A CASE STUDY

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Effect of different tire inflation pressures on drawbar performance of tractor in different gear setting

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ABSTRACT : The field performance of tractor includes the selection of correct tire inflation pressure, drawbar height and suitable gear for the better field performance and reduced cost of operation with increased service life. Keeping these points in view, the study was undertaken to select the height of hitch, tire inflation pressure and gear setting for the maximum drawbar pull and power with reduced fuel consumption by taking four different levels of tire inflation pressures at five different gear settings with 46 hp tractor. The test parameters such as dynamic rolling radius, height of hitch, wheel slip, traveling speed, drawbar pull, drawbar power and fuel consumption were measured as per IS: 12226 (1995). For measurement of the parameters load car with all the sensors measuring the parameters as per the IS code were utilized. At 0.555 m drawbar height and 1.2 kg/cm^2 tire inflation pressure the better values of drawbar pull, drawbar power and fuel consumption together were found for L3 gear at all the tire inflation pressures.

KEY WORDS : Drawbar pull, Tire inflation pressure, Drawbar power, Height of hitch

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The tractor is an important component of any farming system, and an understanding of its performance is essential for engineers involved in agriculture to develop the knowledge and skills necessary to analyze and predict tractor performance, and to advise and assist farmers in the selections and efficient operation of a wide range of tractors. Tractive characteristics and soil pressure beneath the tires of tractors are usually determined by conducting either field experiments or controlled laboratory soil bin experiments. These tests are useful in selecting tire geometry (width, overall diameter, and sectional height), tire type (radial verses bias), lug design, inflation pressure, and dynamic load on axles for various field operations in different field conditions. Moreover, these test data help design engineers to develop tires that perform better under a given set of operating conditions.

Tire and inflation pressure management:

Tire should be selected and managed to provide maximum contact area with the soil surface. Properly inflated radial tire provides a larger and flatter footprint than bias ply tires. Large, dual, radial tires maintained at minimum tire inflation pressures transmit power to the soil through the largest area. Increasing the contact area of tires reduces the pressure exerted by the tire on the ground. The pressure exerted by a tire on the soil surface near the lugs is roughly 0.14 kg/cm^2 greater than the tire inflation pressure. When dual tire are used in place of single tires, each tire carries a smaller portion of the weight of the tractor, hence, tire inflation pressure can be reduced. Whenever tire pressures are reduced, the tire flexes over a larger area and further reduces the pressure applied to the soil surface (Bailey *et al.*, 1996).

Inflation pressure determines tire stiffness, which has a significant influence on the ground contact area of the tire and the pressure distribution over the contact surface. Adjusting tire inflation pressure has been used as a means of reducing soil compaction and improving the tractive performance of agricultural tractors. Effect of inflation pressure on ground contact pressure, pressure beneath the tire as well tractive efficiency, particularly for radial tires, have recently been considered by many researchers (Baily *et al.*, 1996). It is known that optimum tractive performance of a driving tire can be obtained by adjusting the inflation pressure of the tire according to the soil conditions over which it moves. The benefits of lower inflation pressure might include decreased soil-tire interface pressures, increased tire performance, decreased soil compaction, and a smoother ride. Accordingly, inflation pressure has been set at the manufacturer's recommendation for the load on the tire. This will minimize soil stresses and compaction, and maximize tractive efficiency.

Gu and Kushwaha (1992), studied the effect of dynamic load distribution on the tractive efficiency, traction ratio and power distribution of a ¼ scaled model tractor on two different soil conditions. The effects of the interactions of dynamic load distribution with travel reduction and total dynamic load were investigated. Brixius (1987), developed equations to predict the tractive performance of bias-ply tires operating in cohesive-frictional soils. Bashford *et al.* (1992), compared the dynamic traction ratio and tractive efficiency for a tractor equipped with three different size rear tires each operating at three different inflation pressures and two different soil surfaces were used.

Justification of proposed study:

Running tractor tire at the wrong pressures can have a direct effect on tractor performance, tire wear, and soil compaction and that can have a severe financial impact on owner. Incorrect tire pressures means tractor can waste 20-40% of engine power through tire slip and rolling resistance and losses that also occur from transmissions and ancillary equipment such as alternators and water pumps.

