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PULL, TORQUE SLIP CHARACTERISTICS OF BRAKED WHEEL OF SEED DRILLS AND PLANTERS

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Abstract: Sowing or planting is one of the most important farm operations. Generally it is done by seed drill and planters. Metering device govern the seed to seed spacing in sowing operation. A constant velocity ration between the ground wheel shaft and the shaft of metering device helps in maintaining regular hill to hill spacing. Metering device requires torque for its operation which is derived from the ground wheel. Therefore, the ground wheel in seed drills and planters works as a braked wheel. The braked wheel experiences negative slip which is known as skid. Excessive value of skid will result in alteration of spacing between hills. Skid increases with the increase in braking torque resulting in large variations in hill to hill spacing. Hence, the relationship between braking torque and skid is important to the designer of seed drills and planters. The relationships between pull, torque and slip characterizes the behavior of the braked wheel. An experiment was carried out to determine skid at different lug height (15, 20, 25, 30, 35 and 40 mm), different axle load (98.1, 147.15 and 196.2 N) and different torque. A regression model was developed relating skid (s) with lug height (L) and torque (T). Axle load had no significant effect on skid in the range studied. The regression model was a quadratic polynomial equation having (R^2 = 0.82). Expected value of skid at different values of lug height and braking torque were calculated from the regression equation and given in a table. This can be used for determining lug height when torque requirement and permissible level of skid were known. It can be seen that skid increases with decrease in lug height almost for all values of braking torque.

Key words: *pull, torque, skid, axle load and ground wheel*

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INTRODUCTION

In any crop production program sowing or planting is one of the most important farm operations. Traditional sowing methods include broadcasting manually, opening furrows by a country plough and dropping seeds by hand and dropping seeds in the furrow through a bamboo or metal funnel attached to a country plough. Generally dibbling is practiced for sowing in small areas. Multi row traditional seedling devices with manual metering of seeds are quite popular with experienced farmers. Traditional sowing methods results in non-uniformity in distribution of seeds and poor control over depth of seed placement. Proper placement of seeds and fertilizers enhances productivity [1].

The basic objective of sowing operation is to put the seed and fertilizer in rows at desired depth and seed to seed spacing, to cover the seeds with soil and to provide proper compaction over the seed. Improved seed-cum-fertilizer drills are provided with seed and fertilizer boxes, metering mechanism, furrow openers, covering devices, ground drive system and a set of controls for variation of seed and fertilizer rates. The major difference in the different designs of seed drills and planters is in types of seed and fertilizer metering devices and in types of furrow openers [1].

Power required for operating the metering devices is taken from transport wheel, transport-cum-depth gauge wheel, press wheel and float type ground wheel. In case of tractor operated machines, power is taken from PTO shaft of tractor, transport-cum-depth gauge wheels and floated type ground wheel. The type of drive wheel to be used on drills depends on the ground conditions [9].

Metering device govern the seed to seed spacing in sowing operation. The metering devices of seed drills and planters draw the power required for their operation from the ground wheels. Wheels are of iron and closed type for better traction. This ground wheel or drive wheel is attached to the frame in front of the implement. A constant velocity ratio between the ground wheel shaft and the shaft of metering device helps in maintaining regular hill to hill spacing.

Rate of seeding with the fluted wheel in bulk flow seed metering devices is controlled by moving the wheel axially to change the length of flutes exposed to the seed in the feed hopper [9]. Primary method of controlling the seed rate with double-run feed is by changing the speed ratio between the ground wheels and the feed shaft. Power from ground wheel is transmitted to a shaft mounted on front frame. Power transmission unit consists of drive wheel, shaft, idler, sprocket and roller chain. From this shaft power is transmitted to seed and fertilizer metering shafts through chain and sprocket arrangement. However, size of roller chain and sprocket can vary in different models. The idler has been provided to tighten or loosen the chain for its smooth running.

The ground wheel in seed drill or planter works as a braked wheel. A braked wheel experiences skid which is known as negative slip. Excessive value of skid will alter spacing between hills. Metering device requires torque which is provided by the ground wheel. When braking torque increases skid also increases, due to skid hill to hill spacing will vary. The forward speeds of the experiment were taken 3 to 5 $km \cdot h^{-1}$ [7]. The relationship between braking torque and skid is important for design of the power transmission. The relationships between pull, torque and slip of the braked wheel will be useful for designers of seed drills and planters.

