

To Increase the Turning Angle of the Wheel from 35° to 55° for a Tractor Assembly

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Abstract

The main aim of this research paper is to increase the turning angle of a tractor assembly. The methodology is based on the analytical formula developed for the four bar linkage mechanism of steering. The present design that is used is restricted with the steering angle of around 35 degree. With the improved design we are trying to achieve the steering angle of nearly 55 degree. This research aim to design, develop and analyze the new mechanism for improving the steering angle. Primary function of steering system is to achieve angular motion of front wheels to negotiate a turn. This is done through linkage and steering gear which converts the rotary motion of steering wheel into angular motion of front rotary wheels.

Keywords: Vehicle Dynamics, Steering Angle, Turning Radius

INTRODUCTION

The agricultural tractor is the backbone of the agriculture because it does all the different field processes. It must be improved to suit the conditions and potentials of the farmer to increase the efficiency of its operation. This study aims to develop steering in particular. It aims to design a mechanism which can be controlled hydraulically to work on the front land-wheels. The geographical condition of agricultural land is different at every area and the tractor has to perform according to that, this is the main reason why we should increase steering angle of tractor more than 35 degree. Primary function of steering system is to achieve angular motion of front wheels to negotiate a turn. This is done through linkage and steering gear which converts the rotary motion of steering wheel into angular motion

of front rotary wheels. And secondary function of steering system is

- To provide directional stability of vehicle when going straight ahead.
- To provide perfect steering condition i.e. perfect rolling motion of the road wheels at all times and to minimize tire wear.

Advantages of increased steering angle are:

- Tractor will have least radius of rotation.
- Effort of the tractor will be increase in agriculture field.
- It will decrease the time consumption of doing any work.

The steering angle is designed as per the Ackerman's principle which is as follows:-

$$\cot \phi - \cot \theta = \frac{W}{W_B}$$

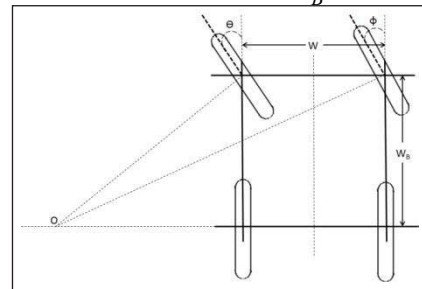


Figure 1: Position of axle for correct steering

PROPOSED METHODOLOGY

For the analysis of the steering angle tractor made by John Deere model 5310 (55 HP), 2400 rpm has been taken. The dimension as per the specification has been mentioned below.

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Table 1: Dimensions of four bar Linkage Mechanism for Jhon Deere Tractor Model 5310

Configuration No.	W (mm)	W/2 (mm)	TR (mm)	r (mm)	$\cot \phi - \cot \theta = \frac{W}{W_B}$
1	800	400	760	160	0.39
2	920	460	874	184	0.45
3	1040	520	988	208	0.51
4	1190	595	1130.5	238	0.58

Total weight	2110 kg
Wheel base (WB)	2050 mm
Overall length	3500 mm
Overall width	1865 mm
Ground clearance	450 mm
Turning radius with brakes	3215 mm

To increase the turning angle of the front wheel single hydraulic piston cylinder arrangement can be used. The proposed design shows if length of the hydraulic cylinder (L) is increased with other dimensions constants for various ratio of steering pivot distance to wheel base i.e (W/WB= 0.39, 0.45, 0.51 and 0.58) we can achieve the front wheel steering angle of around 55°. Presently with the above dimension of the tractor the ratio of steering pivot distance to wheel base is 35° maximum.. The theoretical steering angle can be derived from the equation (1) and (2)

$$\sin \theta = \frac{\frac{W}{2} - TR + L \cos \alpha}{r} \quad (1)$$

$$\cot \phi - \cot \theta = \frac{W}{WB} \quad (2)$$

Where L = Hydraulic cylinder length

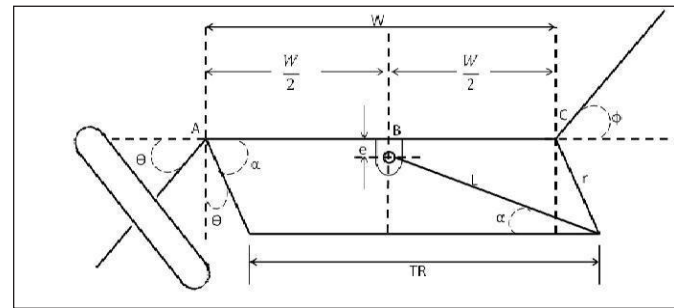
R = Steering arm length

TR = Tie rod length

α = Piston steering angle

θ = Inner front wheel angle

Φ = Outer front wheel angle

**Figure 2: Geometry showing different dimension for achieving greater steering angle**

Results and Discussions

The main aim of this project was to increase the operation efficiency of agricultural tractor to suit the conditions and potentials of the farmer. This leads to increase the rates of the Fadden production and raise the value of the yield per Fadden. This meets the requirement to achieve the strategic goals of the agricultural development by modifying and developing the modern technology, especially the agricultural tractors to suit the local environment in all agricultural operations, including plowing.

