith, D.W., Hoki, M., 1989. *Tractors and Their Power Units*. Van Nostrand Reinhold, 115 Fifth Aveneu New York, New York 10003.

[5] Mandang, T. dan Nishimura, I., 1991. Hubungan Tanah dan Alat Pertanian. JICA-DGHE/IPB PROJECT: JTA-9a(132) . Proyek Peningkatan Perguruan Tinggi Institut Pertanian Bogor, Bogor.

[6] Oida, A. (1992). *Terramechanics.* Departemen of Agricultural Engineering Faculty of Agriculture Kyoto University. Kyoto, 606-01 JAPAN.

[7] Watyotha, C. and Salokhe,V.M., 2001. Tractive Performance of Cage Wheels With Opposing Circumferential Lugs. *J. agric. Engng Res*. 79 (4), 389-398.