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Draftbility of Power Tiller with Different Lug Angle of Cage Wheels in Puddle Soils for Paddy

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Abstract

The experiment was conducted on IGKV research farm in wet puddle condition in April month of 2015. The wet tillage practice was carried out by power tiller cage wheel attached with five tines cultivator. Paddy production increases by puddling of soil before transplanting. Cage wheel is an important traction device for any prime mower. The lug is wing provided in cage wheels which interact with the wet soil to churn the soil .The cage wheel 730 mm diameter with 30º, 45º, and 60º lug angle and three different diameter of 73 mm, 680 mm and 780 mm of 30º was tested at 0 to 50 mm, 50 to 100 mm, 100 to 150 mm and 150 to 200 mm, depth of water level in wet land field. The result was found that cage wheel C1 of 30º lug angle with 730 mm diameter give better performance than other cage wheel. The cage wheel showed the best result in 50–100 mm water level in respect to maximum tractive efficiency was found in the range of 73−78% at 996 N to 1009 N draft and drawbar power was in the range of 478.08 W to 484.32 W. While maximum drawbar power was (523.16 to 555.28 W) was observed at 0 to 50 mm water level. Therefore cage wheel of 30º lug angle with 730 mm diameter was found suitable for wet land paddy field condition.

Keywords: Cage, lug angle, draft, drawbar power, tractive efficiency

1. Introduction

Power tiller is a low horse power walking type tractor where the operator trails behind the machine, holding two handle of tiller also seat is provided in some design. Technological improvement in Indian agriculture through the mechanization from last sixties year come revolution in agriculture production. The timeliness of operations has assumed greater significant in obtaining optimal yields from different crops, which has been possible by way of mechanization (Singh, 2007). Contribution of tractors and power tillers was only 2.54% of the total farm power in 1960−61 increased to about 50% in 2013−14 in this period tractor population in India has grown from 0.037 million to 5.237 million units at an annual compound growth rate of about 10 per cent during the last 53 years (Singh et al., 2010). Application of a drawbar load improves the performance of lighter tractors on wet soil because it increases the driving axle load by the effect of weight transfer (Baloch et al., 1991). Cage wheel is the important traction device for wet land field. The lugs of the cage wheel are the basic elements to interact with the wet soil. Rice production calendar generally includes the period of soil puddling and transplanting of rice seedling processes in which rice field soils are in flooded or slurry-like condition. At this period, farm vehicles have to struggle with severe loss of their mobility even in the field with appropriate hardpan. Cage wheel using fixed lugs also have a soil blocking problem among the lugs when operated paddy soil and using open, flat-lugged wheels for a small power tiller operated on agricultural soils, it was observed that the cross-sectional area of blocked soil (i.e. amounts of soil wedge) became smaller when the lug angle was increased reported by Triratanasirichai et al. (1990). soil adhesion plays a significant role for soil sticking on cage wheel lugs as reported by Salokhe and Gee-Clough (1988a), they found later that a coating of lug surfaces with teflon tape, ceramic tile and enamel did not affect the lug forces. Rizaldi et al. (2014) 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° and found that 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 top layer of wet soil has low shear strength so that sufficient thrust cannot be developed Abubakar et al. (2009). Salokhe and Gee-Clough (1988) observed that cage wheels ranging smaller diameter of the drive wheel should be fitted to tractors. Arvind and Baruah (2016) experimented over two lug plates ,each set of lugs were fitted on cage wheel frame at 450 angular spacing for testing its field performance at two levels of soil moisture contents (23% and 36%). Split lug cage wheel fitted power tiller operation resulted about 27% less wheel slip associated with about 14% saving of fuel (l ha^{-1}) in comparison of non-split lug in moist field. The forces under a single cage wheel lug were measured by and Salokhe et al. (1990a). They observed that the forces under a single cage wheel lug were affected by lug sinkage and soil moisture content. These 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.

