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THE INFLUENCE OF THE UNDERCARRIAGE AND TIRE INFLATION RATING ON DRAWBAR CHARACTERISTICS OF TRACTORS

P. Vykydal, F. Bauer, P. Sedlák, A. Polcar

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Abstract

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The aim of the measurement was to verify the drawbar characteristics of chosen tractors with different undercarriages. The tractors were of the same engine power as well as type of gearbox (PowerShift – gears full shifted while loaded). We were dealing with the wheeled tractor John Deere 8320 and crawler tractor John Deere 8320RT. The measurement was implemented in the land register of Vrbovec (Znojmo region) in an area where green peas were grown as the main product and winter wheat as the preceding crop. The measured and the counterproductive tractors were interconnected by the rope containing strain-gauge force sensors. The wheeled tractor was decelerated by the tractor crawler. The tractor crawler was decelerated by two wheeled tractors. The wheeled tractor's stress-strain properties were also measured applying two pressure rating alternatives. Variant A presented inflation pressure of 160 kPa on the front axle and of 140 kPa on the rear axle. Variant B applied inflation pressure of 120 kPa on the front axle and of 100 kPa on the rear axle. Measured and calculated findings reveal that the tractor crawler achieved higher drawbar power and lower specific tractive consumption and traction slip than the wheeled tractor with both variants of inflation. Comparing the stress-strain characteristics of the wheeled tractor with a different tire inflation illustrates that using variant B, higher drawbar power and lower specific tractive consumption and traction slip were measured.

tractor, drawbar pull, drawbar power, traction slip, specific tractive consumption

Modern agriculture brings with it a variety of new technologies and constructional innovations in terms of the appliances which enable productivity improvements as well as a reduction in energetic demands, reduction of the fuels consumption and its associated undesirable emission reduction in particular, together with their new existence in the market. Taking into consideration those tractors of higher operational levels, that are the basic energetic means applied in agriculture, generally working 1 500–1 800 hours a year, the expenses linked to the purchase of fuel represent one of the largest items of the financial share. Manufacturers are forced to seek new solutions which can ensure energy savings. These solutions are not just concerned with the main operational parts such as the engine and gearbox but also with the software equipment with precise navigation and new concepts in the area of undercarriage parts. Agricultures, who with a perfect knowledge of the machine are able to use the full potential of the energy resource, are the largest energy cost saving. The aim of the study was to compare, on the basis of the field measurements, the tractors' drawbar characteristics with different undercarriage constructions as well as to compare how the tire inflation impacts on the stress-strain properties of the wheeled tractor.

MATERIAL AND METHODS

Tensile test measurements of the tractors John Deere 8320 R/RT were implemented in July 2010 on the land of agricultural cooperation Vrbovec

(48°48'3.444"N, 16°5'56.851"E),in Znojmo region on the land called "Za Mariňákem" which is formed by sandy loam brown soil. The product which is grown on the land is green peas and the preceding crop is winter wheat. There was a harvest-field just after the harvest of the green pea with removed crop residues. At the time of measurement, the soil in a depth of 10 cm demonstrated the average moisture of 14.7 %.

The measurement of the stress-strain properties of both tractors was realized on the plane surface of the 50 metres long land. Speed gears selected for the test were 5, 7, 9 and 11 regarding the wheeled tractor with higher tire inflation (inflation pressure variant A – front axle 160 kPa, rear axle 140 kPa). Tested speed gears relating to the wheeled tractor with lower tire pressure were 5, 7 and 9 (inflation pressure variant B – front axle 120 kPa, rear axle 100 kPa) and 5, 7, 9, 11 and 12 relating to the tractor crawler. A variety of measurements were implemented for each speed gear in order to examine the characteristic process of the thrust horsepower as accurately as possible. Each single measurement ran together with a constant loading force, which was increased for every other measurement in order to examine the whole process of the thrust horsepower. The loading force was ensured by the interconnected tractor. The tractor crawler was used as a loading vehicle for the wheeled tractor. The tractor crawler was loaded by two wheeled tractors (Fig. 1). The measured and loading tractors were interconnected by the rope containing strain-gauge force sensor Hottinger type U2A with a range of force 0–200 KN (see Fig. 1). The measurement was done in one direction of travel with the interconnected rope of the high of 580 mm. There was a sufficiently long trail between the start and the area of measurement in order to achieve required speed and stabilize the measured parameters. Apart from the tension force, data from internal and external sensors attached to the tractor were recorded. The internal sensors were obtained thanks to a computer connected to the CAN data bus. The speed of the data scanning was of frequency 20 Hz. Fuel consumption, engine revs, theoretical and actual speed, engine load, actual torque, temperatures of the operational fluids, etc. were represented in this data. The external sensors were represented by GPS module and infrared trigger module determining the beginning and the end of the measured area. GPS module was used to explore the real speed of the tractor during tests. Information about the real and the theoretical speed were applied in order to calculate the traction slip of the wheels or tracks in compliance with correlation 1.

$$\delta = \frac{v_t - v_s}{v_t} \times 100 \text{, [\%]} \quad (1)$$

where:
v_t.... theoretical speed of vehicle
v_s ... real speed of vehicle.