Keeping the above facts in mind a study was undertaken to determine the effect of lug size on slip characteristics of a braked lugged wheel. The purpose of this study was to determine the effect of lug height, axle load and braking torque on the skid experienced by the lugged rigid wheel.

MATERIAL AND METHODS

Experimental Method and Materials. The experimental setup used in this study is shown in Fig. 1(a) and (b). The dimensions of testing of wheel lugs were same as the dimension of zero till seed drills drive wheel lug. Because of traction requirement in both equipment's are similar. The lug heights of testing wheel were varied from 40-15 mm at 5 mm interval (40, 35, 30, 25, 20 and 15 mm). Lug width is equal to rim width. Total 16 numbers of lugs are attached at 22.5 degree angle on the testing wheel. Material used for lug is mil steel.

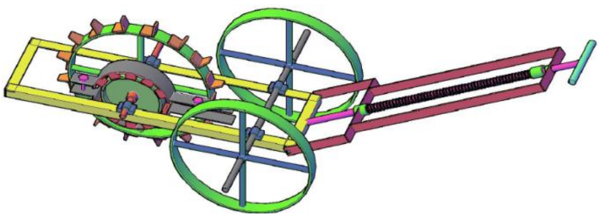

Figure 1. Isometric view of braked wheel test setup

Development of Test Setup. The main objective of this test was to determine an optimum lug size of rigid braked wheel for given field condition. Lugs of different heights were prepared for the purpose of testing. The lug height was varied between 40, 35, 30, 25, 20, 15 mm in steps of 5 mm. The test setup consisted of test wheel, prony brake dynamometer, support wheels (two), handle bracket and spring, frames and dead weights.

Pictorial views of the braked wheel test setup is given in Fig. 1 (a & b) and a photograph of the same is given in Fig. 2. The spring measuring the pull was calibrated by measuring its deformation under static load applied through dead weights.

Experimental Method. The performance of lugged wheel used as ground wheel in seed drills and planters evaluated at 6 different lug heights (15,20,25,30,35 and 40 mm), four different braking torque and three different loading condition (98.1 N, 147.15 N and 196.2N). The load coming on the axle of the braked wheel including weight of the wheel and axle was 348N (35.5 kg). The experimental details are shown in Table 1. The lugged wheel was installed in a test setup and the test setup was pulled by a man. The magnitude of pull is measured by deflection in a calibrated spring and the braking torque is measured by a digital scale installed at the arm of brake drum. The lugged wheel setup was tested in the Experimental Farm of Agricultural and Food Engineering Department, IIT Kharagpur. The experiment was conducted with three replication and pull, torque and skid were measured. In this study torque, lug height and normal load on axle were taken as independent parameters where as pull and skid (negative slip) were taken as dependent parameters. The value of average cone index for first and second field were measured and reported separately.

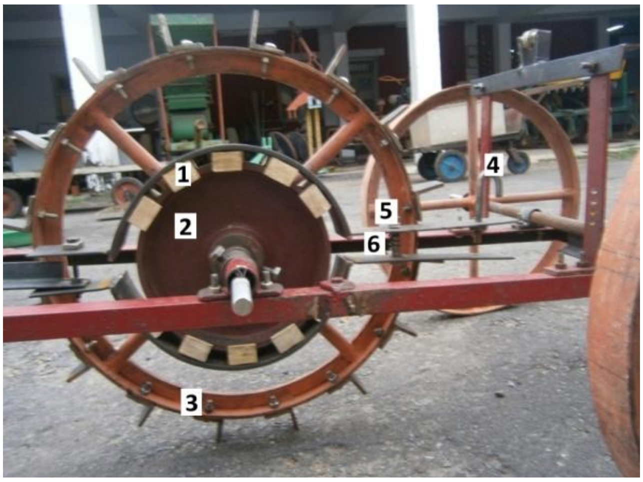

Figure 2. Photograph of braked wheel test setup
1. Wooden brake shoe, 2. Brake drum, 3. Testing wheel attached with iron lugs, 4. Hinge, 5. Bolt, 6. Load bar with compression spring

Table 1. Independent and Dependent Parameters in Testing of Braked Wheel

Independent variables	*Lower limit*	*Upper limit*	*Levels*	*Values*
Lug height [mm]	*15*	*40*	*6*	*15, 20, 25, 30, 35, 40*
Axle load [N]	*98.1*	*196.2*	*3*	*98.1, 147.15, 196.2*
Torque [N·m]	*Corresponding to 0 to 20% skid*	-	-	-
Dependent variables	*Skid (%)*		*Pull (kg)*	
Replications	*3*			

Experimental Procedure. The experiments were conducted in the Experimental Farm of Agricultural and Food Engineering Department. Each experiment was conducted on 15×15 m area.