2. Material and Methods

The field experiments were conducted at the research farm of SVCAET and RS Faculty of Agricultural Engineering, IGKV, Raipur (C.G.), India in April, 2015. The implement, cage wheel for power tiller was fabricated in the faculty work shop. The testing and performance evaluation of different cage wheel in terms of tillage, tractive power, drawbar power in wetland condition, attached with five tynes of cultivator of power tiller. The designed dimensions and drawings were prepared by using the solid works software. The selection of materials and fabrication were done following the standard manufacturing procedures. Different part of cage wheel were described in Figure 1.

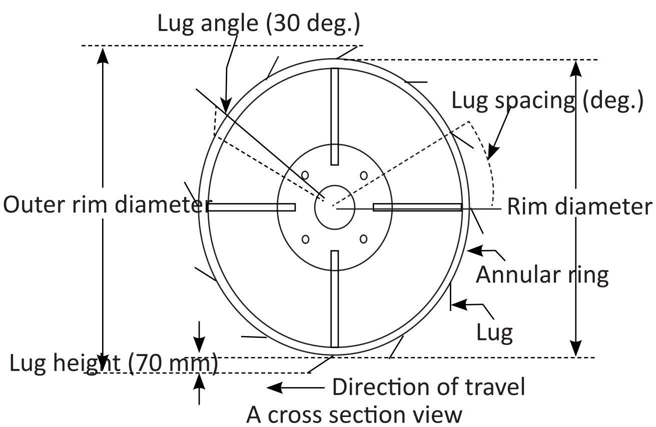

Figure 1: Sketch of cage wheel describing different parameters

2.1. Experimental details

A simulation study was done by solid works analysis for FEA to know the stress and strain effect on the different part of cage wheel. The wet land operation was carried out with power tiller with Beausani implement at different depth of water level of 0 to 50 mm, 50 to 100 mm, 100 to 150 mm and 150 to 200 mm in field condition. Three types of cage wheel in which three different lug angle of cage wheel was tested Figure 2.

Drawbar power was calculated by using following formula

$$DP=\frac{P\times V}{1000} \quad ....1$$

Where,

Dp=Drawbar power (kW) ,

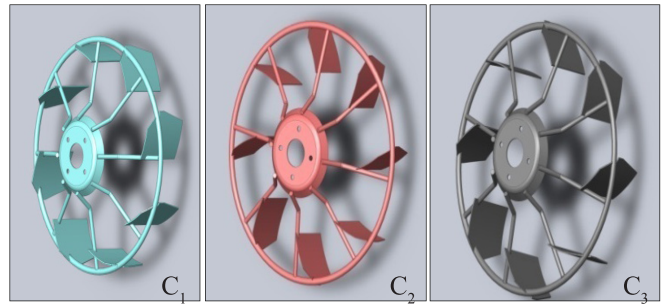

Figure 2: Cage wheel of different lug angle C_1 (30°), C_2 (45°) and C_3 (60°)

V=actual forward speed (with load) (m/s), and

P=pull generated (N).

Tractive efficiency was calculated by following formula

$$\text{Tractive efficiency}=\frac{\text{Drawbar power}}{\text{Axle power}} \quad ....2$$

Where,

Drawbar power W=draft (N) ×forward speed (m/s),and

Axle power=torque (N-m)×wheel revolution ω(rad/s).

2.2. Power tiller and wet tillage implements

A 9.69 kW power tiller was used to test the drawbar performance and tractive performance on a wet land field attached with five tynes cultivator with cage wheel having different lug angle. A total mass of 54 kg (27 kg on each wheel) was mounted on the sides of the wheels to study its effect on draft, drawbar power and tractive efficiency. The fuel consumption was measured with a burette mounted at the front portion of the power tiller. The specifications of cage wheel were described on below in Table 1.

