Design of Mini Tractor Cage Wheel For Wet Land Ploughing

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Abstract- Agriculture is one of the oldest profession but the development and use of machinery has made job title of the farmer a rarity. A tractor is an engineering vehicle specially designed to deliver a high tractive effort such as "Torque" at low speeds, for the purpose of agriculture and construction. The main purpose of our tractor is for wet land ploughing by using cage wheels and making the arrangement simple. Cage wheel are designed by considering dimensions and they are attached directly to the rim of the tires mainly to reduce the time in assembling and dissembling them in normal tractors. The fabrication of prototype of ratio 1:4 is developed.
Keywords – Chassis, Cage wheels, Tractor, Wet land, Ploughing.

I. INTRODUCTION

A Mini tractor is an engineering vehicle specifically designed to deliver a high tractive effort (or torque) at slow speeds, for the purposes of hauling a trailer or machinery used in agriculture or construction. Most commonly, the term is used to describe a farm vehicle that provides the power and traction to mechanize agricultural tasks, especially (and originally) tillage, but nowadays a great variety of tasks. Agricultural implements may be towed behind or mounted on the tractor, and the tractor may also provide a source of power if the implement is mechanized. The main type of tractor that is used for farming is farm tractor. This type of tractor is generally used for ploughing the land, planting, etc.

1.1 Farm tractor

The most common use of the term "tractor" is for the vehicles used on farms. The farm tractor is used for pulling or pushing agricultural machinery or trailers, for plowing, tilling, disking, harrowing, planting, and similar tasks. A variety of specialty farm tractors have been developed for particular uses. These include "row crop" tractors with adjustable tread width to allow the tractor to pass down rows of corn, tomatoes or other crops without crushing the plants, "wheatland" or "standard" tractors with fixed wheels and a lower center of gravity for plowing and other heavy field work for broadcast crops, and "high crop" tractors with adjustable tread and increased ground clearance, often used in the cultivation of cotton and other high-growing row crop plant operations, and "utility tractors", typically smaller tractors with a low center of gravity and short turning radius, used for general purposes around the farmstead. Some farm-type tractors are found elsewhere than on farms: with large universities' gardening departments, in public parks, or for highway workman use with blowtorch cylinders strapped to the sides and a pneumatic drill air compressor permanently fastened over the power off. These are often fitted with grass (turf) tyres which are less damaging to soft surfaces than agricultural tires.

The design of cage wheels to the mini tractor such that the rear tires attached to the tractor does not require any disassembling .The cage wheels are directly attached to the rim of the rear tires such that it reduces the time for attaching and removing of the cage wheels for the tractors.

1.2 The cage wheels

Tractor is used for many different tasks. As it is a versatile machine, perators sometimes stretch the use of the tractor beyond what the machine can safely do. In the process accidents occur. Nearly 50% of tractor fatalities come from tractor overturns. No other machine is more identified with the hazards of farming as the tractor.

The cage wheels give high traction, support the vehicle by distributing the weight of the machine over as great an area as possible, reduce soil compaction and prevent it from bogging down. Cage wheels for these conditions are inexpensive and easy to fabricate, and can be made much wider than a conventional tyre. Improvement in the traction performance of the conventional cage wheel is a challenge. Of the various design factors for the cage wheel, lugs have received the most attention and several parameters were found to affect its performance such as lug angle, lug spacing, lug size, lug shape, lug sinkage, lug mechanism and circumferential angle. The performance of a cage wheel depends mainly upon the performance of the lug because the lug of a cage wheel is the basic element to interact with soil and to produce the pull and lift forces.

Two types of wheels are used in a tractor operation – Pneumatic wheel and cage wheel. Cage wheel is extensively used in cultivation of paddy and wheat. It is used to mix the black soil properly while preparing the land for crop plantation. The tractor cage wheels are made up of heavy-duty steel angle bars. They are suitable for fixing on all types of tractors due to their versatile design. The cage wheels are also used for breaking down big boulders into small pieces.

Tractor cage wheels can be classified into two categories based on the method of attachment.

They are:

* Fixed tractor cage wheel or half cage wheels.
* Detachable tractor cage wheel or full conventional cage wheel.