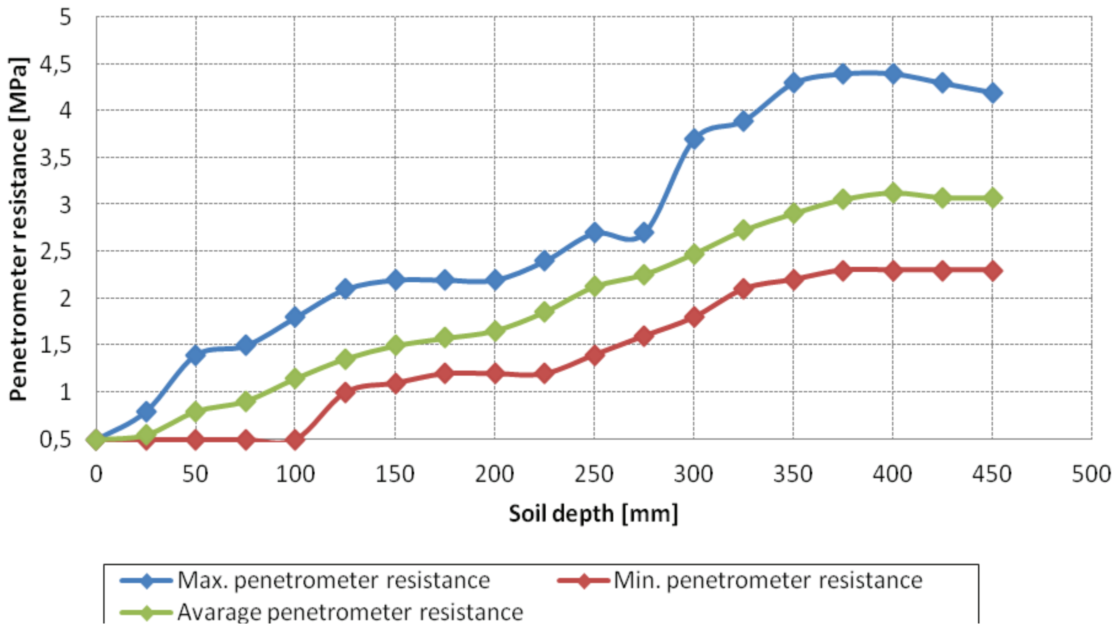
Soil samples were collected from the measured areas during the tests for moisture determination. These samples were weighted using the scale Accurat 5000 and subsequently placed into electric furnace where they were gradually dried to a constant weight. After the completion of desiccational process, reweighting and recalculating of the moisture in compliance with correlation 2 was implemented again.

$$w = \frac{m_v}{m_z} \times 100 \text{, [\%]} \quad (2)$$

where:
m_v .... weight of the water in sample [g]
m_z .... weight of the sample before desiccation [g].

Soil in depth of 10 cm was of the moisture of 14.7 %. Furthermore, measurement of soil compaction with the use of penetrometer was completed to be able to recognize other characteristics of the land.

1: *Set of the measured and the loading tractor interconnected by the rope containing strain-gauge sensor*



2: *Processes of penetromerer resistance on the measured land*

The process of penetrometer resistance is shown in Fig. 2.

The wheeled tractor John Deere 8320R examined with the standard as well as lower tire inflation and the tractor crawler John Deere 8320RT were used during the measurement.

Technical parameters of the tractor John Degree 8320r

Engine: engine number RG 6090L078771*, tractor number: *1 RW 8320RVAP006517*, year of manufacture 2010, maximum output 255 kW, nominal speed 2 100 $min^{-1,}$ number of cylinder: 6, diameter of the cylinders in the engine: 118,4 mm, stroke: 136 mm, total displacement: 9 dm^3, number of valves: 24, powered cooling fan: varicool – system with variable speed of the powered cooling fan, supercharging: turbo blower, injection system: high-pressure Common Rail with full electric control. **Gearbox:** type: Powershift, the number of speed gears 16F/5R. **Tires:** front axle: Michelin 600/70 R30, rear axle: Michelin 710/70 R 42. **Weight:** front weight 20 × 50 kg (1 000 kg), rear axle: 3 × 925 kg. Total weight 14 340 kg. Weight distribution of the tractor: front axle 6 920 kg, rear axle 7 420 kg.

