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THE INFLUENCE OF THE TIRE INFLATION ON PULL PROPERTIES OF AGRICULTURE TRACTORS

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Abstract

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Agricultural tractors are robust and versatile machines, which must comply with the basic requirements of users under various conditions. The main requirements include economical and reliable operation and high performance. Fuel economy could be improved using multiple methods, for example a well trained operator, adequate farming conditions and optimal tire inflation. Tractor tires transmit engine power to the surface and as such they are crucial to tractor operation. In the first part of the field measurement, all tires were inflated to 180kPa, while in the second part of the field measurements the tire pressure was set to 75kPa in front tires and to 65 kPa in rear tires. The results of the field measurement of the John Deere 6920S tractor with different tire inflation shows that pull performance increased by 9.9% and wheel slip decreased by 9.7%.

tire inflation, fuel consumption, pull performance

Agricultural tractors are versatile machines, which must comply with basic requirements of users under various conditions. The main requirements are economical and reliable operation and high performance. Modern agriculture tractors are equipped with high performance engines, CVT transmissions and automatic systems, which improve efficiency and reduce costs. Fuel economy could be improved significantly using a well trained operator, adequate farm conditions or optimal tire inflation. Tractor tires transmit engine power to the surface and as such they represent very important parts of any agricultural tractor. Tire manufacturers respect this fact and they produce many types of tires with different properties. The newest tires may be used with low tire inflation. Modern agricultural tractors could be equipped with automated system for tire pressure adjustment. One way how to determine the influence of tire pressure on the output parameters of an agricultural tractor is direct comparison of pull characteristics. For such experiment, tractor with two different tires inflation levels can be used (BAUER, F. *et al.*, 2006). Effect of tire inflation on tractor pull properties was investigated in field measurements with tractor John Deere 6920S.

MATERIAL AND METHODS

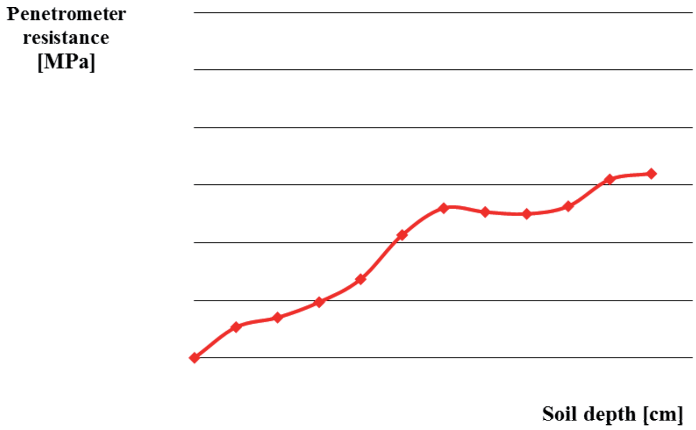
First, the engine speed data were obtained in a laboratory site. In the first part of the field measurement, all tires were inflated to 180 kPa. For the second part of the field measurements, the tires featured pressure of 75 kPa (front) and 65 kPa (rear). The measurement was carried out on the field called Březí in Týn nad Vltavou (see Fig. 1). The field was pre-processed with cultivator to a depth of 10cm two weeks prior to the experimental run. Type of soil on the site is a light sandy loam. The field is situated to the south of Týn nad Vltavou with an overall area of 18.45 ha (BAUER, F., SEDLÁK, P., 2006).

During the measurement, samples of soil were tested in order to find soil moisture level. First, the samples were weighed. Then, they were dried in an oven at 105 °C until a constant weight was reached. Finally, the samples were weighed again.

1: *Test field Březí near Týn nad Vltavou (from www.mapy.cz)*

I: *Results of the soil moisture measurement*

Section	Sampling depth	Soil moisture	Note
	h	w	
[-]	[cm]	[%]	
1	5	22,98	Tensile tests
2	5	25,48	
3	5	21,69	



2: *Average penetrometer resistance values*

Soil moisture w was calculated according to the following relation:

$$W = \frac{m_v}{m_z} \times 100 \ [\%],$$

where m_v is water weight in the sample [g] and m_z is weight of the sample before the drying [g]. The results of the soil moisture are shown in Tab. I.

Indirect measurement of soil compaction with penetrometer was carried out as well. Average values of penetrometer resistance are shown in Fig. 2.