From figure (5-8) it is clear that the inner and outer front wheel steering angles increased with the hydraulic cylinder length for all W/WB ratio (0.39, 0.45, 0.51, 0.58). The inner and outer steering angles decrease with the increased values of W/WB ratio. The maximum values of inner and outer of front wheel steering angles are (73.5°, 55.54°) for 0.39 W/WB, (74.3°, 53.83°) for 0.45 W/WB, (73.64°, 51.2°) for 0.51 W/WB, (71.84°, 47.7°) for 0.58 W/WB ratio. These values are calculated from the theoretical derived formula. A prototype model can be prepared to validate the analytical and graphical values of inner and outer front wheel steering angles.

With the dimensions given in Table 1 for the Jhon Deere tractor model 5310 graphical values of front wheel inner and outer steering angles. These angles are obtained by varying the length of hydraulic piston cylinder keeping all other dimensions constant. The values obtained are given in Table 2.

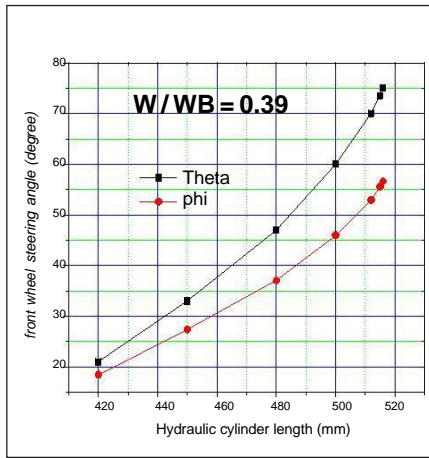


Figure 3: W/WB =0.39

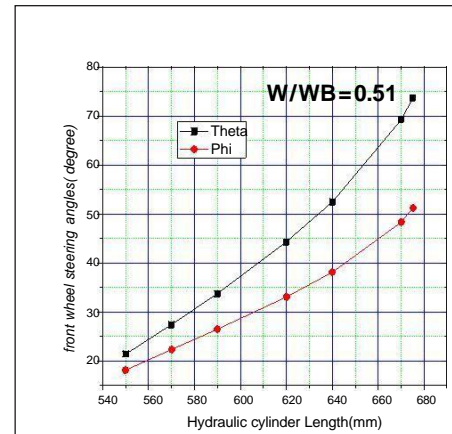


Figure 4: W/WB =0.51

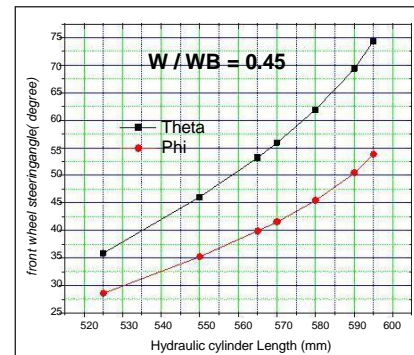


Figure 5: W/WB =0.45

Table 2: Analytical and Graphical Values of Inner and Outer Front Wheel Steering Angles

$\cot\phi - \cot\theta = \frac{W}{W_B}$ ⇒		0.39			0.45			0.51			0.58		
LENGTH OF HYDRAULIC PISTON CYLINDER (L) IN MM		480	500	515	550	570	590	620	650	675	725	750	775
INNER STEERING ANGLE (θ^0) ⇒	ANA.	43.2	57.6	69.6	42.3	53.2	67.7	39.9	55.8	71	45.9	57.5	73.1
	GRAPH.	36	50	51	35	42	54	32	45	50	42	45	54
% ERROR		16.89	13.19	26.7	17.25	21.05	20.20	19.79	19.35	30	8.4	21.74	26.1
OUTER STEERING ANGLE (ϕ^0)	ANA.	34.5	44.3	52.7	32.8	39.8	49.3	30.4	40.0	49.5	32.8	39.4	48.5
	GRAPH.	22	38	40	25	31	44	28	35	40	30	35	40
% ERROR		36.23	14.22	24.09	23.78	22.11	10.70	7.89	12.50	19.50	8.54	11.16	17.5

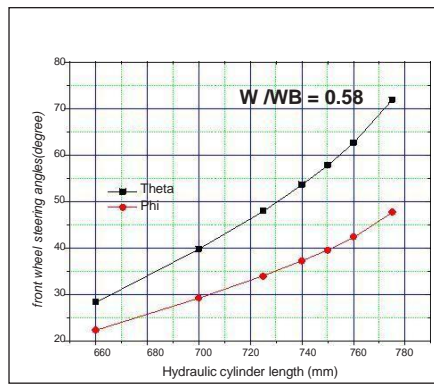


Figure 6: W/WB =0.58

Fig (7-10) shows the comparison between analytical and graphical values of inner and outer front wheel steering angles. Maximum inner wheel steering angle obtained by graphical method is 54° for $L=775\text{mm}$. These values of steering angles can further be increased by increasing the length of the piston cylinder up to an optimum and feasible value.

