USING THE BRIXIUS MODEL TO PREDICT TRACTION OF HEAVY SUGARCANE MACHINERY

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Abstract

From 1976 to 2003, 60% of sugarcane harvests in the north of Villa Clara in Cuba have been affected by heavy rainfalls, averaging 215 mm. Many interruptions to the harvesting operation have been caused by infield transport not being able to traverse the soft vertisol soils that prevail in this area. The Brixius model was used to predict the tractive performance of a New Holland 110-90 tractor with a cone index (CI) of less than 700 kPa. The main ratios and forces that characterize traction dynamics (motion resistance, net traction, motion resistance ratio, gross traction ratio, net traction ratio and tractive efficiency) were obtained as a function of soil strength and dynamic wheel load. The results showed that the RA-6 Cuban trailer can only be pulled with a CI higher than 400 kPa, working on 20 % wheel travel reduction (wheel slip).

Keywords: sugarcane, harvesting, transport, traction, cone index, simulation, Brixius model

Introduction

Sugarcane harvests in Cuba every year show the necessity to introduce a machine system that will solve the transport discontinuity in regions with soft vertisol soils, which make up 37% of the total area. Although vertisols occur throughout the country, they are prevalent on the plains of the north and south coasts in the provinces of Villa Clara, Sancti Spiritus, Ciego de Avila and Camaguey. Over the period 1976 to 2003, 60% of harvesting seasons were affected by rainy weather, with transport difficulties causing no-cane stops at the mills.

Cuban cane transport is not capable of working on soils with a moisture content of more than 45% (Rodriguez *et al*., 1999), as the 4x2 tractors used have high ground pressure, uneven weight distribution, and small tire contact area and low weight on the driving axles. The trailers also have a high draught force due to high pressure tires, high axle weight and small tire contact area.

Use of the Brixius simulation model (Brixius, 1987) has enabled experiments to be done at minimal cost. The specific objectives of the research presented in this paper were to:

- Estimate the drawbar pull for a heavy tractor on soft soils
- Establish the cone index (CI) limits after which infield transport is not possible because the tractor drawbar pull is insufficient for hauling a trailer
- Assess the weight transfer from the trailer to the tractor as a way of improving traction.

Procedures

The tractor used in the experiments was a New Holland 110-90, traction class 30 kN, 4x4 and weight 53 kN. The mathematical expressions used were those from Brixius (1987). These expressions were proposed by Srivastava *et al*. (1992), Zoz and Grisso (2003), Goering *et al* (2003) and ASAE (1998)and others. The model was processed on MS Excel.

1. The travel reduction which generates maximum traction efficiency on a CI of 400 kPa was obtained, corresponding with the strength of a vertisol soil with high moisture content (Gonzalez *et al*., 2002). Brixius (1987), Zoz and Grisso (2003) and Goering *et al*. (2003) classified a soft soil from 0-700 kPa. A travel reduction range of 4-30% was established, because under normal working conditions a reduction of more than 30% is not appropriate, as traction efficiency decreases from values close to 30% (Forrest *et al*., 1962; Al-Hamed *et al*., 1990; Zoz and Grisso, 2003).

2. The model was run with the travel reduction selected in (1), for a CI from 250 to 700 kPa, to obtain net traction (NT), motion resistance (MR), motion resistance ratio (ρ), gross traction ratio (μ_g), net traction ratio (μ_n) and travel efficiency (TE).

3. A weight of 10 kN was added to the tractor rear axle without affecting the total tires dynamic load.

Results and Discussion

Efficiency is the most important of the traction parameters, and is commonly known as a fraction of axle power that is converted to net power by the drive wheels. The tractive efficiency is determined by the loss of pull and speed due to travel reduction and tractor motion resistance. Figure 1 shows the relationship between traction efficiency and travel reduction as the independent variable. Zoz and Brixius (1979) stated that a maximum TE of about 94% is all that can be obtained at realistic tire loadings, working on a concrete surface. For the 400 kPa of CI, the highest value obtained was 0.48 for travel reductions of 16, 18 and 20%. The model was run with a travel reduction of 20%, because the biggest net traction was obtained with this value.