Technical parameters of the tractor John Deere 8320rt

Engine: engine number: RG 6090L07567*, tractor number: *1 RW 8320RLAP901556*, year of manufacture 2010, maximum output 255 kW, nominal speed 2 100 min^{-1}, number of cylinders: 6, diameter of the cylinders in the engine: 118,4 mm, stroke: 136 mm, total displacement: 9 dm^3, number of valves: 24, powered cooling fan: varicool – system with variable speed of the powered cooling fan,

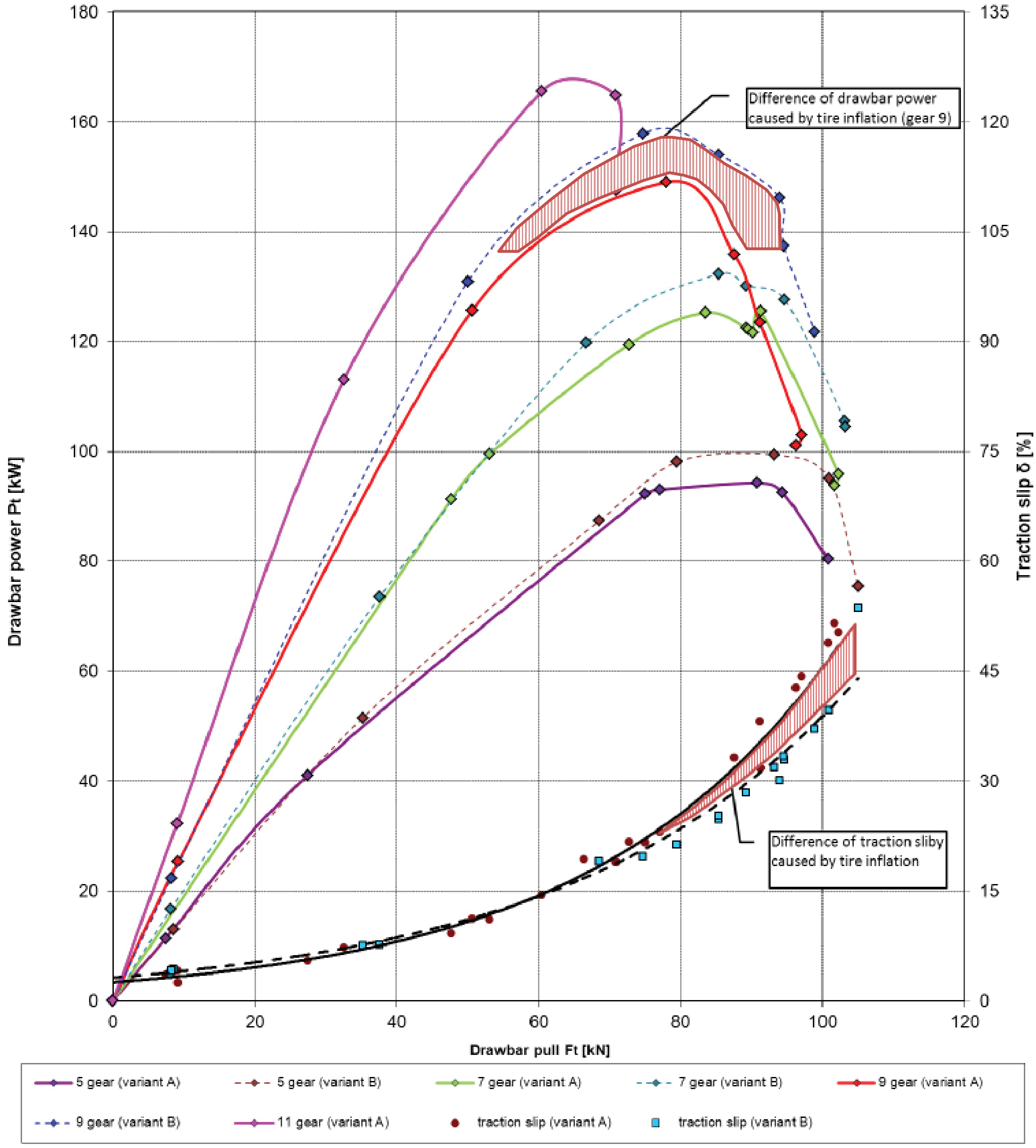
3 + 4: *Tractors John Deere 8320RT and John Deere 8320R*

supercharging: turbo blower, injection system: high-pressure Common Rail with full electric control. **Gearbox:** type: Powershift, number of speed gears 16F/5R. Width of tracks 630 mm. **Weight:** front weight 20 × 50 kg (1 000 kg). Total weight 16 460 kg.

RESULTS AND DISCUSSION

Measured and calculated values of the tractors crawler John Deere 8320/RT are graphically processed in the Figs. 5 to 9. Fig. 5 shows thrust horsepower depending on tension force of the wheeled tractor with higher tire inflation (variant A) as well as with lower tire inflation (variant B). Looking at the Fig. 5, it is evident that the wheeled tractor with higher tire inflation (variant A) reached the greatest drawbar pull of 102.2 kN using speed gear 7 and traction slip of 50.3 %, drawbar power of 95.9 kW and specific tensile consumption of 548.3 g/kW.h. The tractor reached the drawbar power horsepower of 165,5kW using speed gear 11 and drawbar pull of 60.4 kN, traction slip of 14.5 % and specific tensile consumption of 320.9 g/kW.h.