The field measurements were performed with agriculture tractor John Deere 6920S (see Fig. 3).

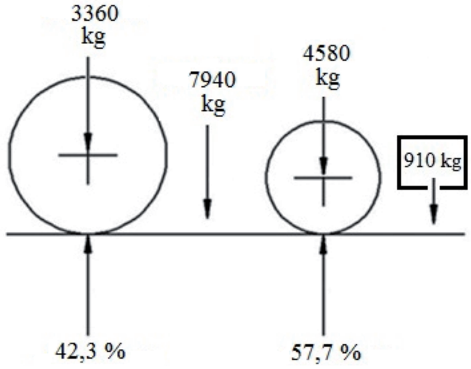
3: *The John Deere 6920S tractor used in the experiment*

John Deere 6920S – Technical Specifications

Manufacturer: John Deere, Mannheim. **Type**: 6920S AutoPowr. **Engine:** John Deere 6068 HL 474. Six-cylinder diesel engine, turbocharged with intercooler. Injection system: Common-Rail. Displacement: 6788 cm^3. Rated power: 104.8 kW at 2 100 rpm. Maximum power: 115.1 kW at 1 800 min^{-1}. Maximum torque: 662 Nm at 1 500 rpm. **Transmission:** CVT AutoPowr. **Tires:** Front: Michelin 520/60 R28 Xeobib, rear: Michelin 650/60 R38 Xeobib. **Weight:** Front axle: 4 580 kg. Rear axle: 3 360 kg. Total weight: 7 940 kg. Weight of front ballast: 910 kg. Weight distribution: see Fig. 4 (BAUER, F., SEDLÁK, P., 2006).

Force Measurement

The tow rope between the measured tractor and the loading tractor was equipped with a Hottinger U2A strain sensor (see Fig. 5). The sensor was connected to Spider8 frequency module with connection speed of 4.8 kHz. The maximum force detectable by the sensor is as much as 100 kN.



4: *Weight distribution of the John Deere 6920S tractor*

Speed Measurement

The actual speed was measured using the RDS TGSS radar unit which was mounted on the tractors chassis (see Fig. 6). The radar operates at frequency of 24.124 GHz. The slope of the radar relative to horizontal plane was 37 degrees. The overall accuracy of the system ranges from 1 to 4%. The radar was connected to Spider8 frequency module.

CAN-Bus Data Acquisition

Additional parameters were read from the CAN-Bus network including actual speed, engine load, fuel consumption, coolant temperature, fuel temperature etc. The CAN-Bus of the John Deere 6920S is fully compatible with the SAE J1939 standard.

GPS Module Data

Additional data formed a matrix of values from Garmin GPS GPS module with RS 232 output line and 1 second response rate.

Wheel Slip

To calculate the wheel slip of the John Deere 6920S tractor, it was necessary to measure the actual distance covered by 5 revolutions of driven wheels. Theoretical distance was measured at 5 revolutions of driven wheel when the John Deere 6920S was pulled with other tractor. Differential lock was active during all tests (BAUER, F., SEDLÁK, P., 2006).

The measurements of pull characteristics of John Deere 6920S on the field were performed with full dose of fuel. Pull parameters were measured by

