Functional and performance test of modified lug wheel on two wheels tractor with pivot type trailer

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Abstract. Palm oil fields with slopes require special wheels for transportation for transporting fresh fruit bunches (FFB), the special wheels in question are modified wheels from the existing cage wheel, the modified wheels can adjust the slope conditions on the land with the lug angle adjustment mechanism. The objective of this study was to test the functional and performance of the modified lug wheel as a means of transporting FFB on sloping land using a hand tractor on a pivot type trailer. Functional testing on the modified lug wheel was carried out by observing changes in the angle of the lugs ($0, 15, 30, 45$) by lifting one of the tractor shafts first using a jack, after which the locking pins were released. The angle change rim can be moved clockwise or anticlockwise by hand according to the desired lug angle. Performance testing on the modified lug wheel is carried out by observing and calculating the slip on the wheel. Functional testing on trailer pivots is carried out by observing all components of the towing system when installed and operated, to determine whether the trailer towing system can function properly. Performance testing on the pivot trailer is done by observing and calculating the turning radius when the tractor turns. Performance testing is also carried out by observing the stability of the two-wheel tractor and trailer. The slope of the land and the angle of the lugs greatly affect wheel slip, the higher the slope on a land, the higher the possibility of wheel slippage during operation. The test results show that the use of modified lug wheels shows better performance at $30^\circ$ lug angle, as seen from the smaller slip value at $30^\circ$ lug angle.

1. Introduction

Two-wheel tractors are the driving force for a number of agricultural tools and machines such as plows and harrows [1]. This type of tractor is in great demand by farmers, especially for relatively small lands due to its low operating costs. The use of a two-wheeled tractor is actually not only for plowing but can also be used for other uses if it is adjusted to some parts and parts added to the two-wheel tractor, the use of a two-wheel tractor can be used in the fertilization process if it is adjusted to the width of the wheel and the trailer of the fertilizer as well as the spraying designation. The two-wheeled tractor can even be used as a means of transporting agricultural products on agricultural land if a transport trailer is used. Two-wheeled tractors are used only for tillage in paddy fields, so the cycle of use is very short and limited, not optimal, the management of the farmers who own the tractors is also less than optimal (not economical), while there are still several other activities after tillage until harvest and processing.
next soil is maintenance activities such as fertilization, cleaning of nuisance plants (weeds) and others [1].

According to [2], in Indonesia, two-wheel tractors are used in operation for various kinds of work, namely tillage, as a means of transportation (pulling trailers), and other agricultural cultivation activities. Two-wheeled tractors as a means of transportation are used to transport seeds, fertilizers, equipment, and various agricultural products. The operation of a two-wheel tractor coupled with a trailer is considered very efficient for transporting plantation products on narrow and sloping land, especially in oil palm plantations.

Indonesia has an area for oil palm plantations of around 16,381 million ha, and in Aceh itself has an area of 71,661.53 ha for oil palm plantations. Most oil palm plantations in Aceh have sloping land which can make it difficult to access transportation means for transporting fresh fruit bunches (FFB). Palm oil fields with slopes require special wheels for transportation for transporting fresh fruit bunches (FFB), the special wheels are modified wheels from the existing cage wheels, the modified wheels can adjust the slope level conditions on the land with the lug angle adjustment mechanism.

Transportation by means of conveyance will be more effective and efficient. In addition to using a conveyance, the transport capacity will be greater and can cover longer distances. A trailer coupled with a two-wheel tractor is one of the most common means of transportation used by Indonesian farmers. However, in terms of ergonomics, the use of trailers and two-wheel tractors is very less ergonomic. The operation of the steering handlebar of a two-wheeled tractor with a trailer has drawbacks that occur when the tractor is operating on a sloping land, where the trailer cannot be controlled when the tractor is down. This results in reduced operator control of the steering wheel.

Two-wheel tractors have not been widely used as a means of transporting agricultural products on agricultural land due to the difficulty of their operation. This difficulty occurs because there is no trailer design that fits the hand tractor both at the operator's seat and at the trailer towing point so that the operator feels less ergonomic, the problems that must be a concern are the seat, the tow point, braking, and the wheel model that must be adjusted with the land.

The objective of this study was to test the functional and performance of the modified lug wheel as a means of transporting FFB on sloping land using a hand tractor on a pivot type trailer.

2. Materials and methods

2.1. Modified lug wheel functional test

Functional testing is carried out by observing the function of the lug wheel as a pulling tool from a two-wheel tractor. At the time of testing, the flange can be attached properly to the boss on the tractor wheel axle. The test for changing the angle of the lugs (30, 45) is also carried out by lifting one of the tractor shafts first using a jack, after which the locking pin is released. The angle change rim can be moved clockwise or anticlockwise by hand according to the desired lug angle.

![Figure 1. Illustration of adjustable lug angle lugned iron wheel [3].](image-url)
2.2. Modified lug wheel performance test

The wheel slip angle is the angle between the longitudinal axis of the wheel and the direction of wheel movement. Wheels turning on the road will have a slip angle and their rolling resistance value will increase significantly. Rolling resistance is the force that the wheel exerts against motion, as well as the force required to move the wheel forward.