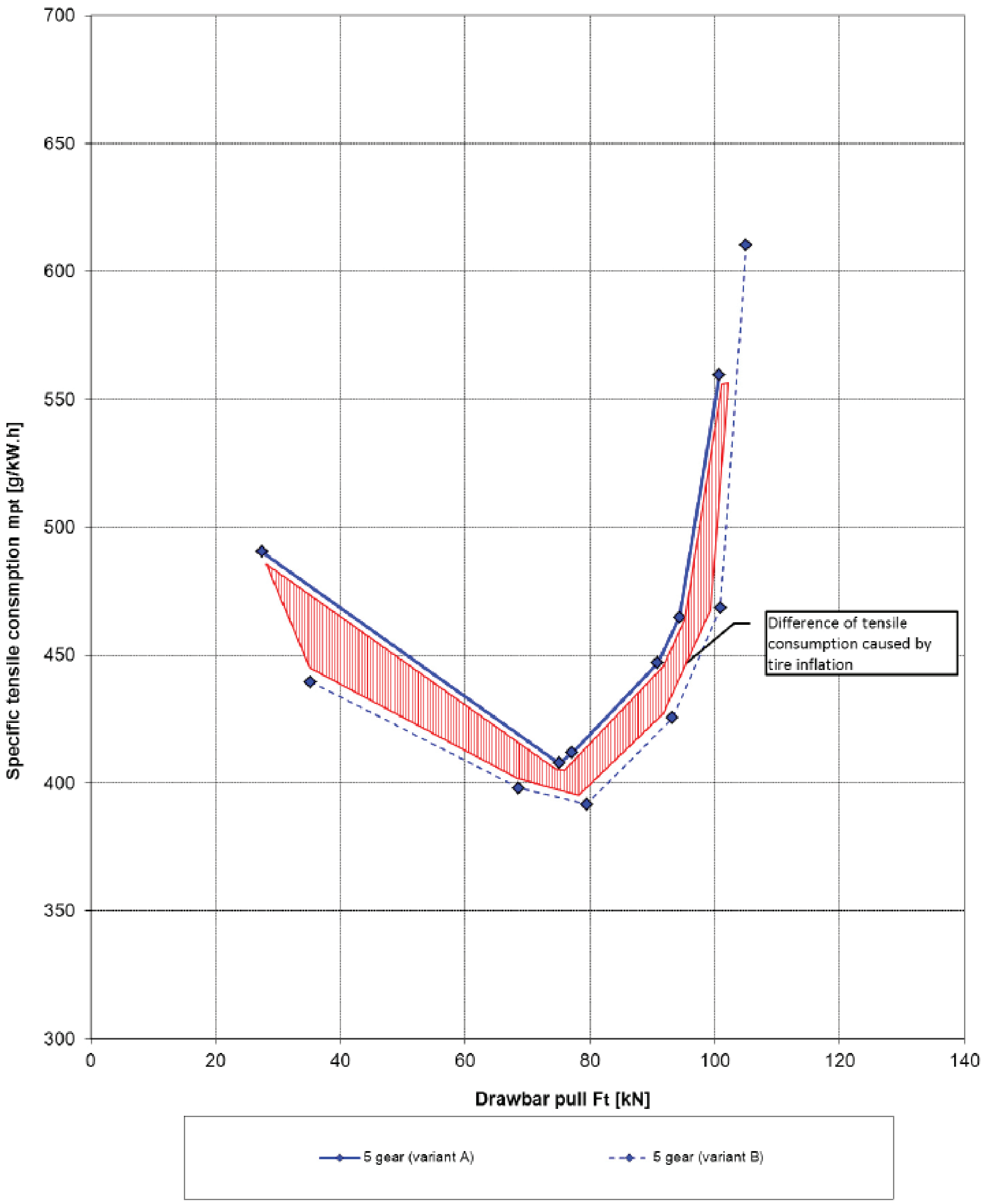
Measurements of the wheeled tractor with low tire inflation were implemented (variant B). Tensile characteristics of the tractor with low tire inflation



