DRAWBAR PULL OF SMALL TRACTOR WITH SPECIAL LUG WHEELS

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Abstract
This contribution is aimed at increase in drawbar pull of small tractor. The special lug wheels were designed for standard tractor driving wheels. If lugs are in base position, a tractor uses standard tires to transport on roads. Protruded position of the lugs allows to improve tractive properties of the tractor in terrain. Drawbar pull at 100% driving wheels slip was measured on cultivated soil at soil moisture 30.98%. Field measurements were repeated seven times to eliminate measurement errors. The results of experiments with special lug wheels were compared with standard tires. The test tractor developed the greater drawbar pull due to the special lug driving wheels. The experimental results show the increase in drawbar pull 23.1% in case of the tractor in second gear.

Key words: *tire; wheels slip; tractive performance; agricultural machinery.*

INTRODUCTION

Today's agricultural tractors are characterised by high rates of standardisation and feature a range of additional attachments which allow the wider use of each tractor and greatly facilitate its operation *(Kosiba et al., 2012)*. The need for tractors and agricultural machinery to be tested from the point of view of their suitability to agricultural use will grow continuously because these machines directly affect agricultural production *(Hujo et al., 2017)*.
Driving wheels are significant part of a tractor construction because they transmit power to a ground. Therefore, tractor wheels affect a total energy efficiency *(Vitázek et al., 2016; Vitázek et al. 2018)*, a fuel consumption *(Uhrinová et al., 2013)*, and a soil compaction *(Malý et al., 2015; Rataj et al. 2009; Hrubý et al., 2013)*.
Agricultural tractor loses a lot of energy by a driving wheels slip. To reduce the wheels slip, an additional ballast load loads the tractors. This solution improves a drawbar property of the tractors but on the other hand increases the soil compaction and tires wear on a hard surface *(Semetko et al., 2002)*.
The drawbar efficiency affects the fuel consumption and an emission production. The wheels slip reduction improves the fuel consumption, reduces the emission production and so improves an economy and an ecology of a tractor operation.
Many authors *(Kučera et al., 2016; Adamchuk et al., 2016)* researched an impact of driving wheels on the tractor drawbar properties and an environment. This paper is aimed at a research on a new type of the special driving wheels to improve the tractor drawbar pull without a need for the addition ballast load.

MATERIALS AND METHODS

Special lug wheels

The special lug wheels are shown in Fig. 1 and were designed at the Department of Transport and Handling of the Slovak University of Agriculture in Nitra. A support tube (1) is a basic part of the whole mechanism. It enables the remaining parts of the whole mechanism to be attached to each other. On the support tube, there are welded three locking tabs (2), three brackets (3) by which the whole mechanism is connected to the tractor wheel, and a driving disc (6) containing blades (5) mounted by means of ten pins. On the support tube, there are also welded spacer plates (4) through which the mechanism position is centred with respect to the tractor wheel disc. After the driving disc (6), the support tube contains a freely rotating blade control disc (7) for the control of blades. The blade control disc contains, on its circumference, twenty pressed guide pins by means of which blades move into the protruded or base positions. On the other side of the blade control disc, there are four locking holes (9) to fix the position of blades in the protruded position. Three buffer plates (11), attached by six screws to the locking tabs (2), fix the blade control disc on the support tube.

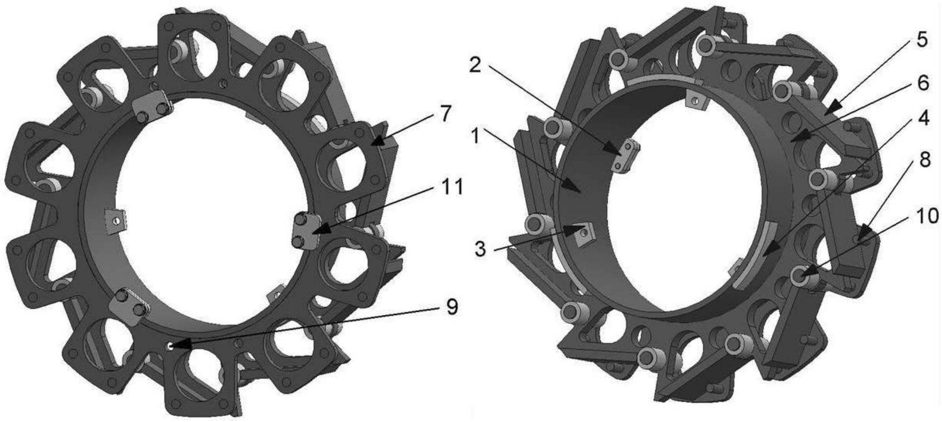

Fig. 1 Special lug wheels: 1 – support tube, 2 – locking tab, 3 – bracket fastening the mechanism to the wheel disc, 4 – spacer plates, 5 – blade, 6 – driving disc, 7 – blade control disc, 8 – guide pin, 9 – locking hole, 10 – blade pin, 11 – buffer plate

Drawbar pull measurement

Drawbar pull at 100% wheels slip was used to compare the special lug wheels with standard tires. The test tractor was equipped with standard tires TS-02 6.5/75-14 4PR TT type (Mitas a. s., Czech Republic). The drawbar pull measurements were realized in accordance with STN ISO 789-9 *(Simikić et al., 2014)*.