Grisso *et al.* (1991), evaluated the tractive performance of 18.4R42 and 18.4R46 tractor tires mounted on 2 WD and 4 WD agricultural tractors on three different firm soil conditions. From their study they concluded that when the 2 WD tractor operated on a disked surface, the tractive efficiency of the 18.4R42 tires was slightly higher than the 18.4R46 tires. The tractor operated with single rear tires tended to pull more at a given slip that a tractor equipped with duals. The results showed no tractive advantage of 18.4R46 tires over 18.4R42 tires. The results were influenced by high tire inflation pressures and firm soil conditions. A tractor used on the road with tire pressure set too low for the load being carried will start to wear its lugs. Not uniformly, through- the backs of the lugs will wear down first. In more general use, unbalanced wear and sidewall creasing can be expected, but the most immediate and costly damage is bead slip. Whenever the tractor tire is under inflation there is unbalanced wear, sidewall damage, bead slip and increased fuel use. If a tractor tire is over inflated there will be greater soil compaction, more wear and tear on tractor and tire, reduced tire life and increased fuel consumption.

Ill effects of drawbar power utilization due to incorrect setting :

It is known that, the rear part of the tractor is heavier than the front to get the higher tractive efficiency. However, sufficient weight on the front axle is also required to facilitate easy steering and to compensate the effect due to weight transfer. Baily and Burt (1982) studied the effects of ballast and inflation pressure on tractive efficiency of bias-ply and radial-ply tractor tires operating on field conditions. When the load is pulled, the tendency of front axle is to become light by loosing some weight and the same adds to the rear axle. The higher the pull, the greater the weight transfers.

From this it is clear that, the longitudinal stability of the tractor depends on the hitch height. The higher the hitch, greater is the weight transfer. However, the hitch height is limited to a value beyond which the tractor's front wheels will lift and may topple over.

Work done in past :

A commonly recommended approach to reducing soil compaction is to reduce the unit ground pressure through the use of dual tires or high- flotation tires (Janzen, 1990). McLeod *et al.* (1966) examined the traction and compaction characteristics of overinflated single, overinflated dual, and low pressure single tires. Less compaction occurred with the low- pressure and dual tires compared to the overinflated single tire.

Wiley *et al.* (1992) noted improvement in both tractive performance and power hop control when they operated both four-wheel-drive (4WD) and modified front-wheel-drive (MFWD) tractors equipped with radial tires at the correct inflation pressures.

Inflation pressure determines tire stiffness, which has a significant influence on the ground contact area of the tire and the pressure distribution over the contact surface. Adjusting tire inflation pressure has been used as a means of reducing soil compaction and improving the tractive performance of agricultural tractors. It is known that optimum tractive performance of a driving tire can be obtained by adjusting the inflation pressure of the tire according to the soil conditions over which it moves. The benefits of lower inflation pressures might include decreased soil-tire interface pressures, increased tire performance, decreased soil compaction, and a smoother ride. Accordingly, inflation pressure has been set at the manufacturer's recommendation for the actual load on the tire, which is the minimum acceptable inflation pressure for that load. This will minimize soil stresses and compaction, and maximize tractive efficiency. Effects of inflation pressure on ground contact pressure, pressure beneath the tire as well tractive efficiency, particularly for radial tires, have recently been considered by many researchers (Raper, *et al.,* 1995; Bailey *et al.*, 1996; Jun *et al.*, 2004).

Objectives :

By keeping the above points in view the study was undertaken with following objectives:

– To evaluate the height for maximum pull and power for wheel slip in recommended range.

– To evaluate maximum drawbar pull, drawbar power, wheel slip and fuel consumption at various tire inflation pressures in different gears for the best suitable hitch height.

– To select gear-tire inflation pressure combination for higher drawbar pull and lesser fuel consumption.

METHODOLOGY

Selection of tractor:

According to the Indian conditions and various factors like land holding cropping pattern, soil condition, climatic condition the tractors power ranging between 35 to 50 hp were mostly used.

Therefore, 46 hp tractor with tank full of diesel fuel was selected for the test. The following adjustments were made before the test was to be started. Free play of clutch and brake pedal was set. Torqued all the drawbar linkages as per recommendation. Checked all the reservoirs if empty filled it. Taken the front and rear weight of tractor by adding 65 kg mass of driver. Ensured new rear tires. Inflated the tractor rear tire at 1.4 kg/cm^2 for starting research work.

