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Research Paper

Improving the tractive performance of walking tractors using rubber tracks

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The pneumatic wheels of a walking tractor were replaced with rubber track system to improve draught. Performance was evaluated in agricultural soils and compared with that when fitted with wheels. Tests were carried out in sandy clay loam soil with cone index (CI) varying from 250 to 1000 kPa for both the tractors. Data of motion resistance, pull and slip were acquired using different sensors and data acquisition system. For CI of 250, 500 and 1000 kPa, the observed motion resistance values for tracks were found to be 1012, 775 and 620 N, respectively, which represent 18.75%, 14.36% and 11.5% of the weight of the tested walking tractor and 935, 675 and 530 N for the wheeled walking tractor which represents 17.32%, 12.5% and 9.8% of its weight, respectively. Rubber tracked walking tractor developed greater drawbar pull than the wheeled one in all soil conditions. The drawbar pull developed with tracks is 115.2%, 75.9% and 62.4% more than that developed by comparable walking tractor fitted with standard wheels, respectively in soils with CI 250, 500 and 1000 kPa. Tractive efficiency (TE) of walking tractors fitted with rubber tracks was higher in all soil conditions. Also, tracks reached peak TE at higher net traction ratio (NTR) and maintained higher TE for a wider range of NTR. Wheels reached maximum TE at lower values of NTR, which drops off at higher NTR values. The results indicate a significant improvement in the tractive ability of walking tractor.

1. Introduction

Walking tractors are single axle tractors that are a well-accepted source of power for paddy cultivation in India and many other parts of the world. The most commonly used walking tractors have engine power in the range of 6.62–8.95 kW and a mass of about 480 kg which is supported on two drive wheels (Sahay, Thomas, & Satapathy, 2009). Another wheel provided in the rear is used for depth adjustment during transportation and field operation. In view of scarcity of labour and need for timely completion of various farming operations, their demand is rapidly increasing. Annual sales of walking tractors in India have increased from 17,781 units in 2004 to 56,000 units in 2014 (Anon, 2015). Despite this increased demand, the utilisation of walking tractors still lags behind that of tractors. This is evident from the fact that annual use of a walking tractor is only 300 h compared to 1000 h for tractor (Narang & Varshney, 1995). The lower annual usage of walking tractors may be largely attributed

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Nomenclature

NTR	Net traction ratio
DP	Drawbar pull
W	Weight of vehicle
TE	Tractive efficiency
S	Slip
V_a	Actual velocity
V_t	Theoretical velocity
ρ_w	Soil bulk density
CI	Cone index
ASABE	American Society of Agricultural and Biological Engineers
ANOVA	Analysis of variance
DAS	Data acquisition system
ANCOVA	Analysis of covariance

to their reduced drawbar power making them unsuitable for efficient primary tillage operations. Attempts have been made to use mouldboard plough, cultivators, etc. with walking tractors but with little success. Low drawbar power has limited their use for pulling even for small-sized implements. The main reasons for low drawbar power are the low weight of this type of tractor and the use of small pneumatic tyres for traction.

Various studies have reported on the low draught of walking type tractors. Narang and Varshney (2006), reported a draught of 773N and 803N at 2000 rpm engine speed for two different gears which corresponded to a drawbar power of only 0.476 kW and 0.393 kW, respectively from an 8.95 kW walking tractor operated on a tilled soil, indicating nearly 90% loss of power. A summary of research carried out to evaluate the performance of walking tractors is given in Table 1. The results indicate that draught produced by the walking tractors is low. Thus, walking tractors have not been popular for high draught farming operations. To increase the versatility of walking tractors, there is a need to improve their traction. Rubber tracks have been shown to be effective device for improving traction (Bashford & Kocher, 1999; Culshaw, 1988; Esch, Bashford, Von, & Ekstrom, 1990; Evans & Gove, 1986; Molari, Bellentani, Guarnieri, Walker, & Sedoni, 2012; Zoz, 1997). Improved grip between soil and lugs, improved floatation and the potential for reducing ground pressure are among the advantages of tracks (Wong, 2001). Wong and Huang (2006) compared the traction performance of tracks and tyres. They concluded that the traction of wheeled vehicles, in general, cannot match with that of comparable tracked vehicles due to the shorter contact length of tyres compared to the tracks. They also concluded that traction of the wheeled vehicles is closer to that of tracked vehicles on frictional soils such as sand than on clay soil since the traction of frictional soils is dependent on normal load whereas on cohesive soils it primarily depends on total contact area. Rasool and Raheman (2015) conducted a laboratory analysis to explore the suitability of rubber tracks as traction devices for walking tractors. They concluded that walking tractors fitted with rubber tracks could nearly double draught force developed when compared with pneumatic wheels for the same operating conditions. Based on their results, a rubber track system suitable for walking tractor has been developed.

The aim of this paper is to evaluate the tractive performance of a walking tractor fitted with rubber tracks in different soil conditions and compare its performance with a comparable walking tractor fitted with standard pneumatic wheels.

2. Materials and methods

In the present study, a conventional walking tractor was modified by replacing its pneumatic wheels with rubber tracks. The walking tractor is powered by a 9 kW, single cylinder, water cooled diesel engine. Some of the technical specifications of standard walking tractor are given in Table 2.

2.1. *Rubber track system for walking tractors*

The rubber track system for walking tractor comprised two continuous rubber tracks, each mounted between a large diameter drive wheel at the rear and a small diameter front idler, with smaller road wheels or rollers in between. The total mass of the modified walking tractor, including the rubber tracks, was 550 kg. The drive mechanism which consisted of V-belt drive, drive train, steering mechanism and braking mechanism was the same as in the original walking tractor. Drive wheels were mounted on the axle powered by the engine of the walking tractor. The drive wheel of the track system is the most important component which propels the vehicle with sufficient vehicle torque; it controls the vehicle speed fluctuation and maintains the vehicle tractive performance. The walking tractor was provided with drive wheels of 0.55 m diameter and front idlers of 0.34 m diameter. Both the

Table 1 – Draftability of walking tractors on different traction media.

Author	Power (kW)	Traction device	Traction medium	Wheel slip (%)	Draft (N)	Drawbar power (kW)
Alvi and Pandya (1968)	7.56	Pneumatic wheel (127 × 355 mm)	Earthen road	18	N.A	1.38
Narang and Varshney (1995)	6.75	Pneumatic wheel (152.4 × 304 mm)	Tar Road	15	2110	2.89
Narang and Varshney (2006)	8.95	Pneumatic wheel (152.4 × 305 mm)	Tilled land (CI = 247 kPa)	25	803	0.393
Narang and Varshney (2006)	8.95	Steel wheel (170 × 745 mm)	Tilled land (CI = 247 kPa)	25	1034	0.611