For conducting the test following steps were adopted:

1. Experimental field was selected and measured.
2. Experimental field was prepared ploughing with a mould board plough followed by one pass of cultivator, two passes of disc harrow and one pass of leveler.
3. Cone index of the field was measured by cone penetrometer.
4. The value of torque, pull, forward speed and skid were recorded simultaneously.
5. For measuring skid the method used was the distance travelled method.
6. For measuring skid the method used was the distance travelled method. The theoretical distance was calculated from the rim diameter without lug. For actual distance we pull the trolley and measured the distance along with number of revolution of testing wheel.

$$Slip\ (\%) = (dt - da) \cdot dt^{-1} \cdot 100 \tag{1}$$

where:

dt [-] - theoretical distance travelled for a given number of revolutions,
da [-] - actual distance travelled for a given number of revolutions.

For braking torque the distance from the centre of the wheel to the lever end was multiplied by the force (kg) read from the scale.

Equation for the calculation for braking torque:

$$T = 9.81 \cdot M \cdot r \tag{2}$$

where:

M [kg] - mass on hanger,
r [m] - distance from centre of flywheel to hanger,
T [N·m] - torque applied.

Pull was measured by noting down the deformation of spring on the handle bar. The angle θ of the handle from horizontal at the time of pull was also measured (θ = 43.56°). Lugs of different height were fitted on the test wheel during the test. Photographs taken during conduct of the test are shown in Fig. 3.

Figure 3. Figure of testing of braked wheel in field conditions

RESULTS AND DISCUSSION

The main purpose of the study was to design the ground wheel of the seed drills and planters and to find the lug height for ground wheel at maximum braked torque at minimum skid. Proving ring was calibrated first. Afterwards methodology was adopted for the rim diameter and rim width from the seed drill and planters for test setup at six different lug heights (15-40 mm) at 5 mm interval. Optimized power requirement is needed for metering mechanism from ground wheel in which lug height having skid within 3-10 %. Optimization was done with respect to the response surface plot obtained from the experiment. Variance analysis was done after that to test the adequacy of the model.

Calculation of cone index. We have data for deflection of gauge reading with depth of penetration of cone penetrometer. The cone index was calculated by formula:

$$Cone\ Index = \frac{m \times deflection \times 9.81 \times 1000}{323} \tag{3}$$

The value of cone index measured at two plots of the field are given in Tab. 2. Cone Index of the first plot (*KPa*) 916.66 and of the second plot (*KPa*) 888.3.

Table 2. Soil properties of the experimental site

Depth [cm]	*Sand [%]*	*Silt [%]*	*Clay [%]*	*EC [at 20 ms]*	*Available N [kg·ha^{-1}]*	*Available K [kg·ha^{-1}]*	*Available P [kg·ha^{-1}]*	*pH in water*
5	*62.5*	*24.2*	*24.2*	*0.3*	*178*	*123*	*16*	*6.1*
20	*59.6*	*20.4*	*20.4*	*0.5*	*150*	*89*	*15*	*6.2*
40	*55.4*	*22.4*	*22.4*	*1.6*	*100*	*75*	*14*	*6.7*
60	*52.4*	*20.2*	*20.2*	*0.3*	*84*	*44*	*12*	*6.9*
80	*48.4*	*21.2*	*21.2*	*0.2*	*78*	*56*	*4*	*6.7*

Response Surface Model and ANOVA Analysis. The values of skid at different lug height and torque were analysed using ANOVA given in Fig. 5. A response surface model showing the interaction between torque and lug height corresponding to skid was developed. This is shown in Fig. 6. Regression model developed relating skid (*s*) with lug height (*L*) and torque (*T*) was shown in Eq. (4). The quadratic polynomial equation was developed for skid as a function of lug height and torque. The developed regression equation describes the relation among *s*, *T* and *L* with high correlation coefficient (R^2 = 0.82) depicting that almost 80% of the data are within the acceptable limit. Difference between actual and predicted response was not so widely spread. The model can be well accepted with more or less satisfactory correlation coefficient (R^2 > 0.8).