Measurement of dynamic rolling radius (DRR):

The dynamic rolling radius (DRR) was measured by marking the numbers on the lugs of the tractor in such a way that the lug on the ground was marked as 1 and marking is done clockwise on the circumference on the tractor wheel. The DRR was calculated by the following formula (I).

$$\mathbf{DRR} = \frac{\textbf{Distance traveied (m)}}{2\pi \times 5} \qquad (1)$$

The dry RCC track was used for the test.

O - O → Test track (Levelled concrete surface, 0.8 km circumference, oval shape).

1 → Hitch height adjustment device on load car to maintain straight line of pull

2 → Load cell (75 kN drawbar pull capacity)

3 → Coupling (Tractor linkage drawbar connecting with front tow hook of load car)

4 → Drawbar height (Vertical distance between ground level and centre of linkage)

5 → Fifth wheel (To measure distance coverage for travelling speed and wheel slip calculations)

6 → Control panel of load car

7 → Eddy current dynamometer

8 → Generator of load car

9 → Blower fan for dynamometer.

Test procedure:

The load car attached to the tractor showing different components are shown in the Fig. A. The tractor was attached to load car and made the necessary connections *i.e.* fuel to tractor and fuel return lines. The fuel to tractor was provided from the load car. The sensors were connected to telescopic boom gave the reading of various parameters like temperature of engine oil, transmission oil, and water inlet and exhaust gases and speed of PTO shaft (*i.e.* engine rpm). Firstly started the generator then started the main supply to system. Then started the tractor and simultaneously started the water pump, fuel pump etc. Afterwards the actual working was begun; set the tractor in lowest gear and started working in full throttle. Increased the load of an interval of about 10% of the weight of the tractor, the tractor will either exert a pulling force on the load car or else the load car will exert a pushing force on the tractor. Drawbar pull, power, wheel slip, fuel consumption, engine rpm, SFC, temperatures etc. were recorded to cover 30 m distance on test track. The dynamometer mounted in load car was an eddy current dynamometer which was used to apply load to rear wheels of the load car and the test parameters related to tractor were measured with the help of hardware mounted in the load car which automatically captures all the readings. Besides load

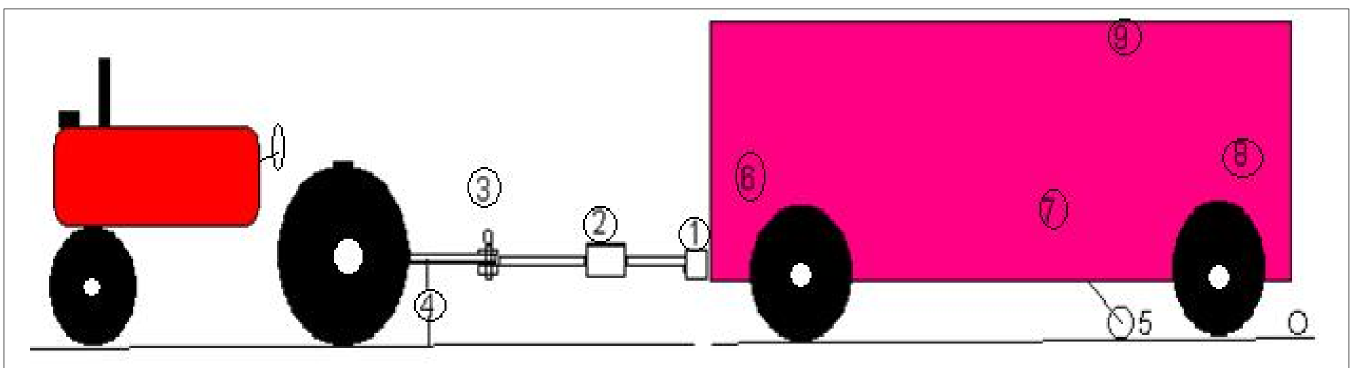

Fig. A : **Load Car attached to tractor showing different parameters**

we could use wheel slip as an input factor to take readings.

RESULTS AND DISCUSSION

The different values of parameters viz. height of hitch, drawbar powder, wheel slip, fuel consumption were recorded and the effect of different tire inflation pressure in different gear settings is discussed in this paper:

Selection of hitch height by comparison of drawbar pulls obtained under different hitch heights:

The Fig. 1 shows the plot of drawbar pull Vs hitch height. It shows the pull obtained by changing drawbar hitch heights from 0.485 m to 0.710 m. Among those 0.555 m was selected as a most efficient and practical hitch height because at which maximum pull and power were obtained at 15 % slip compared to others. Hence 0.555 m was selected as best suitable hitch height for this study.

