REVIEW ARTICLE

CAGE WHEEL FOR TRACTION IMPROVEMENT IN POWER TILLER

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Abstarct: Cage wheel is important traction improvement device in wet puddle soil condtion.In India rice is important crop for crop production and produced first crop as well as second crop where required puddle field condition.during the field operation with machine no of losses such as trafficability of the surface layer is very poor,increased energy consumption,fuel consumption,soil hardpan,plant debris etc.The cage wheel, in particular, provides a floating effect to the power tiller in wet paddy fields, in addition to puddling the soil.use of suitable cage wheel allow well puddle condtionand energy saving operation in wet land.

Keywords: Cage wheel, Traction, Sinkage, Slippage, Drawbar power

INTRODUCTION

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, wheeled farm vehicles have to struggle with severe loss of their mobility even in the field with appropriate hardpan. Thus several types of traction and flotation devices, such as open-lugged wheel have been developed and widely used with conventional tires or instead of tires in many rice producing countries in Asia.The deformation of soil with preceding lug trench must be considered when the multiple lugs of lugged wheel act on soil so that the practical action of them can be analyzed and the working reaction on lugs can be predicted.

Cage wheel is a traction device which 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 by Soemengat (1962). Pneumatic, rubber-tired wheels performed poorly in paddy conditions and the power loss of these wheels was about 66% of the total loss by Zhuorong (1984). Verma (1984) revealed that cage wheel exerted 3 times more pull in comparison with tyres in flooded soil conditions.

Wetland traction

Johrson (1965) studied that in wet land preparation, the soil is made into a mud slurry or puddle, and weeds are pushed 4 to 8 inches beneath the soil surface. The number of passes and deferred of puddling depend upon the water supply, soil type, vegetation, power unit, and implements. Rice soils are usually of heavy clay which is firm when first wet but may be progressively softened as flooding continues. Soil strength values vary with the duration of flooding and with the location of the plow sole or hard pan.Salokhe and Clough (1988) used chains, strakes, tyre tracks (half-tracks), ballasting, cage wheels, and dual wheels as a traction aids to achieve the maximum traction on a given terrain. He revealed that cage wheels are the best suited traction aids for wetland conditions.Salokhe and Clough (1988) studied that cage wheels are traction aids particularly suited for wetland conditions and these are usually used on small two wheel tractors to replace tyres and he observed that cage wheels should be fitted to tractors they are usually fitted to drive wheels with a diameter smaller than the tyre diameter. Puddling leads to soil compaction, increases the bulk density and soil penetration resistance in sub-soils which ultimately decreases their permeability and reduces the water losses Verma and Dewangan (2006).

Field performance of power tiller in wet land

Bernardo *et al.* (1993) studied in wetland condition using 7 hp (5.2 kW) diesel engine during the first pass, the rear mounted and arrangement attained actual field capacity of 0.24 ha/h, a field efficiency of 100 % and fuel consumption of 1.46 l/h at 2.18 kmph. In the second pass, field capacity remained at 0.24 ha/h, field efficiency slightly decreased to 96 % but fuel consumption improve to 1.21 l/h at 2.39 kmph.Ademiluyi and Oladele (2008) evaluate the performance of VST power tiller of 10 kW was carried out in different rice fields located at Shaba Maliki and Ejeti village near Bida on a clayey loamy, sandy soil, under the guinea savannah ecology of Nigeria. The result shows that 93 % and 92 % were recorded for field efficiency at Ejeti and Shaba-Maliki respectively. The difference in effective field capacity obtained at Shaba- Maliki (0.089 ha/h) and Ejeti (0.047 ha/h) was due to the variation in the average time of operation, the operational time at Ejeti (21.7 h/ha) almost doubles that of Shaba-Maliki (13.15 h/ha). In Ghana the field efficiency of VST SHAKTI 130D1 power tillers Biemso and Adugyma were 80.52 % and 82 %. On the other hand, the effective field capacity are 0.15 ha/h and 0.11 ha/h for Biemo1 and Adugyma while the average time of operation are 7.92 h/ha and 8.9 h/ha respectively for the locations in Ghana.