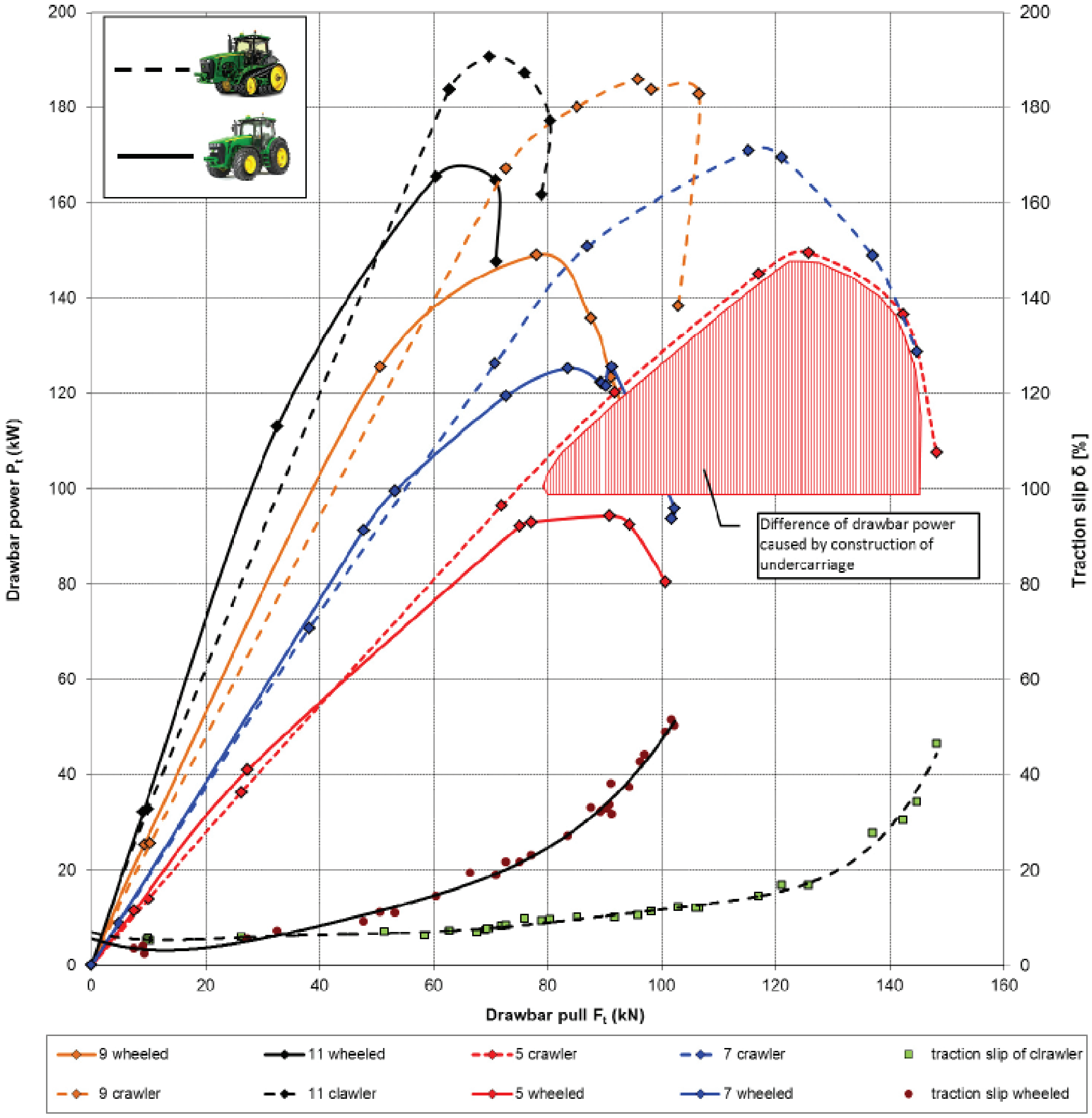
5: *Tensile characteristics of the wheeled tractor JD 8320. Variant A – tire inflation front axle 160 kPa, rear axle 140 kPa. Variant B – tire inflation front axle 120 kPa, rear axle 100 kPa.*

are demonstrated in Fig. 5, where it is apparent that the highest drawbar pull of 105.0 kN was measured while using speed gear 5 and traction slip of 53.6 %, thrust drawbar power of 75.5 kW and specific tensile consumption of 610 g/kW.h. The tractor reached the greatest drawbar pull of 157,8 kW using speed gear 9, drawbar pull of 74.7kN, traction slip of 19.7 % and specific tensile consumption of 323.6 g/kW.h.

In Fig.s 5 and 6, we can see the comparison of tensile characteristics and specific tensile consumptions of the wheeled tractor with higher tire inflation (Variant A) and with lower tire inflation (Variant B). Fig. 5 clearly states that the under-inflation of the tires and subsequent expansion of the contact area between ground and tire and inferential minimization of the traction slip has a positive impact on enhancement of the drawbar