Effect of different gear settings on the parameters selected for the study at 1.4 kg/cm² tire inflation pressure :

Table 1 shows the maximum value of drawbar pull (1767 kg) was obtained at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The reduction in value of drawbar pull from the gear L_1 to L_2, L_2 to L_3, L_1 to H_1 and L_1 to L_4 was 0.56 %, 8.71 %, 23.65 % and 42.33 %, respectively.

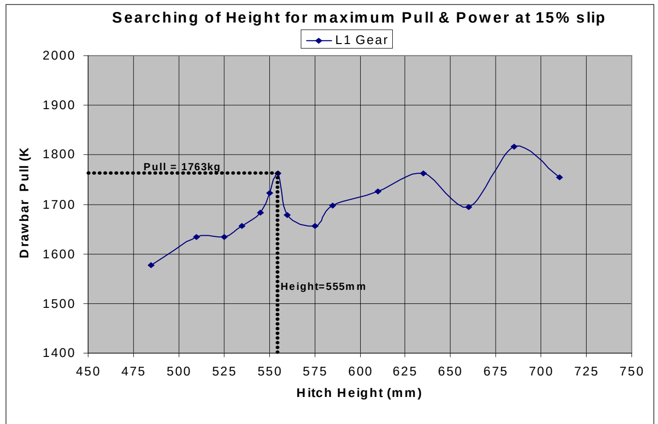

Fig. 1 : Searching of Height of Hitch for maximum drawbar pull and power at 15% slip

The maximum drawbar power (41.9 hp) was at L_4 gear setting followed by H_1, L_3, L_2 and L_1. The percentage reductions in drawbar power from L_4 to H_1, L_4 to L_3, L_4 to L_2 and L_4 to L_1 were 2.38%, 4.05%, 28.16%, and 57.99%

Table 1 : The parameters selected for the study at different tire inflation pressures and different gear settings

Sr. No.	Gear		L_1	L_2	L_3	L_4	H_1
1.	Drawbar pull (kg)	20 kg/cm²	1767	1757	1613	1096	1349
		17 kg/cm²	1652	1650	1644	1135	1373
		14 kg/cm²	1637	1635	1628	1148	1403
		11 kg/cm²	1632	1627	1617	1159	1410
2.	Traveling speed (km/h)	20 kg/cm²	2.8	4.7	6.8	10.5	8.3
		17 kg/cm²	2.7	4.6	6.6	10.4	8.2
		14 kg/cm²	2.7	4.6	6.5	10.4	8.1
		11 kg/cm²	2.7	4.6	6.5	10.2	8.2
3.	Wheel slip (%)	20 kg/cm²	15.2	15	11.2	6.9	9
		17 kg/cm²	15.1	15	14.9	6.2	8.2
		14 kg/cm²	14.9	14.8	14.9	7	9.4
		11 kg/cm²	14.9	14.8	15.7	6.8	9.2
4.	Drawbar hp	20 kg/cm²	17.6	30.1	40.2	41.9	40.9
		17 kg/cm²	16.4	27.8	39.5	42.9	41.3
		14 kg/cm²	16.3	27.6	39	43.6	41.4
		11 kg/cm²	16.4	27.6	38.8	43	42.2
5.	Engine rpm	20 kg/cm²	2219	2188	2109	2104	2103
		17 kg/cm²	2225	2190	2162	2106	2110
		14 kg/cm²	2220	2193	2161	2140	2097
		11 kg/cm²	2190	2220	2162	2100	2139
6.	Fuel consumption (l/h)	20 kg/cm²	4.7	8.05	10.45	10.78	10.46
		17 kg/cm²	5.61	8.05	10.71	10.69	10.58
		14 kg/cm²	6.51	7.92	10.6	10.9	10.61
		11 kg/cm²	6.78	7.91	10.6	10.91	10.65

respectively. The least fuel consumption (4.70 lit/hr) was found at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The percentage increase in fuel consumption from L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 was 41.6%, 55.02%, 55.06% and 56.4%, respectively.