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Mandal and Maity (2011) studied the light weight power tiller of 2.25 kW and concluded that the average forward speed of operation of power tiller was 1.5 and 2.2 km/h when rotary unit speed is 130 and 180 rpm respectively. The average effective field capacity was 0.2 and 0.25 ha/day. The average fuel consumption was 1.0 and 1.2 l/h.Mohamad and Alireza (2013) compared the performance over three types of tractors as two wheeled tractor or power tiller (Kubota GA 70, 5.2 kW), light-weight tractor (Darvana DTM 200, 14.9 kW) and medium-weight tractor (MF 285, 53 kW). Results revealed that effective field capacities for power tiller, light and medium-weight tractors were 0.082, 0.224 and 0.314 ha/h, respectively. Fuel consumption (mean of two stages) was measured to be 2.05, 3.6, and 4.85 lit/h for power tiller, Darvana, and MF 285, respectively.

Traction performance

Pandey and Ojha (1973) Triratanasirichai *et al*. (1990) and Desrial (1994) had studied of 35^0 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 (27.7 cm) and maximum drawbar power was only 110 W.Triratanasirichai *et al.*(1990) conducted study on five sizes of lug angle (15º,30º,45º,60º and 75º) and four sizes of lug pitch were tested to determine the performance of open, flat-lugged wheels for a small power tiller operated on two different types of agricultural soils (sandy and clay loam). They concluded that the 45º lug angle gave the maximum tractive efficiency and the maximum drawbar power in paddy field. He also revealed that as the lug angle increases, drawbar power increases until the maximum value was achieved with a wheel with 45º lug angle.

Draught power of power tiller

Frank (1970) studied the axle torque and drawbar pull at different travel reduction. Drawbar pull is varied from zero to that required to obtain at least 30% travel reduction. During this time, axle torque also varies. An optimum drawbar pull (where efficiency is a maximum) can be determined for each soil condition.Anonymous (1975) tested of a 4.10 kW power tiller for drawbar performance with three-bottom moldboard plough and 5-tyne cultivator revealed that use of 60 kg ballast weight could develop a maximum pull of 1333.75 N with cage wheels under field conditions. Pandey and Ojha(1978) studied dimensional analysis for the effect of wheel parameters, namely the lug angle, lug height, rim width and lug spacing on the traction performance of rigid wheels in saturated soils. The performance of the test wheels was evaluated on the basis of drawbar pull, slip and torque data obtained at different normal loads ranging between 50 and 100 kg (790–980 N). The data were utilized to compute the performance values such as tractive efficiency and overall performance index. The optimum values of lug angle, rim width and lug spacing were found to be 20°, 200 mm and 110 mm respectively for a wheel of 685 mm dia. The wheel parameter most influencing the traction performance of the wheel was found to be the rim width.Sirohi and Panwar (1988) have found that the existing weight of about 200 kg of the IRRI model power tiller was inadequate to develop a pull of 150 kg and recommended that the weight should be at least three times as compared to existing weight.Singh *et al*. (1990) conducted the field studies in different soil conditions, and was observed that the pull of the power tiller wheel fitted with enamel coated lugs was higher than that of wheels fitted with uncoated lugs at any level of slip. Moreover cage wheel blocking was not observed in the case of enamel-coated lugs, but blocking was quite frequent with uncoated cage wheel lugs.Salokhe and Ghazli (1992) developed bow-shaped enamel coated float attachment for a 4.74 kW power tiller and fixed underneath the power tiller between the two cage wheels. The performance of the power tiller with and without the float was studied in flooded and puddled soil conditions. It was observed that the float prevented the cage wheels from digging deeper into the soil when slippage occurred. The float-cage wheel combination eased the operator's work. The statistical analysis showed that there was no significant difference in the pull and power delivered by the power tiller with and without the float in the flooded soil condition. However, in a puddled soil condition the power tiller with the float showed lower performance, in terms of pull and power delivered, than the power tiller without the float, as the cage wheels were prevented by the float from reaching the hardpan layer lying below the top puddled layer to develop enough pull. Narang and Varshney (1995) investigate a 6.71 kW power tiller to evaluated draft and drawbar power on tar roads. Polynomial regression analysis was used to establish the relationship between draft and wheel slip, drawbar power and wheel slip, drawbar power and fuel consumption, and drawbar power and specific fuel consumption. The results of the study showed draft values of 2107, 2110 and 2110 N in second low, third low and first high gears at an engine speed of 1500 rpm with a 15% wheel slip. The respective draft values at engine speed of 2000 rpm with a 15% wheel slip were 2172, 2189 and 2212 N. With the mounting of 40 kg wheel ballast there was an increase in draft of 217, 207 and 291 N at 1500 rpm, and 328, 306 and 344 N at 2000 rpm of the engine with a 15% wheel slip in second low, third low and first high gears, respectively. The increase in drawbar power with 40 kg ballast was 10.88%, 7.83 % and 20.13 % at 1500 rpm and 18.89 %, 16.56 % and 14.88 % at 2000 rpm of engine over the drawbar power available with zero ballast. The fuel consumption with the use of wheel ballast was slightly more than the fuel consumption without any ballast.Anonymous (2001) conducted trials to test a 7.46 kW power tiller for drawbar pull, fuel consumption and wheel slip. At 18% wheel slip, the drawbar power and specific fuel consumption were 1.38 kW and 1.62 kg/db kWh, respectively.Narang and Varshney (2006) studied a 8.95-kW walking tractor to evaluate draft and drawbar power on tilled land. The results indicated 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. The respective draft values at engine speed of 1500 rpm were 748 and 735 N in second low and third low gears under slightly loose soil conditions. Replacement of pneumatic wheels by steel wheels further increased the draft readings to 1034 and 999 N at an engine speed of 2000 rpm and 913 and 935 N at engine speed of 1500 rpm in second low and third low gears, respectively, indicating significant increase in drawbar power both at 2000 and 1500 rpm in second low and third low gears with the use of steel wheels.Gholker (2008) observed that higher drawbar force, and drawbar power, were found on plastic soil conditions at the same wheel slip compared to sticky soil conditions which in turn had a higher drawbar force and power compared to flooded soil conditions; vehicle slip and surface deterioration due to single passing was increased at the same drawbar pull as soil moisture content increased.