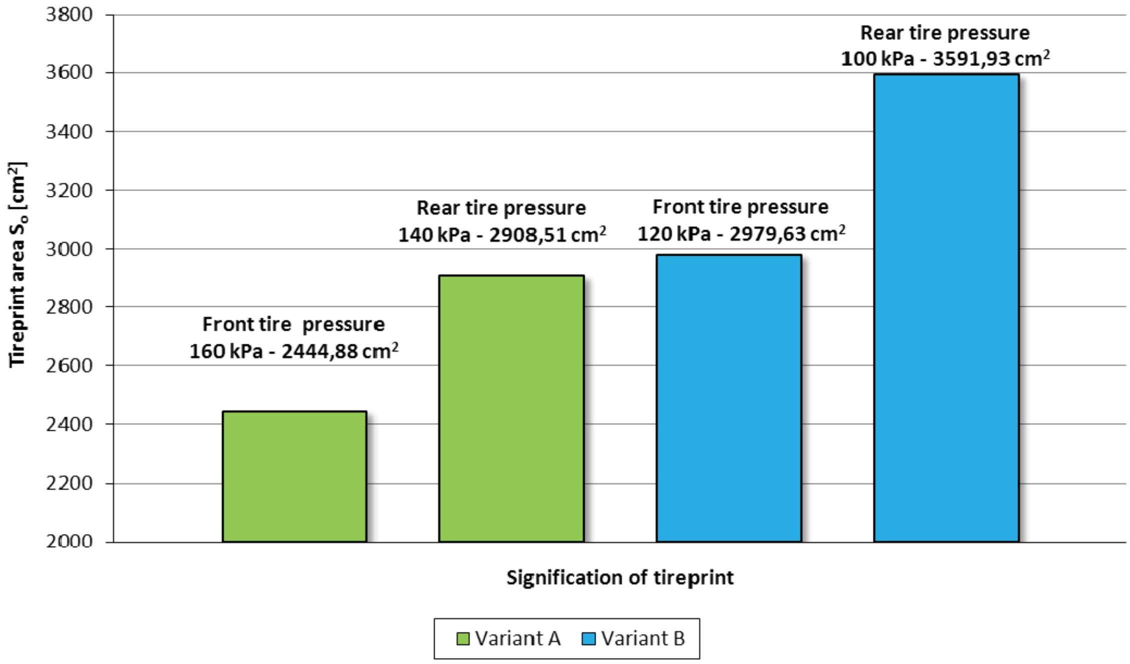
6: *Specific tensile consumption process of the wheeled tractor JD 8320R with higher tire inflation (Variant A) and lower tire inflation (Variant B)*



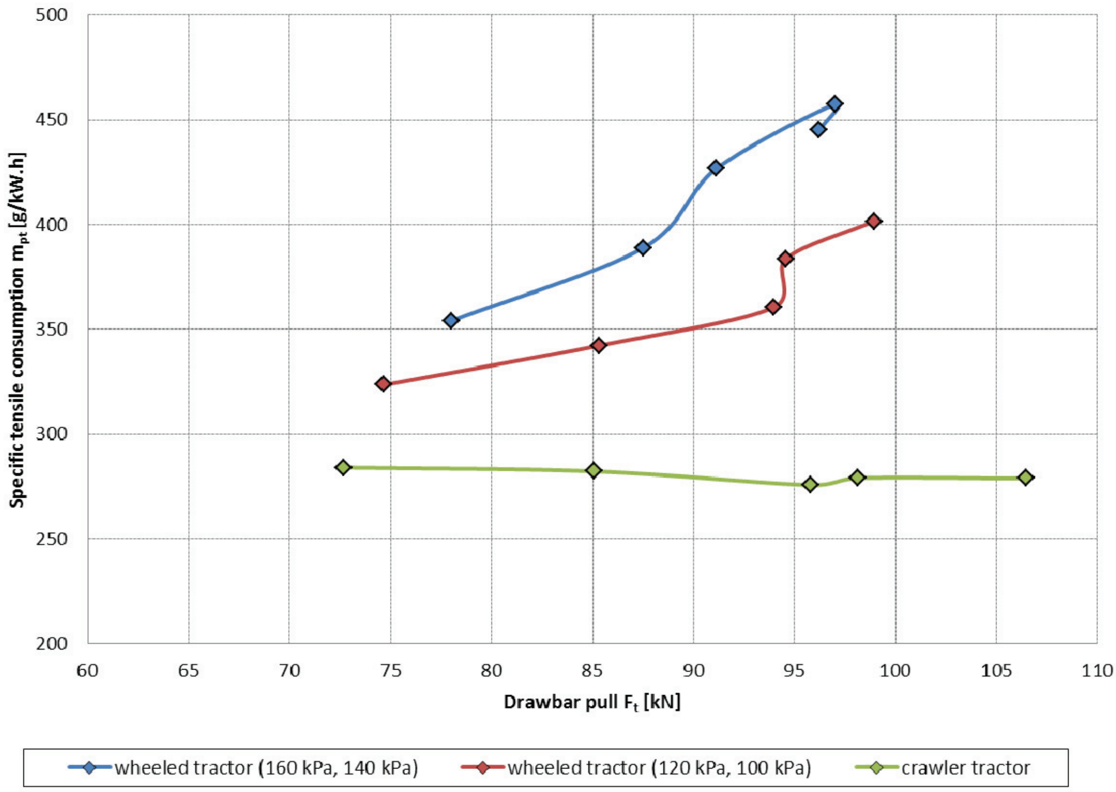
7: *Tensile characteristics of the wheeled tractor (Variant A – tire inflation front axle 160 kPa, rear axle 140 kPa) and the tractor crawler JD 8320R/RT*