Table 1: specification of cage wheels

Table 1: specification of cage wheels

Sl. No.	Parameter	Cage wheel C_1	Cage wheel C_2	Cage wheel C_3
1.	Wheel diameter (mm)	730	730	730
2.	Wheel width (mm)	300	300	300
3.	No of lugs	8	8	8
4.	Lug width (mm)	161	161	161
5.	Lug length (mm)	215	215	215
6.	Lug angle (°)	30	45	60
7.	Lug pitch (mm)	204	204	204
8.	Lug thickness (mm)	4	4	4
9.	Ring thickness (mm)	20	20	20
10.	Supportive rod thickness (mm)	15	15	15
11.	Supportive rod length (mm)	279	279	279

3. Result and Discussion

3.1. Effect of lug angle on drawbar power and tractive performance at 0 to 50 mm depth of water

Drawbar power at different lug angle of cage wheel on wet land condition is shown in Figure 3. It was found that increase

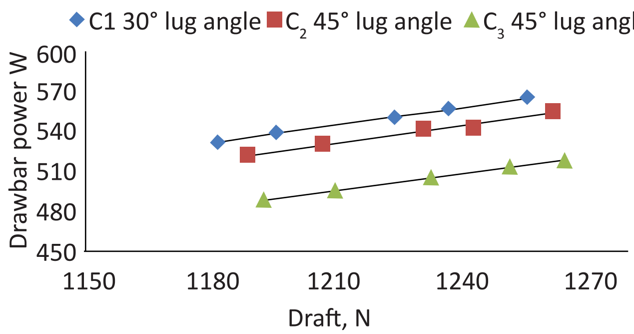

Figure 3: Effect of draft on drawbar power at 0 to 50 mm depth of water level

the drawbar power as increasing of draft and slippage. The maximum drawbar power 565.20 W was found for cage wheel C_1 followed by for C_2 (555.28 W) and C_3 (518.65 W) for cage wheel. Maximum draft was found 1265 N for cage wheel C_3 than the C_1 and C_2. From (Table 2) it was found that increasing lug angle drawbar power reduced. The similar results were reported by Anonymous (1975). Figure 4 shows the relationship between tractive efficiency between efficiency

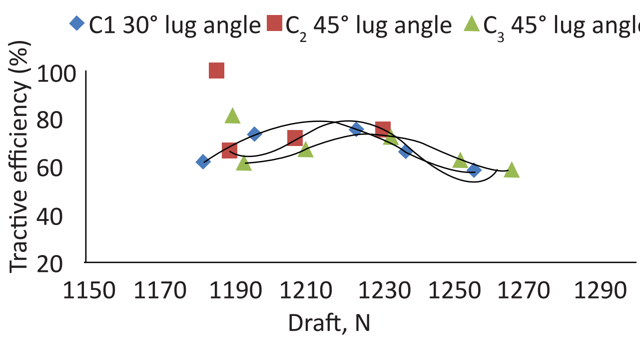

Figure 4: Effect of draft on tractive performance at 0 to 50 mm water level

and draft at different lug angles of cage wheel on wet land condition. The results found that the lug angles significantly affect the tractive efficiency. Results indicate that as the draft increases tractive power increases till a maximum point than further decreases. The maximum tractive efficiency was observed 75.90% with draft 1224N at 10.56% slippage for 30° lug angle for cage wheel C_1. It was also revealed from the study that as draft increases, working speed reduced due to increase in sinkage and slippage. The maximum tractive efficiency 75.54% for cage wheel C_2 at 1231 N whereas, minimum tractive efficiency was observed 58.55% for cage wheel C_3 at 15% wheel slippage with 1265 N draft (Table 2). The similar results were reported by Triratanasirichai (1990).