Effect of design parameter

Jayasundera (1980) used a pair of cage wheels, 93 cm in diameter and 38 cm wide, fitted to a 12.5 kW two-wheel drive tractor in Thailand in flooded, puddled field. The lug angle varied from 0 to 40° in steps of 10 ° and lug spacings were 20, 30, 40 and 60°. The results showed that the power transmitted for 30° lug spacing (with 12 lugs) was highest of all lug settings, and that a 30° lug angle gave the best drawbar power performance.Tanaka and Nakashima (1986) observed the characteristics of soil reaction on a plate of a wheel with 30° lug angle and different lug pitches (6, 9 and 12 lugs) by indoor experiment using loam in a soil bin, they found that the thrust efficiency of the lug becomes maximum at 30% slippage in the case of a wheel with 12 lugs.Xu Da (1987) studied the effect of design parameters of the cage wheel in a soil bin. The experiment results showed that the wheel with 680 mm diameter, 16 lugs and 220 cm lug width gave the optimum dynamic performance. Salokhe and Clough (1987) investigated the effect of lug angle on the soil deformation of wet clay soil under the action of a single lug. It was observed that the existing passive soil pressure theory could not be used to describe soil movement caused by the action of the cage wheel lug. Speculation about the soil failure prediction due to a rigid tine or soil cutting blade has raised doubts about the wisdom of applying this theory to other soil cutting tools.Tanaka and Nakashima (1988) studied the effects of the lug angle on the soil reaction in clay loam in a soil bin. The results showed that the average lift by a lug increases when the lug angle becomes large whilst the average thrust decreases. The thrust efficiency becomes maximum when the wheel slippage is 28.8%.Triratanasirichai *et al.* (1990) evaluate the different angle 15,30,45,60 and 75^0 of the cage wheel. The results show that as the lug angle increases, the drawbar power increases until the maximum value was achieved with a wheel with 45° lug angle for all lug pitches except for 12.33 cm lug pitch on sand, where the maximum value occurred at 30° lug angle. For instance, in the paddy condition, for a wheel with lug pitch of 16.44 cm, the maximum drawbar power is 170 W at 45 ° lug angle. However, as the lug angle increases to 60°, the maximum drawbar power at 50% slip drops to 150 W, which represents a decrease of 12%.Gasparetto *et al*. (1992) conducted study on very narrow, large diameter, lugged or smooth steel wheels fitted on Italian tractors and trailed implements to improve their mobility in wet paddy fields. For measurement of soil texture and cone penetrometer resistance two fields were selected as softest and hardest conditions. Rolling resistance tests were carried out on two narrow lugged steel wheels of different diameter. The wheels were tested both singly and paired as dual wheels; the travelling speed and the vertical load were varied. The results show that the coefficient of rolling resistance is slightly affected by the travelling speed and increases with the vertical load only with the smaller diameter wheel. The values seem to be relatively low, ranging between 0·12 and 0·35 depending on the combination tested.Hendriadi and Salokhe (2002) investigate traction performance of a cage wheel for use in swampy peat soils in Indonesia. The results revealed that increasing the lug angle from 15 to 35° and the length of lug improved the tractive performance of the cage wheel significantly, while increasing the number of lugs from 14 to 18 and width of lug did not improve the tractive performance significantly. A cage wheel with lug size 325×80 mm, 35° lug angle, 14 lugs (26° lug spacing), with 2 circumferential flat rings installed on the inner side of the lugs, outperformed the other settings for use with power tillers in swampy peat soils.