pull as well as the thrust drawbar power and decrease of the specific tensile consumption (Fig. 6). If we compare the measured values using speed gear 9, which is one of the speed gears mostly used for agricultural work, we will see that the tractor with higher tire pressure had the greatest value of drawbar power of 149 kW, drawbar pull of 78 kN and traction split of 27.1% and specific tractive consumption of 354 g/kW.h. The tractor with lower tire inflation using speed gear 9 reached the drawbar pull value of 157.8 kW, tension force of 74.7 kN, traction slip of 19.7% and specific tractive consumption of 323.6 g/kW.h. Speaking in percentage terms, if we consider the tractor with higher tire inflation (Variant A) as a norm, reduction of tire inflation results in an increase in drawbar power by 5.4%, decrease in traction slip by 13.4% and a decrease in specific traction consumption by 8.8%. Similar topics were examined by other authors such as ŠMERDA, ČUPERA (2010) who proved that the reduction of the tire inflation results in enlargement of the contact area between the ground and the tire (see Fig. 8) and its associated increasing drawbar pull and decreasing specific tractive consumption and traction slip.

The measured and calculated values of the stress-strain properties of the tractor crawler JD 8320RT are demonstrated in graphs in Figs. 7 and 9. From the graph of the tensile characteristics (Fig. 7), it is evident that the tractor crawler reached the greatest drawbar pull of 148.1 kN using speed gear 5 and drawbar power of 107.6 kW, drive slip



8: *Impact of tire inflation on the change of the tireprint area (size of the front tire – 600/70 R30, size of the back tire – 710/70 R42)*



9: *Comparison of specific tractive consumption using speed gear 9*

of 46.5% and specific tractive consumption of 480.8 g/kW.h. The tractor reached the greatest drawbar power of 192.6 kW using speed gear 12 and drawbar pull of 67.5 kN, track slip of 6.9% and specific tractive consumption of 273.4 g/kW.h. Specific tractive consumption comparison of the wheeled tractor and the tractor crawler using speed gear 9 is demonstrated in graph in Fig. 9. Speaking in percentage terms, the tractor crawler reached lower specific tractive consumption by 19.5% in comparison to the wheeled tractor and variant A of the tire inflation and by 12.3% in comparison to the wheeled tractor with variant B of the tire inflation. These values are calculated while considering the wheeled tractor as a standard.

The influence of the undercarriage on stress-strain characteristics of the tractors is apparent in graph in Fig. 7 where the drawbar powers using the same speed gears of the wheeled tractor (tire pressure is of 160 kPa on the front axle and of 140 kPa on the rear axle) and of the tractor crawler in dependence on drawbar pull are shown. Higher values of drawbar pull as well as of drawbar power were measured for the tractor crawler than for the wheeled tractor. It was also measured that the tractor crawler had lower values of the track slip and specific tractive consumption using all methods of measurement. By percentage comparison of the wheeled tractor and the tractor crawler with the higher tire inflation using speed gear 9, it is obvious that the tractor crawler reached higher drawbar power values by 24.9% and lower track slip values by 16.5% while using the wheeled tractor as a standard. Comparison of the wheeled tractor and the tractor crawler with inflation pressure of 120 kPa on the front axle and of 100 kPa on the rear axle shows that the tractor crawler reached higher drawbar power by 17.8% and lower track slip by 9.2% while considering the wheeled tractor as a standard. These differences of the measured values are caused by heavier construction of the tractor crawler's undercarriage (the weight difference of the tractors is 2 120kg) as well as by larger contact area between ground and track which results in minimalization of the track slip. Similar topics were examined also by key authors MOLARI *et al.* (2012), who measured such characteristics of the wheeled tractor with tires as well as with exchange tracks (delta tracks). The result clearly implies that the tractor with tracks generally reach markedly higher drawbar pulls than the wheeled tractor. In this case, the exchange of the wheeled undercarriage with the tracked undercarriage increase the weight of the tractor by 2 780 kg. Larger contact area between the ground and the tracks is significant also in agro technical terms as the soil does not appear to be too thickened as it does with the wheeled tractor. The calculated value of specific pressure influencing soil for the wheeled tractor with variant A of the tire pressure rating was 131.39 kPa and with variant B of the tire pressure rating it was 107.03% kPa. However, the specific pressure of the tractor crawler was 50.95 kPa. Immensely higher specific pressure influencing soil under the wheeled tractor in comparison to the tractor crawler were described also by authors ARVIDSON *et al.* (2011).