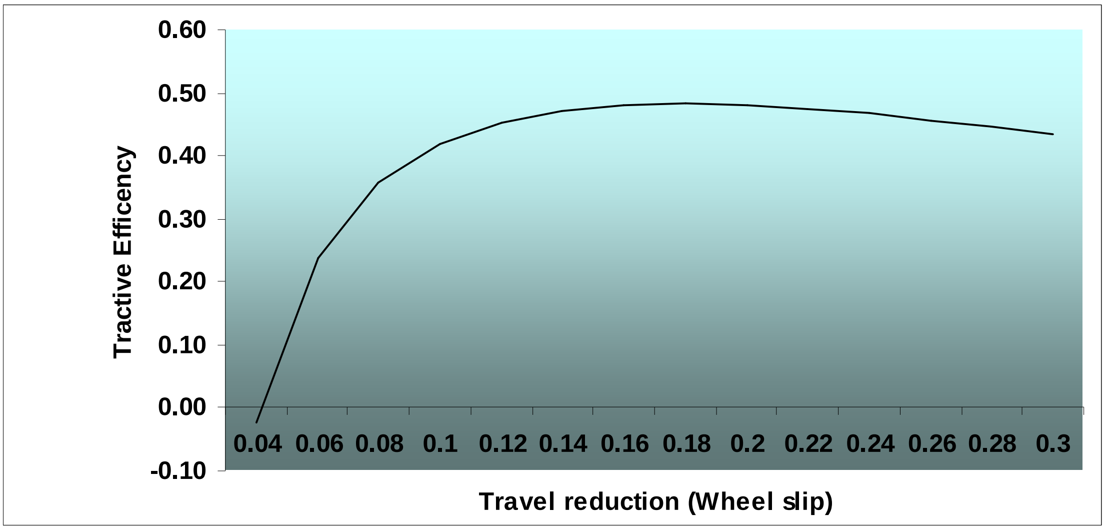

Figure 1 Traction efficiency as a function of travel reduction, for a CI of 400 kPa.

The results of running the model at a travel reduction of 20% as a function of CI (independent variable) are shown in Figures 2 and 3. The net traction with CI from 250 to 350 kPa has values that prevent the pulling of any Cuban trailer. The RA-6 trailer at 11 kN has the lowest motion resistance (Gonzalez, 2002). The New Holland 110-90 tractors have insufficient net traction for pulling heavy trailers on soft soils in wet conditions, as the trailer motion resistance is higher than the tractor's net traction. With the CI used, the motion resistance was very high due to high losses during the formation of the print and the soil displacement at the front and sides of the tires. Towing will therefore need to begin at CI >400 kPa. Working with a lower CI will necessitate a different type of trailer with high flotation tires or less weight. The traction efficiency in Figure 3 shows a very low value from 250 to 350 kPa due to high motion resistance losses. The highest values for net traction, gross traction and traction efficiency were reached in soils with hard conditions which supported the tires.

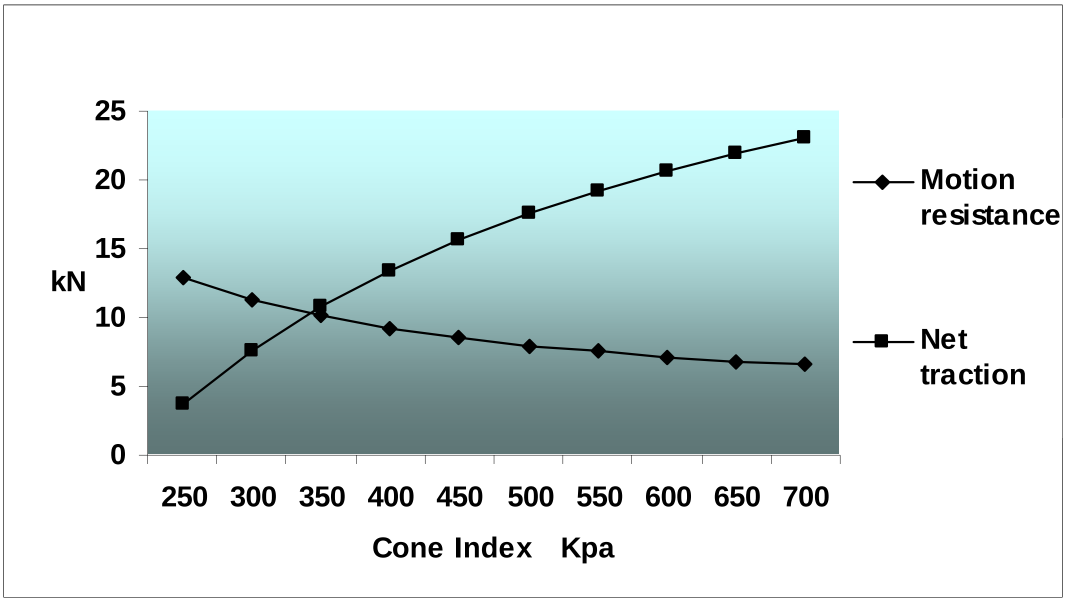

Figure 2 Traction performance as a function of cone index.