Effect of moisture content

Tsunematsu and Matsuj (1954) studied different lugged wheels of different lug shape on power tiller in clay loam soil. The moisture content varied from 7.3% to 44.7%. They found that the drawbar pull was increased in proportion to the increase of lug height. They also observed that the decrease of lug angle brought the increase of drawbar pull.Clough *et al*. (1981) measured the effect of lug angle and spacing on tractive performance in a flooded, puddled Bangkok clay soil and found that optimum spacing was 30º which meant 12-lug in a wheel and highest drawbar power was transmitted at 30º lug angle. Moisture content of the soil was 47.8%.Salokhe *et al.* (1989) investigate the effect of soil moisture content on the lug forces at 40 %, 55 % and in flooded soil condition (58 %). It was observed that increase in soil moisture content caused a decrease in the peak pull force. At 40 %, 55 % and 58 % soil moisture content and in flooded soil condition the peak pull forces at 6.5 cm lug sinkage were 350, 120 and 25 N, respectively.Salokhe *et al*. (1990) measured the forces acting on multiple cage wheel lugs when operating in wet clay soil also studied the effects of soil moisture content, lug sinkage, slip and spacing on lug forces. The lug normal and tangential reactions were measured with the help of strain gauged transducers. These forces were then converted to lug pull and lift forces. It was observed that lug forces on the preceding lug were always higher than those on the succeeding lug. For both the lugs, an increase in soil moisture content caused a decrease in lug forces, but an increase in lug sinkage caused an increase in lug forces. The lug slip did not affect the forces on the preceding lug, but it showed a significant effect on the forces on the succeeding lug. The lug spacing affected the forces on the succeeding lug.

Soil wedge formation on lugs

Salokhe and Clough (1988) studied on the deformation of wet clay soil under the action of multiple lugs and wedge formation. The effect of trench spacing (the distance between trenches cut by successive lugs), lug slip and lug spacing on the soil deformation under cage wheel lugs was studies. It was observed that the soil behavior under multiple cage wheel lugs was significantly affected by lug spacing and slip. The soil wedge formation as well as soil adhering to the succeeding lug was a strong function of lug slip and spacing. Triratanasirichai *et al.* (1990) studied the soil blocking or wedge over the lug plates of the cage wheels at different angle 15,30,45,60 and 75^0 of the cage wheel. The results showed that in a paddy field condition and for the wheels with 15° lug angle, 12.33 cm pitch lugs were nearly completely blocked with soil. When the lug angle was increased the cross-sectional area of blocked soil, i.e. amounts of soil wedge, became smaller and smaller. The cross-sectional area of soil wedge was rather big and decreased when the lug angle increased to 45 °, where the soil wedge disappeared from the lugs.

Effect of sinkage

Salokhe *et al.* (1989) studied the peak and lift force of single acting cage wheel in laboratory soil bin. It was observed that as the lug sinkage increased the pull as well as lift force values also increased. It was observed that at 35% slip, 40% moisture content and 2.5 cm, 4.5 and 6.5 cm lug sinkage the peak pull force values were about 200, 275 and 350 N and the peak positive lift force values were about 150, 300 and 410 N, respectively.