3.2. Effect of lug angle on drawbar power and tractive performance at 50 to 100 mm depth of water

Increase in standing water level from 0 to 50 to 50 to 100 mm, draft was reduced but tractive efficiency increases. Maximum drawbar power was found 531.96 W at 1023 N draft for cage wheel C_1 followed by 492.96 W and 476.56 W for cage wheel C_2 and C_3 with 1036 N and 1027 N draft respectively (Table 3). Increase in draft resulted increases in drawbar power as shown in Figure 5. Increase in water level, reduces, wheel slippage and sinkage that causes reduce in depth of ploughing that causes minimum draft. Tractive efficiency was observed at 50 to 100 mm depth of water level as given in (Table 3). Maximum tractive efficiency 78.72% was obtained at draft

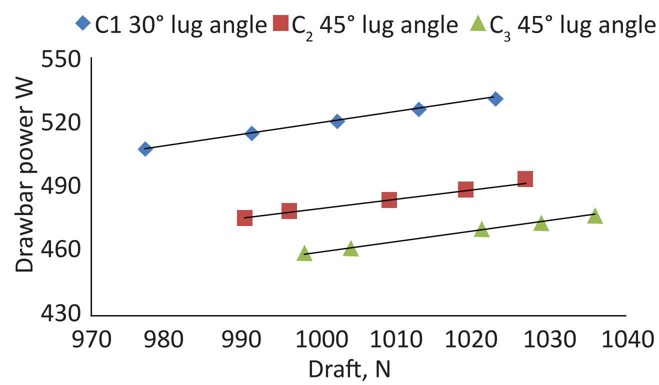

Figure 5: Effect of draft on drawbar power at 50 to 100 mm water

Table 2: Drawbar pull (N) of different angle of cage wheel in 0 to 50 mm water level

Cage wheel	C_1 30° lug angle			C_2 45° lug angle			C_3 60° lug angle		
Sl. No.	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)
1.	1182	531.9	61.82	1189	523.16	66.88	1193	489.13	61.72
2.	1196	538.20	73.27	1207	531.08	71.42	1210	496.10	67.54
3.	1224	550.80	75.90	1231	541.64	75.54	1233	505.53	73.02
4.	1237	556.65	66.54	1243	542.92	62.65	1252	513.32	63.07
5.	1256	565.20	58.18	1262	555.28	59.01	1265	518.65	58.55

Table 3: Drawbar pull (N) of different angle of cage wheel in 50 to 100 mm water level

Cage wheel	C_1 30° lug angle			C_2 45° lug angle			C_3 60° lug angle		
Sl. No	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)
1.	977	508.04	70.01	990	475.20	67.06	998	459.08	64.02
2.	991	515.32	73.58	996	478.08	71.44	1004	461.84	69.46
3.	1002	521.04	78.72	1009	484.32	74.75	1021	469.68	73.30
4.	1013	526.76	65.89	1019	489.12	63.34	1029	473.34	62.87
5.	1023	531.96	62.10	1027	492.96	60.56	1036	476.56	60.13

1002 N for cage wheel C_1 followed by 74.79% at 1009 N and 73.30% at 1023 N draft. It was observed that as draft increases tractive power increases up to maximum value

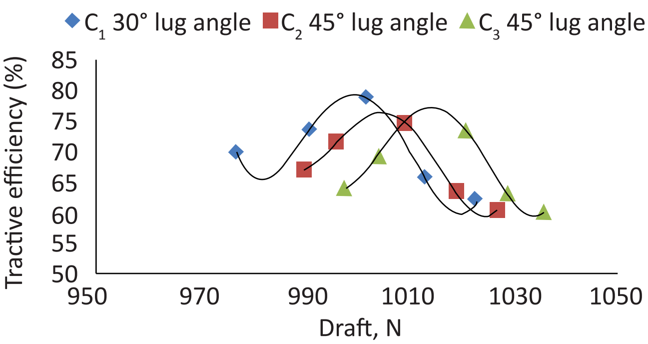

Figure 6: Effect of draft on tractive performance at 50 to 100 mm water

than it further decreases as shown in Figure 6. The minimum tractive efficiency was observed 60.13% for cage wheel C_3 than followed by 60.56% and 62.96% for cage wheels C_2 and C_1. Triratanasirichai et al. (1990) studied of 35° lug angle and 14 lugs in puddled paddy field and they found the maximum tractive efficiency and wheel slip at the maximum tractive efficiency obtained in this study were these values to be 79 and 25%, 68 and 40–50%, and 49.2 and 40.1% respectively in wet clay soils. From this study, it was also revealed that, at the maximum tractive efficiency, the sinkage was high (277 mm) and maximum drawbar power was only 110 W.