5: *Strain sensor on the tow rope*

6: *Radar unit for accurate speed measurement*

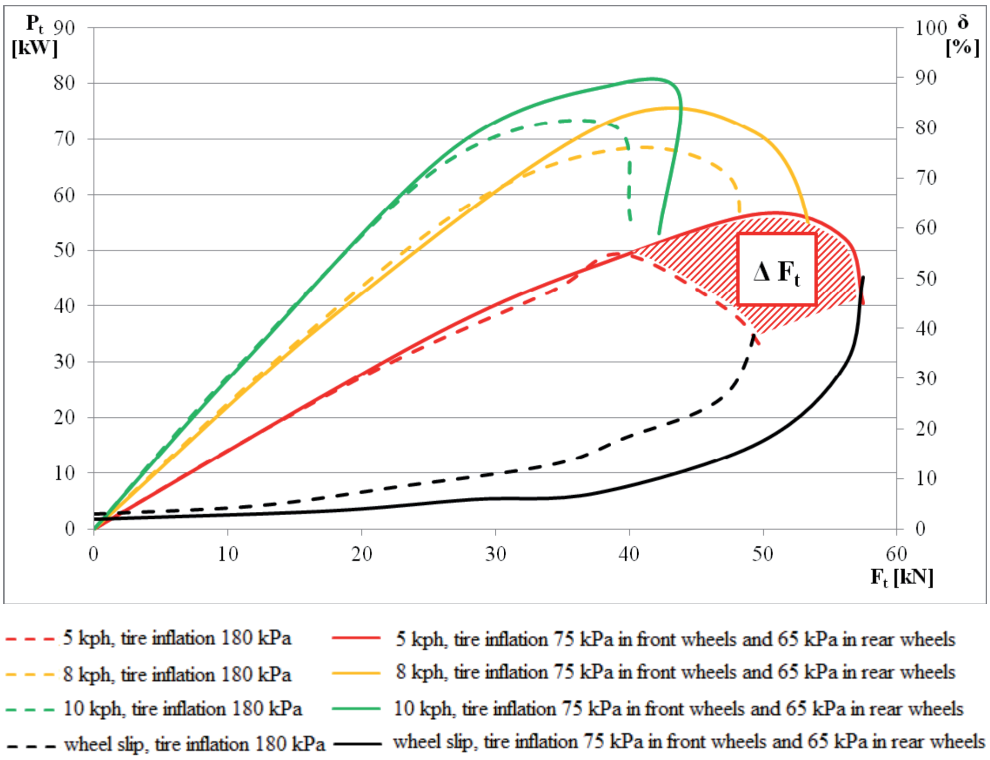
standard pull tests. Every single test was performed with set theoretical speed 5 kph, 8 kph, and 10 kph. Required speed was set by on the dashboard display. Average values for every single test were calculated from data recorded to test computer. Recorded and calculated data are set to the pull characteristics.

RESULTS

The comparison of the results pull tests with different tire inflation are shown in Fig. 8. The pull characteristic shows that with the tire inflation of 180 kPa, the highest pull power of 51.1 kN was reached with wheel slip of 56.3%. The highest pull performance was 72.6 kW. After tire inflation was reduced to 75 kPa in front wheels and 65 kPa in rear wheels, the same pull power was reached with wheel slip 16.2% with difference of 40.1%. The highest pull power after tire inflation reduction was 58.4 kN with wheel slip of 50.3%. The difference of the highest pull powers is 7.3 kN or 12.5% (based on pull power with lower tire inflation). The difference is shown with shaded area in pull characteristic (see Fig. 9). The highest pull performance was 79.8 kW with difference was 7.2 kW or 9.9%.

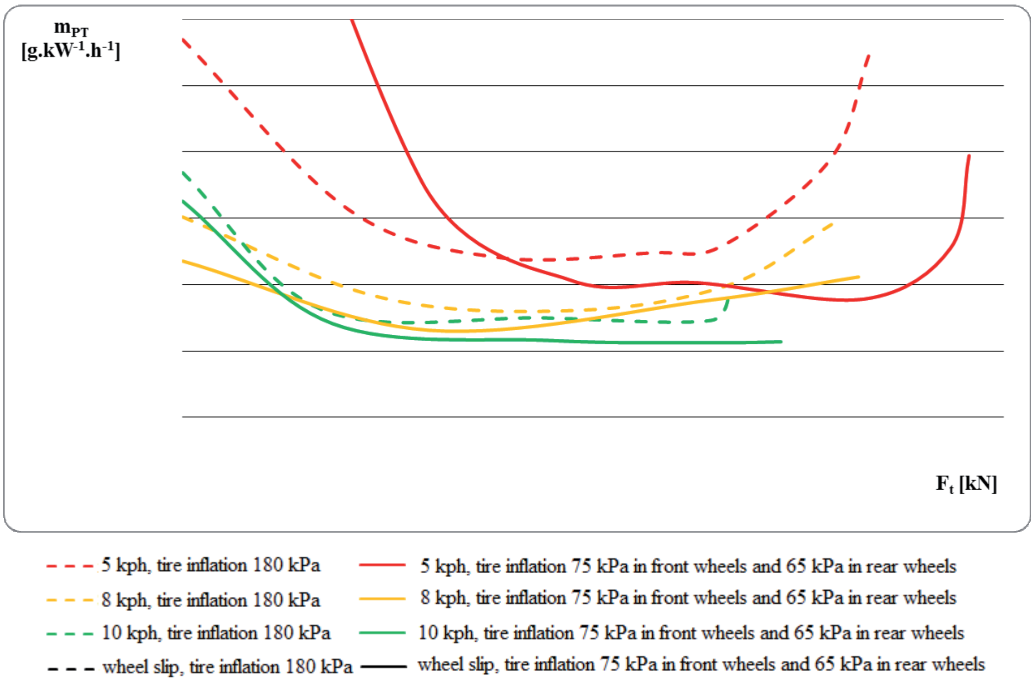
The fuel consumption characteristic shows that lower inflation caused reduction of the specific tractive fuel consumption. The lowest specific