Effect of Slippage

Salokhe *et al.* (1989) investigated the effect of soil moisture content on the lug forces at 40 %, 55 % and in flooded soil condition 58 %. It was observed that increase in soil moisture content caused a decrease in the peak pull force. At 40 %, 55 % and 58 % soil moisture content and in flooded soil condition the peak pull forces at 6.5 cm lug sinkage were 350, 120 and 25 N, respectively.Triratanasirichai *et al.* (1990) conducted that the drawbar power from the test wheels depended on the wheel slippage, increase of wheel slippage leads to increase of the drawbar power until it reaches the maximum value at about 30% slip in for sand and 40-50% slip as in for paddy. When the slippage increases over the above slip values under both soil conditions, the drawbar power decreases to zero at 100% of wheel slip. Salokhe *et al*. (1994) studied the effects of low-to-medium slip, lug spacing and moisture content on lug forces in clay soil were investigated in a laboratory soil bin with the help of two model lugs. The lug slip was varied from 5 to 10, 15, 20 and 25 %. The measurements were conducted in clay soils with 6.3, 27.4 and 51 % soil moisture contents. The lug spacing was varied from 20° to 30° and 40°. The increase in lug slip from 5 to 25 % caused an increase in lug forces on both lugs. The increase in the soil moisture content from 6.3 to 27.6 % caused increase in lug forces on both lugs, but further increase in moisture content to 51 % decreased the lug forces. Lug spacing showed a significant effect on lug forces produced by the succeeding lug. The increase in lug slip increased the lug forces at any given lug spacing and moisture content. Rajaram and Eebatch (1999) investigated effect of drying stress, as influenced by one cycle of wetting and drying, on physical properties of a clay–loam soil in the laboratory. The physical properties studied were soil bulk density, cone penetration resistance, shear strength, adhesion and aggregate size and stability. Three drying stress treatments were made by wetting air-dried soil of initial moisture content of 12% (on dry weight basis) to three different higher moisture contents, namely 27, 33 and 40 %, and then drying each of them back to their original moisture content of 12 %. Thus, the soil was subjected to three different degrees of drying stress. The results showed that the soil strength indicated by cone penetration resistance and cohesion, and soil aggregate size, increased with the degree of drying stress but the soil bulk density did not change significantly. Watyotha *et al.* (2001) investigate the effect of circumferential angle, lug spacing and wheel slip on forces produced by a cage wheel in a laboratory soil bin having Bangkok clay soil with 51% (d.b.) soil moisture content. Six ring-type load-cells were used to measure the soil horizontal, vertical and transverse reactions on the cage wheel lugs. The circumferential angle was varied from 0, 15, and 30 to 45º. The lug spacing and wheel slip were varied from 20, 30 to

40º and 20, 35 to 50% respectively. All the force measurements were done at a constant 7 cm sinkage. The results showed that increasing circumferential angle up to 45º can reduce variation in lug wheel forces, at the same time it had little effect on the mean pull and lift values. The side force was affected by the changes of circumferential angle. The 20º lug spacing not only gave the minimum variations but also maximum mean lug forces. The highest lug wheel forces occurred at 35% wheel slip. Watyotha and Salokhe (2001) conducted study in a laboratory soil bin with clayey soil to determine the tractive performance of cage wheels as affected by opposing circumferential lugs, lug spacing and wheel slip. The performance was compared with conventional or normal cage wheels. The power of the modified wheels reached a peak at about 30-40% wheel slip depending on the circumferential angle and lug spacing. The modified wheels with 15º circumferential angle at 24 and 30º lug spacings showed significantly higher tractive power compared to other combinations. The power of the modified wheels was higher than that of the conventional wheels, the traction efficiencies between the modified and normal wheels were not significantly different. The average wheel slip at the peak tractive efficiency was about 34% for all circumferential angles and lug spacing. Based on the performance and cost of materials, the cage wheel with opposing circumferential angled lugs at 15 º circumferential angles and 30º lug spacing is recommended for the design of power tillers in Thailand.

SUMMARY

The literature is replete the parameters of cage wheel such as lug angle,lug angle, wheel diameter, lug spacing and lug height is affect the performance of tractive efficiency, drawbar power,draft,sinkage and slippage. When the lug angle was increased the cross-sectional area of blocked soil, i.e. amounts of soil wedge, became smaller and smaller. The cross-sectional area of soil wedge was rather big and decreased when the lug angle increased to 45 °, where the soil wedge disappeared from the lugs in wet puddling.

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