3.3. Effect of lug angle on drawbar power and tractive performance at 100 to 150 mm depth of water

Different lug angle of cage wheel was operated at 100 to 150 mm water level. The obtained value of drawbar power presented in (Table 4).The results indicate that as draft increases drawbar power also increases which depend on the wheel slippage, sinkage, sticking and depth of ploughing as shown in Figure 7. Maximum drawbar power was obtained 505.69 W at 829 N draft for cage wheel C_1 which followed by 483.14 W at 833 N and 453.56 W at 840 N draft for C_2 and C_3 respectively. The minimum drawbar power was found 429.84 W for cage wheel C_3 at 796 N draft. The similar results were

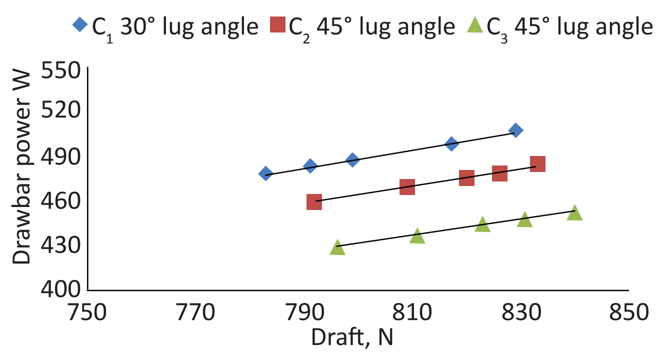

Figure 7: Effect of draft on drawbar power at 100 to 150 mm depth of water

Table 4: Drawbar pull (N) of different angle of cage wheel in 100 to 150 mm water level

Cage wheel	C_1 30° lug angle			C_2 45° lug angle			C_3 60° lug angle		
Sl. No	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)
1.	783	477.63	63.44	792	459.36	61.78	796	429.84	62.09
2.	791	482.51	73.70	809	469.22	66.22	811	437.94	64.71
3.	799	487.29	77.05	820	475.60	71.07	823	444.42	73.79
4.	817	498.37	62.88	826	479.08	63.63	831	448.74	61.84
5.	829	505.69	59.61	833	483.14	56.15	840	453.60	58.74

reported by Pandey and Ojha (1978). Increase in standing water level, increases tractive efficiency due to less sticking of soil on lug surface, easy to cut the soil, less slippage in wet land operation. The maximum tractive efficiency was found 77.05% for cage wheel C_1 at draft of 799 while 73.79% and 71.07 % for C_3 and C_2 at 823 N and 820N respective as shown in (Table 4). It was observed that as lug angle increases tractive efficiency and draft increases. Minimum tractive efficiency was found 56.15% at 833 N draft for cage wheel C_2 due to more slippage and sticking of soil Figure 8.

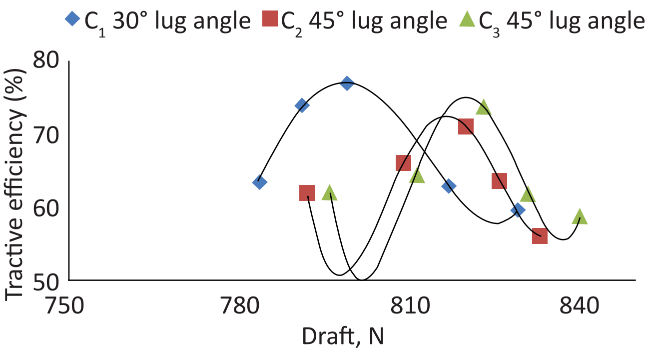

Figure 8: Effect of draft on tractive efficiency at 100 to 150 mm depth of water

3.4. *Effect of lug angle on drawbar power and tractive performance at 150 to 200 mm depth of water*