According to Cebro et al. (2018), wheel slip (s) is known by measuring the linear displacement distance produced by one full rotation of the tractor wheel with a load (la) on the track and comparing it with the linear displacement distance produced in one full rotation of the tractor wheel without a known load (lt) previously. The wheel slip value is formulated as follows:

\[ S = \frac{l_t - l_a}{l_t} \times 100\% \]

2.3. Pivot type trailer functional test

The main function of this two-wheels tractor and trailer towing system is to provide a complete trailer towing and operator seat on the two wheel tractor that is safe and comfortable to operate. Functional testing on trailer pivots is carried out by observing all components of the towing system when installed and operated, to determine whether the trailer towing system can function properly.

The components checked for function are: (a) pivot system, (b) trailer connecting frame, (c) operator seat, (d) auxiliary wheels, (e) brake pads on trailers, (f) operator footrests, (g) hook and pin holes.

2.4. Pivot type trailer performance test

2.4.1. Turning radius. The turning radius is the smallest circle radius that two-wheel tractors and trailers can make when turning. The radius is measured from the center of the tractor wheel axle to the center of the curvature of the two-wheel tractor when turning.

According to Lestari [4]. Testing the turning radius on a two-wheeled tractor with a trailer towing system to determine the turning performance of the auxiliary wheels. The test is carried out at a speed of 0.95 m/s, at a radius to turn left and right. Testing the performance of the towing system was carried out by two experienced operators, with a height of 165 cm and 154 cm, respectively, and a weight of 70.2 kg and 61.1 kg, respectively. The treatments carried out in the experiment were: (1) on the track conditions: asphalt and agricultural soil; (2) under operating conditions: straight and turn 90°; and (3) when the trailer is empty.

2.4.2. Stability of Two Wheel Tractor and Trailer. Observations were made by taking videos of the operation of two-wheel tractors and trailers, namely (1) on track conditions: flat, inclined 10°, and inclined 30°; (2) under operating conditions: straight, turn 45°, and turn 90°; (3) In the condition of empty and full trailer loads.

3. Results and discussion

3.1. Overview of Research Sites

The research was carried out on oil palm land located in Data Cut village, Jantho district, Aceh Besar district. Data Cut Village is one of the villages in the city of Jantho which has a latitude coordinate of 5.150164 and a longitude coordinate of 95.762682 and has a slope of 0° – 35°. This land was chosen as a test because it has a variety of land slopes so that testing of the tool can be carried out on various land conditions.

3.2. Characteristics of FFB

The age of the oil palm plants used in the test of this conveyance is 6-7 years, the total weight of the FFB is about 115.4 kg. FFB used have various sizes and weights. This is because most of the FFB is produced from inter-planted plants. Insertion plants are the second plantings carried out after the first plants, because at the first planting some of them died.
3.3. Performance Testing

3.3.1. Functional Tools. The results of the observations show that each component of the coupling system works well according to the planned mechanism (Table 1).

| Number | Component Name                  | Functional Mechanism |
|--------|---------------------------------|----------------------|
| 1.     | pivot system                    | Good                 |
| 2.     | Trailer connecting frame        | Good                 |
| 3.     | Operator seat                   | Good                 |
| 4.     | operator footing                | Good                 |
| 5.     | Auxiliary wheel                 | Good                 |
| 6.     | Spring                          | Good                 |
| 7.     | Hook hole and pin               | Good                 |
| 8.     | Brake pads on the trailer       | Good                 |

The pivot system functions as a means of transporting FFB, when the pivot system is operating it is stable both when moving straight or turning, in an empty or full load state. The trailer connecting frame is made of 50 mm x 50 mm square hollow steel with a thickness of 4.5 mm. The selection of these materials aims to make the frame strong and sturdy to withstand the forces that will occur when the towing system is used, when the operation is carried out the trailer connecting frame is able to withstand the load given by the trailer pivot and the operator.

The dimensions of the operator's height and seat distance from the handlebar and footrest position were adjusted to the operator's anthropometry for the three percentiles of the Indonesian people, namely 0, 50, and 95%. This is so that the three operators can feel safe and comfortable when driving a tractor with a trailer. The operator seat is equipped with a spring so that it can increase operator comfort, the seat is also designed so that it can be moved back and forth according to the needs of the operator.

The auxiliary wheel used is a live wheel which is generally used on public transportation with a diameter of 360 mm and a thickness of 80 mm. The auxiliary wheel frame is designed by positioning the wheel axle not parallel to the turning of the wheel axle. This is so that the auxiliary wheels can easily turn when operated. The pull spring mounted in front of the auxiliary wheel is a motorcycle shockbreaker. The choice of this motorcycle shockbreaker was due to its higher tensile strength than ordinary springs, so that when operating in various land conditions, it was able to follow the motion of the auxiliary wheels properly and the trailer did not tip over or overturn.

