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Suitability of rubber track as traction device for power tillers

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Abstract

Suitability of using rubber tracks as traction device in power tillers replacing pneumatic tires was studied using an experimental setup consisting of a track test rig for mounting a 0.80 m × 0.1 m rubber track and a loading device for applying different drawbar pulls. Tests were conducted in the soil bin filled with lateritic sandy clay loam soil at an average soil water content of 9% dry basis by varying the cone index from 300 to 1000 kPa. Data on torque, pull and Travel Reduction Ratio (TRR) were acquired using sensors and data acquisition system for evaluating its performance. Maximum tractive efficiency of the track was found to be in the range of 77–83% corresponding to a TRR of 0.12–0.045. The Net Traction Ratio (NTR) at maximum tractive efficiency was found to be between 0.49 and 0.36.

Using non-linear regression technique, a model for Gross Traction Ratio (GTR) was developed and it could predict the actual values with a maximum variation of 6% as compared to an average variation of 50% with Grisso's model. Based on this model, tractive efficiency design curves were plotted to achieve optimum tractive performance of track for any given soil condition.

Keywords: Track tester; Soil bin; Traction ratios; Travel Reduction Ratio; Tractive efficiency

1. Introduction

Power tiller is designed primarily for carrying out rotary tilling for seedbed preparations in small farms and in hill farming and also carrying out spraying operations in food crops and horticultural crops. The adoption of power tillers by the farmers for carrying out farming operations is lower as compared to tractors. For this, the annual use of power tiller is only 300 h compared to 1000 h for tractor (Narang and Varshney, 1995). The basic reason of lesser annual usage may be attributed to the availability of lesser drawbar power for carrying out primary tillage operations. Low drawbar power has limited the use of power tillers for pulling small sized implements.

Particular	Description
ASAE	American Society of Agricultural Engineering
B_n	mobility number (Brixius)
CI	cone index
d.b	dry basis
DAS	data acquisition system
DF	degree of freedom
DWI	dynamic weight index
DWR	dynamic weight ratio
GTR	Gross Traction Ratio
NTR	Net Traction Ratio
MRR	motion resistance ratio
SAS	Statistical Analysis System
TE	tractive efficiency
TL	track length
TRR	Travel Reduction Ratio
TW	track width
v_a	actual velocity
v_t	theoretical velocity

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The main reasons for low drawbar power are its lesser weight and the use of small sized pneumatic tires as traction devices. Various studies have been conducted to measure the draftability of power tillers fitted with 7.45–8.95 kW engine. The results indicated that the draftability of power tillers is very low. The drawbar power obtained was in the range of 0.434–0.618 kW resulting in a loss of around 90% engine power.

Narang and Varshney (1995) evaluated a 6.75 kW power tiller weighing 485 kg fitted with 6–12 tires on tarmacadam road. The results revealed that a draft of 2110 N was obtained at a slip value of 15% for an engine speed of 1500 r min^{-1}, and the drawbar power obtained was 2.89 kW with fuel consumption and specific fuel consumption of 0.969 ℓ h^{-1} and 0.475 ℓ (kW h)$^{-1}$, respectively. The results also indicated an increase of draft by 10–14% with the use of 40 kg ballast weight at 1500 r min^{-1} engine speed and 15% slip.

Narang and Varshney (2006) evaluated a 8.95 kW power tiller weighing 485 kg and fitted with pneumatic tires of size 6–12 with 6 ply rating on tilled land. The values of draft, drawbar power and fuel consumption were measured at 25% wheel slip. The draft values were found to be 803 N and 773 N in 2nd low gear and 3rd low gear, respectively as compared to 901 N and 921 N by mounting a ballast weight of 40 kg. Replacement of pneumatic wheels by steel wheels further increased the draft readings to 1034 N and 999 N at the same engine speed.

Sahay et al. (2009) conducted tests on a 8.1 kW power tiller to determine its draft on tilled land. The average cone index of the soil was 420 kPa. The draft was measured at two forward speeds i.e. slow and fast corresponding to 0.5–0.03 m s^{-1} and 1.3–0.1 m s^{-1} walking speed of an operator walking behind the power tiller, respectively. A single axle trolley with a capacity of 1 ton was attached behind the power tiller with a specially designed bracket to accommodate an orthogonal ring transducer between the power tiller and the trolley to measure draft. The results indicated that the draft developed by the power tiller at 20% slip was 1077 N and draw bar power available was 0.538 kW and 1.273 kW at the speeds of 0.49 and 1.18 m s^{-1}, respectively.

Hence, to increase the versatility of power tillers, there is a direct need to improve the traction ability of these tractors. The choice of tractive devices used on agricultural tractors has a major effect on generating tractive forces. Tracks increase the soil contact area, which reduces soil vertical pressure and increases the cohesion component in the horizontal shear force developed in traction. This reduces sinkage and thus rolling resistance, and increases gross traction. Thus tracks provide increased net traction and tractive efficiency (Keen et al., 2012).

Servadio (2010) found a highly significant correlation between clay–tire–track numeric (Nc,r) and traction performance (TP) where the vehicle equipped with four rubber tracks and a low power rubber tracked tractor equipped with large or standard tracks, have obtained: higher values of Nc,r (>20), higher values of TP, traction coefficient values between 0.7 and 0.9 and traction efficiency values between 0.74 and 0.8.

Several studies have been conducted comparing the performance of rubber tracked tractors with the wheeled tractors (Evans and Gove, 1986; Esch et al., 1990; Zoz, 1997; Bashford and Kocher, 1999). From these studies, it was concluded that tracks perform better than tires over a wide range of soil conditions. Therefore, attempt has been made to develop a track suitable for power tillers and to determine its tractive performance.

2. Materials and methods

2.1. Experimental set-up

To evaluate the tractive performance of track, experiments were conducted using a soil bin facility (Fig. 1) consisting of soil bin, soil processing device, track tester and drawbar loading device.

2.1.1. Soil bin

The overall dimensions of the soil bin were 15 m × 1.8 m × 0.6 m. To facilitate the movement of soil processing trolley and guide trolley, two horizontal rails were provided along the length of soil bin. The bin was filled with lateritic sandy clay loam soil.

2.1.2. Track tester

The track tester rig consisted of a carriage which housed the rubber track and it was powered by a 7.5 kW, 3 phase, 1425 r min^{-1} electric motor coupled to a transmission system (gear box and chain with sprocket). The speed of the motor was initially reduced by a gearbox with a reduction of 40:1 and then further by chain and sprocket mechanism with a reduction of 2.5:1. The final linear speed of axle obtained was 0.278 m s^{-1} with a driving wheel diameter of 0.420 m. The constructional details of track tester is shown in Fig. 2.

Fig. 1. General view of soil bin.