7: *Pull characteristics measurement*



8: *Pull characteristics of the John Deere 6920S with tire inflation of 65/75/180 kPa and speeds of 5/8/10 kph*

fuel consumption was 312.5 $g.kW^{-1}.h^{-1}$ and it was achieved at speed of 10 kph and tire inflation 75 kPa and 65 kPa (front and rear wheels, respectively). With the tire inflation 180 kPa and speed 10 kph, the lowest specific tractive fuel consumption of 346.1 $g.kW^{-1}.h^{-1}$ was achieved. The difference



9: *Specific tractive fuel consumption of the John Deere 6920S with tire inflation of 65/75/180 kPa and speed of 5/8/10 kph*

of the specific tractive fuel consumption was 33.6 g. $kW^{-1}.h^{-1}$ or 9.7% based on specific tractive fuel consumption with tire inflation of 180 kPa.

DISCUSSION

The results of the field measurements of the John Deere 6920S tractor clearly show the positive effect of lower tire inflation on the pull characteristic of the machine. The pull characteristic of the John Deere 6920S shows that with tire inflation of 180 kPa, the highest pull power was 51.1 kN with the wheel slip of 56.3%. After the tire inflation had been reduced, the wheel slip decreased to 16.2% with the same pull power, which makes difference of 40.1%. The highest pull power after tire inflation reduction was 58.4 kN with the wheel slip 50.3%. The difference of the pull powers is 7.3 kN or 12.5%. The results show positive effect of the tire inflation reduction on the pull properties of agriculture tractor.

João M. Serrano made field measurement focused on pull properties of the Massey Ferguson 3060 agricultural tractor. The tractor was aggregated with disk harrows and its tire inflation was 140 kPa in the first test and 100 kPa in front wheels and 70 kPa in rear wheels in the second test. The results shows that after increasing tire inflation to 140 kPa the wheel slip increased by 18% and the fuel consumption increased by 15% per hectare (SERRANO, J. M., 2008). Both field measurements prove positive effect of tire inflation reduction on output parameters of agriculture tractors.

ŠMERDA, T. made field measurement focused on tire inflation and its influence on drawbar characteristic of a plough set. The measurements were performed with two different tire inflation values. The tire inflation was reduced from 180 kPa to 75 kPa in front tires and 65 kPa in rear tires. The results showed that lower tire inflation had positive impact on the specific tractive fuel consumption that decreased (3.4 to 16%) and the maximal drawbar power increased (9.1 to 14.6%) (ŠMERDA, T., 2010).

SUMMARY

The paper deals with the influence of tire inflation on the agriculture tractor output parameters. The field measurements of the pull properties of the John Deere 6920S were performed on wheat stubble processed with disc harrows. Tires inflation values were 180 kPa and 75 kPa in front wheels and 65 kPa in rear wheels. Every single test was performed with a theoretical speed of 5 kph, 8 kph, and 10 kph.
The results of the field measurements of the John Deere 6920S clearly show the positive effect of reducing tire inflation on the pull characteristic. The reduction of tire inflation caused increasing of the area between tires and land surface. This led to lower wheel slip. The wheel slip was reduced by 6% at the highest pull power. The pull characteristic shows that with the tire inflation 180 kPa, the highest pull power 51,1 kN was reached with wheel slip 56.3%. The highest pull performance was 72.6 kW. After the tire inflation had been reduced to 75 kPa in front wheels and 65 kPa in rear wheels, the same

pull power with wheel slip of 16.2% was reached, which represent a difference of 40.1%. The highest pull power after tire inflation reduction was 58.4 kN with wheel slip of 50.3%. The difference of the highest pull powers was 7.3 kN or 12.5%.

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