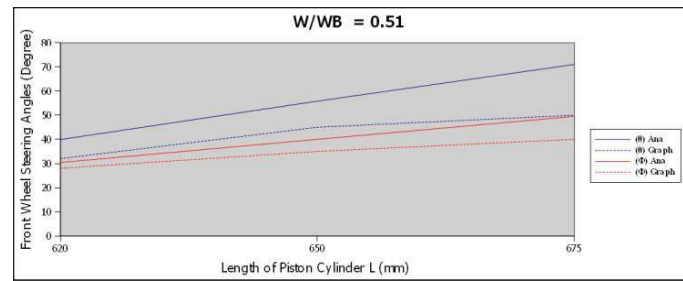


Figure 9: W/WB =0.51 (Comparison)

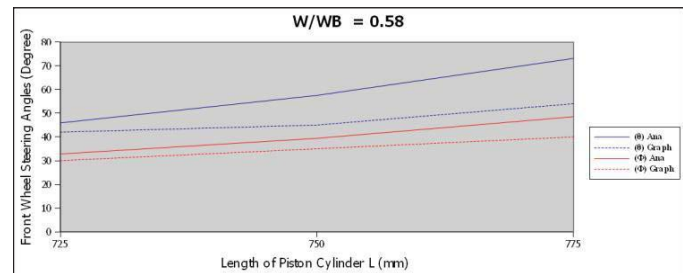


Figure 10: W/WB =0.58 (Comparison)

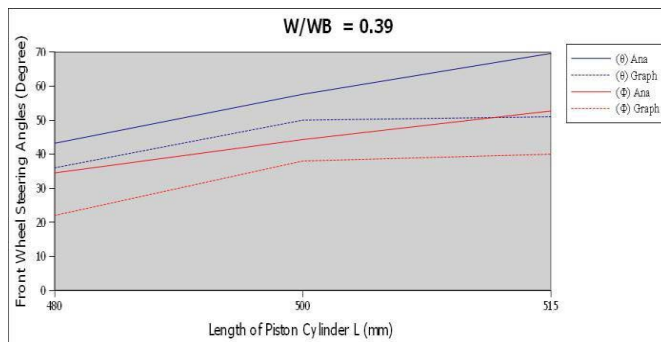


Figure 7: W/WB =0.39 (Comparison)

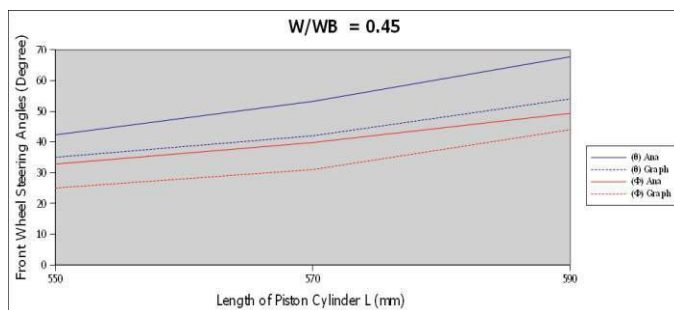


Figure 8: W/WB =0.45 (Comparison)

Conclusions

After doing analytical and graphical calculations a model has been prepared in Auto CAD for the optimal dimensions giving the inner wheel steering angle 54° . Also a Prototype

(Table 3) has been prepared for the same dimension which well satisfies the analytical and graphical results.

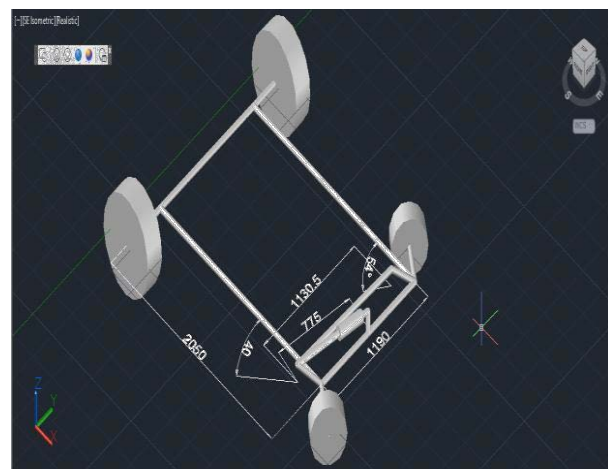


Figure 11: Auto CAD Model for optimum inner steering angle (54°), $W/WB = 0.58$

Table 2: Dimensions for Prototype

Link	Name of component Part	Actual dimension (mm)	Prototype dimension (mm)
AB	Track width	1190	53.28 (1ft 9in)
AC	Wheel base	2050	91.44 (3ft)
EF	Tie rod length	1130.5	50.61 (1ft 8in)
OF	Hydraulic Cylinder length	775	30.70 (1ft 2in)
AE	Steering arm length	238	10.65 (4.4in)



Figure 12: Prototype for Optimum Inner Steering Angle (54 degree), W/WB =0.58

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