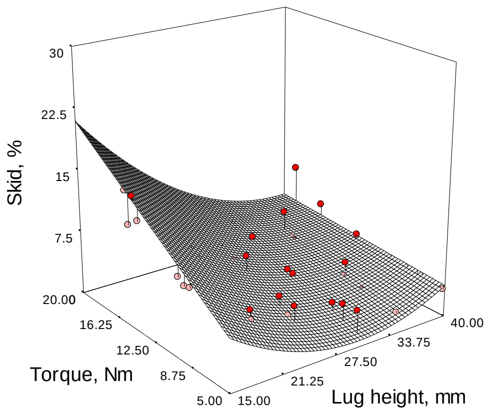

Figure 5. Response surface plot of torque, lug height and skid

At minimum value of braking torque if lug height was increased, skid was decreased up to 30 mm lug height value and after that skid started to increase with braking torque again. At 15 mm minimum lug height braking torque increased with skid rapidly. At the maximum lug height of 40 mm variation in torque with skid was little yielding a straight line with insignificant slope at *T-s* plane in Fig. 6. At 35 and 30 mm lug height, the corresponding braking torque increased with minimum variation in skid. But after 15, 20 and 25 mm lug height, increase in braking torque was not constant with respect to the increase in skid value. The recommended skid was within 3-10% at the highest braking torque. The criteria was fully satisfied at 40 lug height condition.

The contour plot given in Fig. 6. confirmed the presence of opposite sign of the coefficients of $L \times T$ and L^2 which suddenly change the direction of iso skid line at higher values of torque (> 14 N·m) and lug height (> 30 mm).

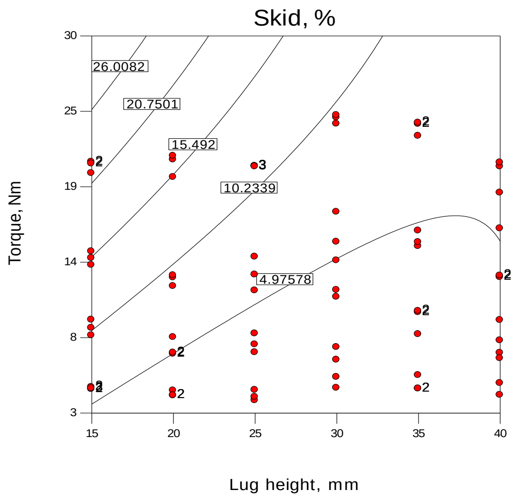

Figure 6. Contour plot of skid different values of lug height and torque

Table 3. ANOVA table for regression model on skid of braked wheel (with significant and insignificant values)

Source	Sum of squares	df	Mean square	F-value	P-value	
Model	1924.35	9.00	213.82	37.90	< 0.0001	Significant
L	694.64	1.00	694.64	123.13	< 0.0001	Significant
N	21.15	1.00	21.15	3.75	0.0574	Insignificant
T	741.07	1.00	741.07	131.36	< 0.0001	Significant
L.N	3.06	1.00	3.06	0.54	0.4641	Insignificant
L.T	245.51	1.00	245.51	43.52	< 0.0001	Significant
N.T	15.07	1.00	15.07	2.67	0.1072	Insignificant
L^2	206.73	1.00	206.73	36.64	< 0.0001	Significant
N^2	10.27	1.00	10.27	1.82	0.1822	Insignificant
T^2	2.41	1.00	2.41	0.43	0.5158	Insignificant
Residual	349.77	62.00	5.64			
Total	2274.12	71.00				

Analysis of variance of the above regression relationship is given in Tab. 3. It can be seen that the fitted model as well as the constituent terms (L, T, $L \times T$ and L^2) where significant. Load on the axle (N) was found to be non-significant at 5% level of significance. The quadratic terms of N and T are insignificant (p>0.05) to the model along with the interaction term of L and T. The relationship between values predicted by the above empirical relationship by Eq. 4 and the measured value are shown in a plot given in Fig. 5. It can be seen that the above empirical relationship can be used to predict the skid satisfactorily.