(a) (b)

Figure 1. (a) Half cage (b) Full cage (image courtesy by the Trichy agro Industries)

1.3 Literature

Patel Vijay Kumar [1] published a journal on design modifications for the chassis considering the weight reduction parameters and also about the stuctural analysis of the designed chassis. N.Lenin Rakesh[2], K.Gowtham Kumar[3], Dr.J. Hameed Hussain[4] these three authors published a journal related to design and analysis of the chassis by considering the loading consitions. Siswoyo Soekarno[5] and V. M. Salokhe [6] experimented on the different types of soils and found the soil reactions on the cage wheels with staggered echelons of half width lugs in wet clay soil. Piyush Pradhan[7] explained about the lug angle in the cage wheels and also about the design of hub and also about the design of power tillers. Vijayan[8] published a journal related to design and analysis of the automotive chassis considering cross section and the material properties. S.S.Bhavikatti[9] explained about the calculations regarding the centre of gravity by considering the assumptions. R.S.Kurmi[10] and S.Ramamrutham[11] explained about the calculations regarding the shear force and bending moment.By studying all the above journals and books, we designed our chassis by following all the considerations and the static analysis of the chassis is done by applying forces. The cage wheels are designed as per the above references and a prototype of 1:4 ratio is prepared by considering the properties required for the fabrication.

II. DESIGN OF CAGE WHEELS

2.1 general design consideration

Cage wheel was designed to operate power tiller to overcome problems of sinkage, slippage, power and low trafficabilty in wet land field. If the forecast for the demand of such a machine is favorable the engineering design process may be initiated and should involve a few selected manufacturers and farmers as cooperators. It has been designed on the basis of following consideration: a) Wheel Diameter b) Lug Angle c) Soil conditions d) Slippage e) Sinkage

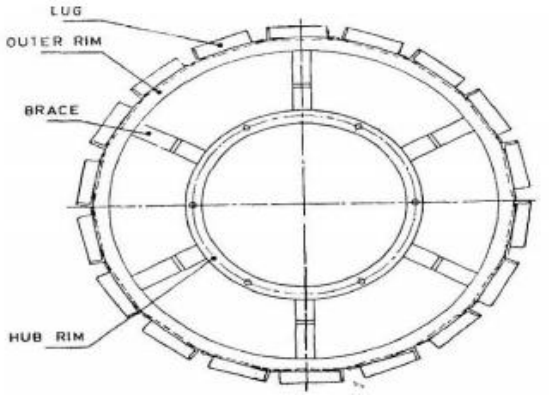

Figure 2. Features of Half cage wheel

2.2 pull, lift and side force characteristics of cage wheels with opposing circumferential lugs

The forces acting on a single model cage wheel lug were measured when operating in a wet clay soil. After initial lug entry into the soil, the normal and tangential forces acting on the lug increased up to a certain peak value and then dropped as lug rotation increased further. The tangential force later attained a negative peak value. The pull force showed the same trend as lug normal force. The lift force showed the same trend as tangential force, however, the positive peak value of lift force was much higher than the positive peak value of tangential component. The lift force was higher than the pull force. Increase in lug sinkage showed almost proportionate increase in lug forces while increase in soil moisture showed decrease in lug forces. The effect of lug slip on lug forces at constant sinkage was found to be statistically non-significant. The lug forces, normal and tangential, on a single model cage wheel lug were measured in a wet clay soil. These normal and tangential forces were converted into lug pull and lift forces. The effect of lug sinkage, slip and soil moisture content on lug forces was investigated. Lug normal and pull forces increased up to a certain degree of lug rotation and then after attaining a peak value decreased. The lug tangential and lift force also increased up to a certain angle of lug rotation, then dropped continuously, attained a negative peak value and finally rose again to become zero at lug exit. Increase in lug sinkage showed an almost proportionate increase in lug forces while increase in soil moisture content caused a decrease in lug forces. The effect of lug slip on lug forces at constant sinkage was found to be statistically non significant as lug slip was always high. Using the passive pressure soil failure theory the lug forces were predicted and compared with the measured values. 6.3 COMPONENTS OF CAGE WHEELS: 6.3.1 Design of cage wheel rims: The rim of the cage wheel binds the lugs together with equal spacing and number of lugs. These rims are placed at certain width according to design considerations. Diameter of the outer rim 34 inch and inner rim 30 inch.