The pivot has a hook hole and a vertical pin with the aim of minimizing the possibility of the trailer connecting frame breaking when going through a bumpy track. The pivot is also equipped with brake pads, the brake pads used are deer car brake pads. The choice of brake pads for the deer car is due to its higher tensile strength, so that when operating the trailer in various land conditions it is able to hold the trailer wheels well and the trailer does not tip over or overturn.

3.3.2. Turning radius. The results of testing the turning radius of a two-wheel tractor with a pivot type trailer towing system can be seen in Table 2

| Weight       | Area (cm²) |
|--------------|------------|
| Empty Load   | 480        |
| Full Load    | 510        |
Based on the table above, the results of testing the turning radius at slow speeds obtained a turning radius of 480 cm for an empty load and 510 cm for a full load. The full speed test was not carried out because the tractor using modified lug wheels could not be controlled by the operator.

3.3.3. Stability of two-wheels tractor and trailer. During the test, on average, all the wheels on the tractor and trailer tread perfectly on the track without lifting and the towed trailer does not tip over when turning. The addition of brake pads on the trailer pivot keeps the trailer balanced and the trailer tires tread perfectly on the operator's test ground. Auxiliary wheels and brake linings allow tractor and trailer wheels to tread well on 0°, 10°, and 30° incline, and 30° slopes, and can help keep the trailer balanced as it descends on operator-tested terrain.

![Figure 2](image2.png)

**Figure 2.** Trailer wheels and auxiliary wheels tread well when climbing a 30° slope.

![Figure 3](image3.png)

**Figure 3.** Brake pads help keep the trailer balanced when descending a 30° slope.

3.4. Slip

Based on the picture above, it can be seen that the slip value on flat land using a 45° lug angle is 3.75% and a 30° lug angle is 2.56%, on a 10° sloping land with a 45° lug angle is 4.92% and a 30° lug angle is 0, 17%, on 30° sloping land with 45° lug angle, namely 10.74% and 30° lug angle 5.78%. This is also in accordance with the research results of Idkham [5] where the lug angle is the most influential indicator of changes in wheel slip. This illustrates that changes in lug height in the same angle condition produce relatively similar patterns of lug movement in the ground, such as at 30° angle conditions with lug heights of 7 cm, 10.5 cm and 14 cm resulting in slips of 35.5%, 34.1% and 34.2, respectively %. On the other hand, changing the angle of the lug with a constant lug height condition produces a relatively large slip value, as in the 7 cm lug height with changes in the lug angle of 30°, 40° and 45° resulting in slippage of 35.5%, 41.4% and 42.4%, respectively. Based on the research results of Idkham et al. 1 smallest wheel slip value is produced by 30 degree lugs.

[3] also stated that the highest slip occurred at a lug angle of 45° and the lowest slip occurred at a lug angle of -15°. In this case, it can be seen that the higher the slope, the greater the horizontal load (tensile load) supported by the soil which is transmitted through the lugs so that the slip increases, but there is no visible tendency to reduce slip at a smaller lug angle.
Based on the picture in Figure 4, the slope of the land and the angle of the lugs greatly affect wheel slip, the higher the slope on a land, the higher the possibility of wheel slippage during operation, it can be seen in the slip value produced by each lug angle, where the 30° lug angle produces a value slip is 2.56%, 0.17% and 5.78% and the angle of the lug 45° is 3.75%, 4.92% and 10.74%. With a smaller lug angle, the resulting wheel slip value is getting smaller as well.

Figure 4. Graph of modified lug wheel slip calculation with full load.

Ansar [6] states that the slip calculation is done by measuring the difference between the distance traveled by the tractor without a load and the distance traveled by the load divided by the distance traveled without a load, with the addition of the load, wheel slip also increases. For each additional load variation, the tractor slip ranges from 10-15%. This is due to the reduced grip of the wheels on the ground, so that the resulting traction also tends to decrease. This is in accordance with the opinion of [7], which states that wheel slippage can occur on dry or wet soil conditions with the tractor load and the soil condition itself.

Based on Figure 4, it shows that the 30° lug angle works more effectively for transporting FFB on sloping land than the 45° lug angle, it can be seen that the slip value obtained from the 30° lug angle is smaller than the 45° lug angle. From the research results Purwantana, et al. [8] states that the average tractor wheel slip observed along a 10 meter tillage track, each with 10 replications. These results indicate that the application of the control spring on the coupling system is actually able to automatically adjust the angle of the plow blade in the soil mass [9-13]. However, if the spring is too strong, the setting becomes less effective. As a result, the angle of the plow blade cannot perfectly reflect the magnitude of the resultant force acting on the moldboard, and is less able to reduce the slip of the drive wheels.

4. Conclusions
The test results show that the use of modified lug wheels shows better performance at 30° lug angle, as seen from the smaller slip value at 30° lug angle. The test results also show that each component of the pivot type trailer towing system has been functioning properly according to the planned mechanism. The addition of brake lining on the tailer shows an increase in the stability of the tractor and trailer on flat and sloping land.
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