Effect of different gear settings on the parameters selected for the study at 1.2 kg/cm² tire inflation pressure:

Table 1 shows the maximum value of drawbar pull (1652 kg) was obtained at L1 gear setting followed by L_2, L_3, H_1 and L_4. The reductions in value of drawbar pull from the gear L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 were 0.12 %, 0.48 %, 16.88 % and 31.29 %, respectively.

The maximum drawbar power (42.9 hp) was at L_4 gear setting followed by H_1, L_3, L_2 and L_1. The percentage reduction in drawbar power from L_4 to H_1, L_4 to L_3, L_4 to L_2 and L_4 to L_1 was 3.72 %, 7.92 %, 35.19 % and 61.77 %, respectively. The least fuel consumption (5.61 lit/hr) was found at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The percentage increase in fuel consumption from L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 was 30.31 %, 46.62 %, 46.97 % and 47.52 %, respectively.

Effect of different gear settings on the parameters selected for the study at 1 kg/cm² tire inflation pressure:

Table shows the maximum value of drawbar pull (1637 kg) was obtained at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The reductions in value of drawbar pull from the gear L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 were 0.12 %, 0.54 %, 14.29 % and 29.87 %, respectively.

The maximum drawbar power (43.6 hp) was at L_4 gear setting followed by H_1, L_3, L_2 and L_1. The percentage reductions in drawbar power from L_4 to H_1, L_4 to L_3, L_4 to L_2 and L_4 to L_1 were 5.04 %, 10.55 %, 36.69 %, and 62.61 %, respectively. The least fuel consumption (6.51 lit/hr) was found at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The percentage increase in fuel consumption from L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 was 17.80 %, 38.58 %, 38.64 % and 40.27 %, respectively.

Effect of different gear settings on the parameters selected for the study at 0.8 kg/cm² tire inflation pressure:

Table 1 shows the maximum value of drawbar pull (1632 kg) was obtained at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The reductions in value of drawbar pull from the gear L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 were 0.31 %, 0.92 %, 13.6 % and 28.98 %, respectively.

The maximum drawbar power (43.0 hp) was at L_4 gear setting followed by H_1, L_3, L_2 and L_1. The percentage reduction in drawbar power from L_4 to H_1, L_4 to L_3, L_4 to L_2 and L_4 to L_1 was 1.86 %, 9.76 %, 35.81 % and 61.86 %, respectively. The least fuel consumption (5.78 lit/hr) was found at L_1 gear setting followed by L_2, L_3, H_1 and L_4. The percentage increase in fuel consumption from L_1 to L_2, L_1 to L_3, L_1 to H_1 and L_1 to L_4 was 26.92 %, 45.47 %, 45.52 % and 45.67 %, respectively.

Selection of best suitable gear - tire inflation pressure combination:

The different tire inflation pressure at different gear settings gave the various values of the parameters selected for the study as shown in Table 1.

The Table 1 shows that, the maximum drawbar pull of 1767 kg in L_1 gear at 1.4 kg/cm² tire inflation pressure and maximum drawbar power of 41.9 hp was found in L_4 gear at 1.4 kg/cm² tire inflation pressure. Whereas minimum fuel consumption 4.7 l/h was found in L_1 gear at 1.4 kg/cm² inflation pressure, but the maximum value of drawbar pull, drawbar power and least fuel consumption together at particular gear setting is required. As a compromise the best suitable gear setting resulting maximum drawbar pull and drawbar power with minimum fuel consumption in gear L_3 at all the tire inflation pressure levels, selected for the study.

Conclusion:

The following conclusion were drawn for the study

– A hitch height of 555 mm was found to give maximum value of pull (1763 kg) in L_1 gear and drawbar power of 41.29 hp in H_1 gear, keeping the value of wheel slip within acceptable limit (less than 15%).

– Drawbar pull showed a decreasing trend from L_1 to L_3 gear and from H1 to L_4 gear whereas the drawbar power and fuel consumption showed reverse trend for all the pressure levels selected for the study.

– The pull showed decreasing trend from 1.4 kg/cm² to 0.8 kg/cm² tire inflation pressure for the gear L_1, L_2 and L_3 whereas the increasing trend was found for the selection of gears from H_1 to L_4.

– The better values of drawbar pull, drawbar power and fuel consumption together were found for L_3 gear for all the tire inflation pressures.

– The 1.2 kg/cm² tire inflation pressure at L_3 gear showed maximum drawbar pull of 1644 kg.

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