The drawbar power (W) and Drawbar pull (N) of different angle of cage wheel in 50 to 100 mm water level 200 mm standing water level of different lug angle of cage wheel is presented in Table 5. The maximum drawbar power was obtained 505.26W at 802 N draft followed by cage wheel C_2, 492.27W at 807 N and C_3 472.70 W at 815 N draft. It was revealed that increases of standing water in wet land field condition the drawbar power requirement and draft was reduced as shown in Figure 9. Effect of lug angle of cage wheel at 150–200 mm of water level tractive performance presented in (Table 5). It was revealed that maximum tractive efficiency was found 73.71% at 783 N draft for cage wheel C_1. The respective tractive efficiency for cage wheel C_2 and C_3 were 71.42% at 789 N draft and 69.51% at 785 N in flooded soil. Minimum efficiency was obtained 55.72% for cage wheel C_3 at 815 N draft. It was observed that in each lug angle, increase in draft the tractive efficiency increases up to maximum on a point than it reduced as shown in Figure 10. Narang and Varshney (2006) found that the values of draft on tilled land with pneumatic wheels at engine speed of 2000 rpm were 803 and 773 N in second low and third low gears, respectively.

Table 5: Drawbar pull (N) of different angle of cage wheel in 150 to 200 mm water level

Cage wheel	C_1 30° lug angle			C_2 45° lug angle			C_3 60° lug angle		
Sl. No.	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)	Draft (N)	Drawbar power (W)	Tractive efficiency (%)
1.	756	476.28	60.10	762	464.82	57.11	759	440.22	59.93
2.	768	483.28	68.28	771	470.31	62.47	776	450.08	63.52
3.	783	493.29	73.71	785	478.85	69.51	789	457.62	71.42
4.	793	499.59	67.19	796	485.56	63.69	801	464.58	60.93
5.	802	505.26	62.91	807	492.27	58.85	815	472.70	55.72

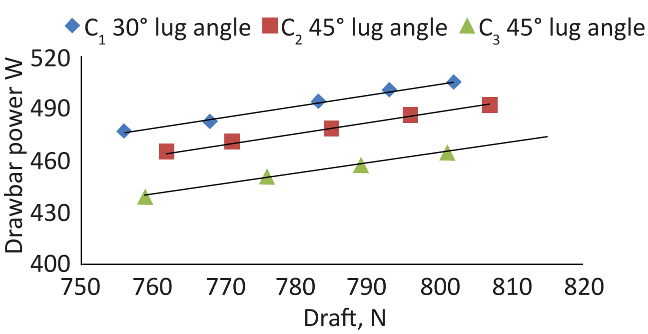

Figure 9: Effect of draft on drawbar power at 150 to 200 mm depth of water

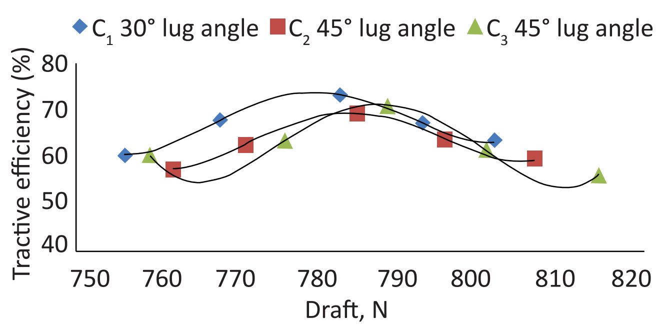

Figure 10: Effect of draft on tractive performance at 150 to 200 mm depth of water

4. Conclusion

The study showed that increasing lug angle decreasing the drawbar power and tractive efficiency. The best result was found in 30° lug angle of cage wheel with min slippage, less sinkage. It was also revealed that increasing water level on field reducing the draft because of minimum soil blocking on the cage wheel surface.

5. Acknowledgement

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