Based on the ANOVA shown in Tab. 2 an empirical relationship was developed using significant terms. The empirical relationship obtained is given below.

$$s = 16.48401 - 1.4166L + 1.5287T - 0.03543L.T + 0.027153L^2 \quad (R^2 = 0.82) \tag{4}$$

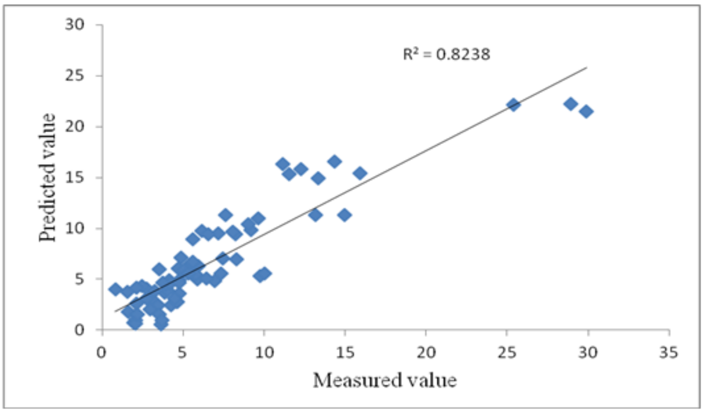

Figure 7. Plot of measured skid against the predicted value of skid by response surface model

Expected value of skid at a different lug height and braking torque calculated from Eq. 1 are tabulated in Tab. 4. It can be seen that skid increases with decreasing lug height almost for all values of braking torque, this table can be used to select lug height for a given braking torque with in an expectable level of skid.

CONCLUSIONS

Field experiment was carried out to study the torque, pull and skid characteristics of ground wheel, used in seed drill and planters. An experiment was carried out to determine skid at different lug height and torque and a regression model was developed. Based on the analysis the following conclusions were drawn.

1. Regression model developed relating skid with lug height and torque. The quadratic polynomial equation was developed for skid as a function of lug height and torque. The developed regression equation describes the relation among skid, torque and lug height with high correlation coefficient (R^2 = 0.82).
2. At minimum value of braking torque if lug height was increased, skid was decreased up to 30 mm lug height value and after that skid started to increase with braking torque again.
3. At 35 and 30 mm lug height, the corresponding braking torque increased with minimum variation in skid. But after 15, 20 and 25 mm lug height, increase in braking torque was not very constant with respect to the increase in skid value.
4. Expected value of skid at a different lug height and braking torque calculated from Eq. 1 are tabulated in Tab. 5.3. It can be seen that skid increases with

decreasing lug height almost for all values of braking torque, this table can be used to select lug height for a given braking torque with in an expectable level of skid.

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KARAKTERISTIKE VUČE, OBRTNOG MOMENTA I KLIZANJA KOČENOG TOČKA SEJALICA I SADILICA

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Sažetak: Setva ili sadnja su među najvažnijim operacijama u poljoprivredi. Merni uređaj na sejalici ili sadilici određuje rastojanje između zrna. Konstantan odnos brzine vratila pogonskog točka i vratila mernog uređaja održava pravilno rastojanje između sadnica. Merni uređaj zahteva pogonski obrtni moment od pogonskog točka. Zato pogonski točak pri trenju sa podlogom radi kao kočeni točak. On trpi negativno klizanje poznato kao klizno kočenje. Porast vrednosti prokljizavanja dovodi do promene rastojanja između sadnica. Povećano klizanje sa povećanjem momenta kočenja dovodi do značajnih variranja u rastojanju između sadnica. Zato je za konstruktore sejalica i sadilica važan odnos kočionog momenta i klizanja. Odnosi između vuče, momenta i klizanja karakterišu ponašanje kočenog točka. Ovaj ogled je izveden da bi se odredilo klizanje pri različitim visinama poteznice (15, 20, 25, 30, 35 i 40 mm), različitim osovinskim opterećenjima (98.1, 147.15 i 196.2 N) i različitim obrtnim momentima. Razvijen je regresioni model koji uključuje klizanje (s), visinu poteznice (L) i obrtni moment (T). Osovinsko opterećenje nije imalo značajan uticaj na klizanje u ispitivanom opsegu. Regresioni model je imao oblik kvadratne polinominalne jednačine (R^2 = 0.82). Očekivana vrednost klizanja pri različitim visinama poteznice i kočionim momentima izračunavani su iz regresione jednačine i prikazani u tabeli. Ovo se može upotrebiti za određivanje visine poteznice kada su poznati potrebni obrtni moment i dozvoljeni nivo klizanja. Može se uočiti da klizanje raste sa opadanjem visine poteznice pri skoro svim vrednostima kočionog momenta.

Ključne reči: *vuča, obrtni moment, klizanje, osovinsko opterećenje, pogonski točak*

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