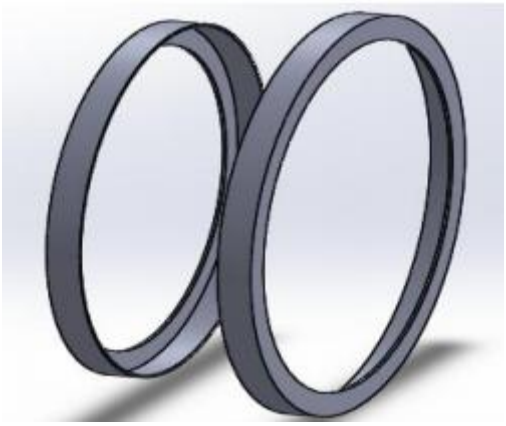

Figure 3. 3-D model of cage wheel hub rim

2.3 Design of lugplate

Lug plate is important part of cage which cut and lifts the soil in puddle Condition. The lug sinkage and slip were varied to 4 cm, 6 cm and 8 cm, lug spacing was varied to 30 and 36 degrees. Under driving condition the lugs will face two types of forces, normal and tangential forces. The normal and tangential as well as pull and lift forces acting on the first lug were higher than the forces on the second lug. In our design we considered L -plated lug with dimension of 9 x 2 x 0.5inch, the lug is shown in Figure 4.

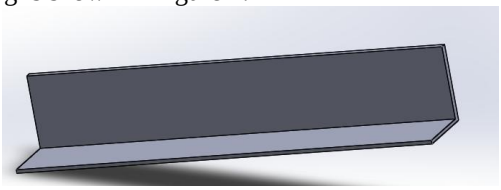

Figure 4. 3-D model of L-shaped lug

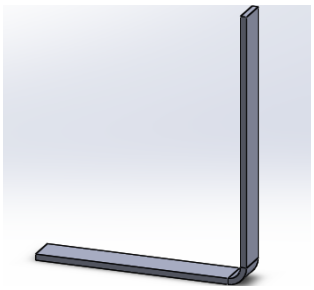

Figure 5. 3-D model of braces

2.4 Design of braces

The braces are used to support lug plate and transfer load to the hub rim. These braces are subjected to compression load and these loads are directly transferred to the hub rim of the cage wheel without any failure in between. These braces act as load intake beams and load transfer beams as shown in Figure 5.

2.5 Design of hub rim

The main hub was strengthen by heat treatment and joining the supportive angle iron pieces edge to edge, joined together by welding so that enough strength can be obtained to withstand the load encountered in actual field condition during the wet tillage operation. Number of holes four (size 15 mm) was drilled at a spacing of 1200.

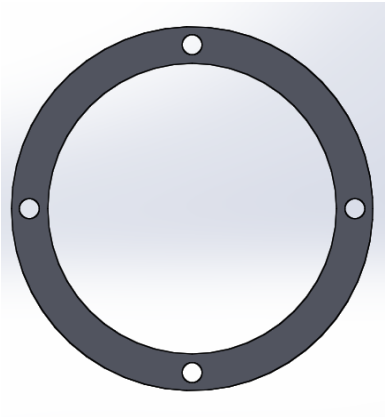

Figure 6. 3-D model of hub rim

III. FABRICATION OF CAGE WHEELS WITH 1:4 SCALE

3.1 Material

The material used for fabricating the cage wheel is stainless steel. Spot welding is performed for the attachment of the cage wheels.

Figure 7. Fabrication of cage wheel

3.2 Eelectrical driving system

3.2.1 AURDINO:

The Aurdino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller;

3.2.2 Motor driver

L293d motor driver to drive the motors. L293D is a dual H Bridge motor driver, so with one IC e can interface two DC motors which can be controlled in both clockwise and counter clockwise direction and if you have motor with fix direction of motion.

3.2.3 DC motors:

The input of a DC motor is current/voltage and its output is torque (speed).