CONCLUSION

Tractors measurement was implemented in order to identify and compare the drawbar characteristics of the tractors of the same type however with different undercarriage construction. From the measured and calculated values, it is evident that the tractor crawler is, due to its distinctive undercarriage construction, heavier and has better drawbar characteristics. For the tractor comparison, speed gear 9 was selected and it was measured (if we consider the wheeled tractor as a standard) that the tractor crawler reached higher drawbar power value by 24.9% and lower traction slip by 16.5% than the wheeled tractor with tire inflation of 160 kPa on the front axle and of 140 kPa on the rear axle and by 17.8% higher drawbar power and by 9.2% lower traction slip as compared with the wheeled tractor and tire inflation of 120 kPa on the front axle and of 100 kPa on the rear axle. For the agricultural profession, operational costs regarding the tractors are also significant. Results of measurement clearly proved that the tractor crawler reached lower specific tractive consumption by 19.5% (variant A of the tire inflation) and by 12.3% (variant B of tire inflation) in comparison with the wheeled tractor. The second part of the measurement was focused on the change of the drawbar characteristics of the wheeled tractor together with the change of the tire inflation. Also now, it was measured and compared using speed gear 9 that the tractor with lower tire inflation (variant B) reached improvement of the thrust horsepower by 5.4%, decrease in the traction slip by 13.4% and decrease in the specific tractive consumption by 8.8% than the wheeled tractor with the standard tire inflation (Variant A) which is considered as a norm.

The results of the field measurement can be useful particular when choosing a new tractor as the potential customer can opt from a variety of the supplemental equipments such as central tire inflating system. With such equipment, operating staff can choose tire inflation in accordance to the actual work. This means that whilst doing some exacting tensile work, under-inflating tires will result in better drawbar characteristics, a decrease in contact force on the soil and its associated lower energy intensity. In agriculture, it is expected that every new machine helps to decrease costs and increase productivity. Choosing an appropriate undercarriage construction of the tractor as well as optimal tire inflation for different agricultural work of the wheeled tractor can lead to the costs decrease or more precisely to the decrease in fuels consumption.

SUMMARY

The aim of the measurement was to verify the drawbar characteristics of the tractors with the same parameters of engines and gear-boxes but with different undercarriage construction. For the study, we used wheeled tractor John Deere 8320R which was examined with the distinctive tire inflation and the tractor crawler John Deere 8320RT. The measurement was implemented on the sandy loam soil in the land register of Vrbovec (Znojmo region) in the area where green peas were grown as a main product and winter wheat as a preceding crop. Drawbar pull was measured by the aid of strain-gauge force sensor which was placed on the rope between the measured and the loading tractor. Moreover, the data was recorded from the on-board system of the Can-Bus tractor as well as from the GPS module. From the measured and subsequently calculated values, it was determined that the wheeled tractor with tire inflation (variant B value of 120 kPa on front axle and 100 kPa on the rear axle) reach higher values regarding drawbar pull as well as drawbar power and lower value of specific tractive consumption and traction slip. In percentage comparison using speed gear 9, drawbar power was increased by 5.4%, specific tractive consumption was reduced by 8.8% and traction slip was also reduced by 13.4%, on the assumption that the tractor with tire inflation of Variant A (front axle 160 kPa, rear axle 140 kPa) is the norm. If we compare the measured values of the wheeled tractor and the tractor crawler with both variants of tire inflation using speed gear 9, we can clearly see that the tractor crawler, due to its weight and undercarriage construction, reached greater thrust horsepower by 24.9% and lower values of traction slip by 16.5% than the wheeled tractor with the standard tire inflation and greater drawbar power by 17.8%, lower values of traction slip by 9.2% in comparison with the wheeled tractor with lower tire inflation, if the tractor crawler is considered as a standard.

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REFERENCES

KELLNER, T., TRAUTNER, A., ARVIDSSON, J., 2002: *Stress distribution and soil dispacement under a rubber-tracked and wheeled tractor during ploughing, both on-land and within furrows,* Soil & Tillage Research 68, 39–47.

BAUER, F. et al., 2006: *Traktory*, ProfiPrees, Praha, 1. vydání, 192 s.

BAUER, F., SEDLÁK, P., ČUPERA, J., TATÍČEK, M., POLCAR, A., VYKYDAL, P., SLAVÍK, J., 2010: *Vyhodnocení měření kolového traktoru John Deere 8320R a pásového traktoru John Deere 8320RT ve vozidlových laboratořích a v terénu*. Mendelova univerzita Brno. Zpráva ze zkoušek.

MOLARI, G., BELLENTANI, L., GUARNIERI, A., WALKER, M., SEDONI, E., 2012: *Performance of an agricultural tractor fitted with rubber tracks*, Biosystems Engineering III, 57–63.

ŠMERDA, T., ČUPERA, J., 2010: *Tire inflation and its influence on drawbar characteristics and performance – Energetic indicators of a traktor set*, Journal of Terramechanics 47, 395–400.

Address

Ing. Petr Vykydal., prof. Ing. František Bauer, CSc., doc. Ing. Pavel Sedlák, CSc., Ing. Adam Polcar., Ústav techniky a automobilové dopravy, Mendelova univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika, e-mail: petr.vykydal@mendelu.cz, frantisek.bauer@mendelu.cz, pavel.sedlak@mendelu.cz, adam.polcar@mendelu.cz