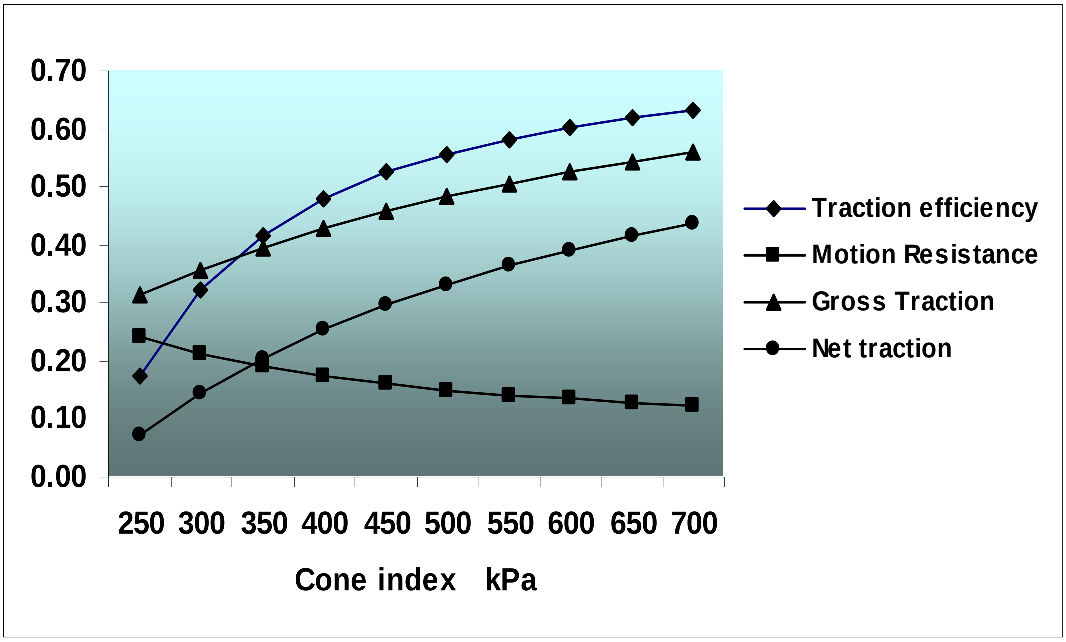

Figure 3 Traction coefficients as a function of cone index.

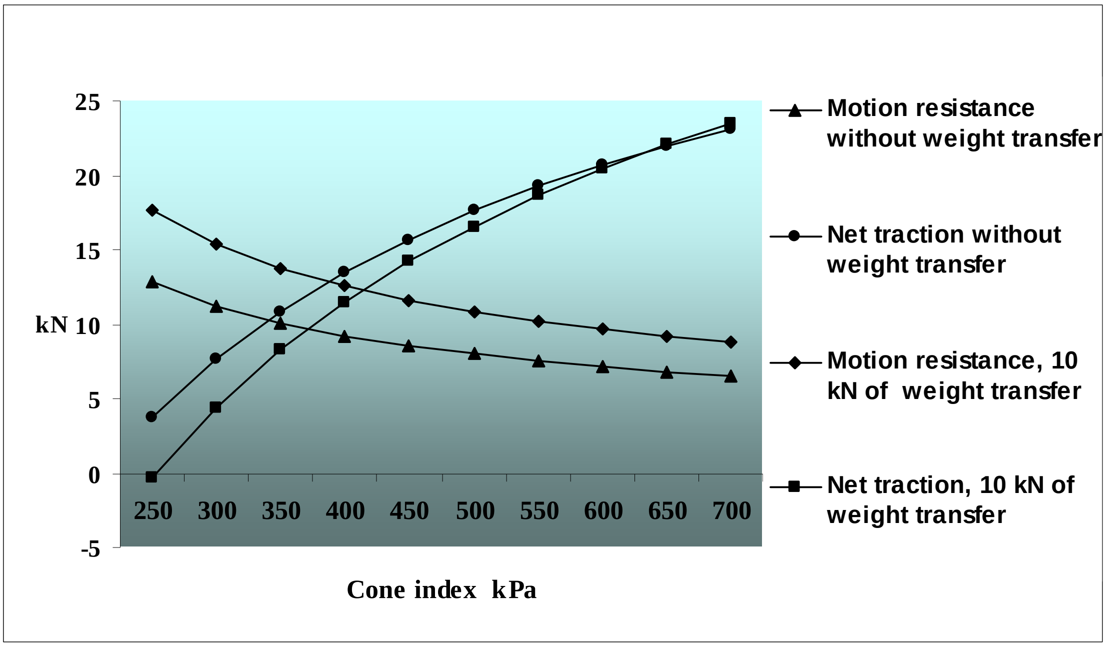

Figure 4 Influence of 10 kN of weight transfer on traction performance.

Weight transfers are made to improve the traction qualities of the tractor and decrease the motion resistance of the trailer. However, it is a mistake to increase the weight on the rear axle of the tractor for CI of less than 650 kPa, because the increase in tractor motion resistance decreases net traction. Trailers should only be pulled from a CI of 450 kPa upward. On soft soils, increasing the weight on the rear axle results in a higher motion resistance; therefore more power is required to overcome the motion resistance.

Conclusions

- The net traction of the New Holland 110-90 tractor is 13.44 kN at a CI of 400 kPa. This represents a critical value for the use of this tractor with Cuban trailers.
- In the 300 to 350 kPa range, a trailer with a motion resistance of less than 7 kN is required.
- The addition of 10 kN of ballast is effective only on CI of more than 650 kPa.

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