TORQUE CALCULATIONS:

Total weight of the body = 10 Kgs

Weight at each wheel = 10/4 = 2.5kg

Where,

Diameter of rear tire = 0.127m

Diameter of outer cage wheel = 0.2159m

Force = mass ×acceleration

= 2.5 x 9.81 = 24.525 N

Torque = Force x radius of rear tire

= 24.525 x 0.0635

= 1.55 N-m

Torque required for cage wheels = Force x radius of cage wheels

= 24.525 x 0.10795

= 2.698N-m.

The maximum torque required is 2.6998N . So, we are using a 3.5N torque which is enough to run the prototype and it produces a maximum speed of 45rpm.

3.2.4 Servo motor:

Servo motor works on PWM (Pulse width modulation) principle means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears.

3.2.5 Circuit Connections:

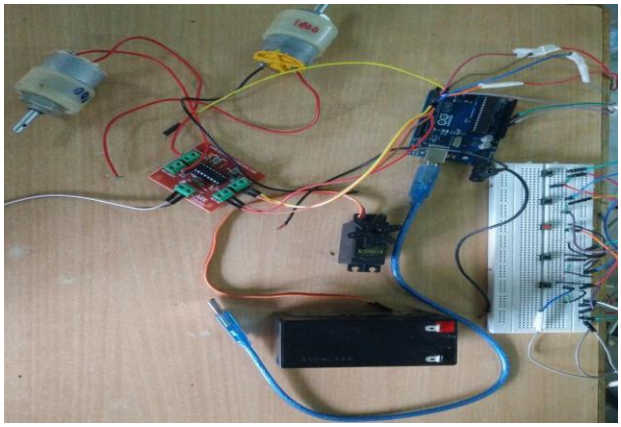

Figure 8. Circuit connections

IV. RESULTS AND DISCUSSION

Design and develop cage wheel successfully for wetland condition considering the standard design consideration such as functional requirement and theoretical consideration. The developed cage wheel prototype was tested for different water level in wet land and performance was found satisfactory at 2-3 cm water level and also the cage

wheel fixed to the rim of the tyre sustains the normal and tangential force acting on the L-shaped lugs and supports for the high pull force and wheel shrinkage. The increase in the diameter of the outer rim of the cage wheel results in deep wheel shrinkage at same pull force. The prototype that is prepared by considering all the dimensions in the ratio of 1:4 is successfully working by using all the motors to run the prototype.

4.1 Soil properties in field during operation:

The experimentation was done on soil having a sandy loam structure. The physico-chemical properties of field soil are given below.

S.NO.	Particulars	Values
1.	%Texture Sand:Silt:Clay	22:43:35
2.	Electrical conductivity	0.24 S/m
3.	Bulk density (unpuddled)	1.74 g/cc

Basic soil properties of experimental field:

4.2 Testing Of Designed Cage Wheel:

Performance of implement parameters for wet land operations:

Operational speed:

In test, plot two poles of 20m apart (A, B) were place approximately in the middle of the test run. The speed was calculated from the time required for the machine to travel the distance (20 m) between the assumed line connecting two poles opposite sides. A stop watch was used to record the time for machine.

Fuel consumption:

The following simple method was used for measuring fuel consumption. The tank was filled to full capacity before and after the test .Amount of refueling after the test was the fuel consumption for the test. When filling of the tank, carefully attention should be keep the horizontal and not to leave empty space in the tank

Wheel sinkage:

The sinking of cage wheel at different level of water at puddle field soil was measured with a suitable tape.

Depth of ploughing:

Depth of ploughing could not be measured accurately due to quick furrow filling in the wet muddy condition of field. Ploughing depth was different for each lug angle and diameter at different point in wet land operation it was measured by suitable measuring scale.

V. CONCLUSION

This study showed that the half cage wheel of different diameters of rims and the inclined L - shaped lugs at 40 degrees lug spacing gave the highest pull and the deepest sinkage. The supporting braces of these half cage wheel is strong enough to withstand the pull force and lift force acting on the L- shaped lugs. This half cage wheel can provide higher pull force and reduced wheel sinkage, and can be recommended for working in wet paddy fields.

The prototype that is prepared by considering all the dimensions in the ratio of 1:4 is successfully working by using all the motors to run the prototype.

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