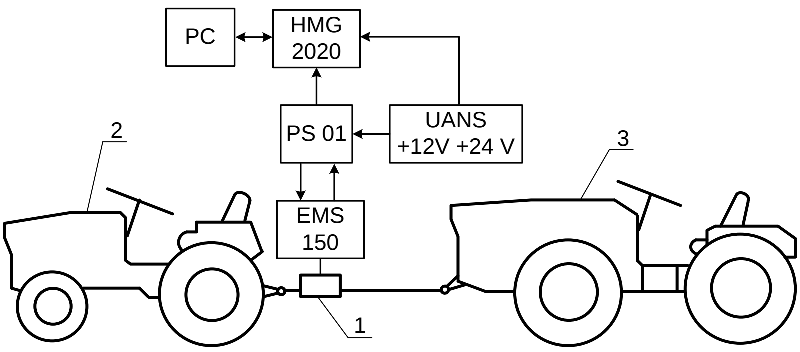

Fig. 2 Schematic diagram of the drawbar pull measurement: 1 – force sensor EMS 150 type, 2 – test tractor Mini 070 type, 3 – load tractor T4K10 type, HMG 2020 – data logger, UANS – universal battery source, PC – personal computer, PS 01 – junction box.

Main parts of a measurement system (Fig. 2) are as follows:

- The test tractor MT8-070 Mini type (Agrozet, Czech Republic) is characterised by gasoline engine with volume capacity 400 ccm, ratted engine power 8 kW and ratted engine speed 3,600 min^{-1}. The test tractor total weight is 310 kg. This tractor drew the load tractor to generate the drawbar pull. The special lug wheels were mounted to the test tractor to compare wheels properties with standard tires on the basis of the drawbar pull. The test tractor with standard tires was equipped with the addition ballast weight in wheel discs to compensate the weight of the special lug wheels. Therefore, there was the same weight of the test tractor under all measurements. The test tractor was operated in second gear.
- The load tractor 4K-14 type (Agrozet, Czech Republic) is characterized by diesel engine with volume capacity 661.6 ccm and maximal output power 13 kW. The load tractor total weight is 870 kg. This tractor loaded the test tractor during the measurement of the drawbar pull.
- The force sensor type EMS 150 (manufacturer: Emsyst s. r. o., Slovak Republic) with strain-gauge bridge in a steel housing (accuracy class: 0.2, rated capacity: 10 kN, rated output: 0 – 10 V). Drawbar pull measurement of tractor Mini 070 is implemented by means of strain tensometric force sensor marked as 150 EMS. Force sensor is connected between the load tractor and test tractor through the steel chain.

- The data logger type HMG 2020 (manufacturer: Hydac GmbH, Germany) is a high-performance portable measuring and data-logging device (Chrastina, et al., 2013) with accuracy ≤ ± 0.1. 1 kHz of a sampling frequency was set. Digital recording unit HMG 2020 was used to record electrical signals from force sensor.
- A power supply contains two accumulators (12 V) connected in series or parallel to supply the sensor and the data logger with a direct voltage (12 V or 24 V). The power supply was manufactured in our Department of transport and handling as a portable device (Cviklovič et al., 2012).

The measurements were performed on the field with a cultivated soil of the Slovak Agricultural Museum in Nitra (Slovak Republic) at soil moisture 30.98% (STN 72 1012) in the spring (May 2015). The Chernozem soil type (World Reference Base for Soil Resources) is typical for the area where the field tests were performed.

Drawbar pull calculation

The driving wheels sank to the ground during the measurements. Rocks, stones or another ground inhomogeneity can negatively affect the value of drawbar pull. Therefore, the measurements were repeated seven times to minimize the measurement errors.

To calculate the drawbar pull of one measurement (Fig. 3), a time interval from a start point 1 to a finish point 2 has to be stated. These points are intersection of two lines namely dotted line (minimum level) and solid line (measured course of drawbar pull). Using drawbar pulls of seven measurements, the mean drawbar pull X of the tractor with the different driving wheels types was calculated. The same methodology was published by *Abraham et al., (2019).*

$$X = \frac{x_1 + x_2 + \dots + x_n}{n} \tag{1}$$

where $x_1, x_2 \dots, x_n$ are values of drawbar pulls repeated seven times (N), n is the measurement repetition.

The special lug wheels and standard tires will be compared according to 95% confidence interval *CI. Švenková et al. (2010) and Kozelková et al. (2018)* present, that the 95% confidence interval is adequate for experiments in agricultural praxis.

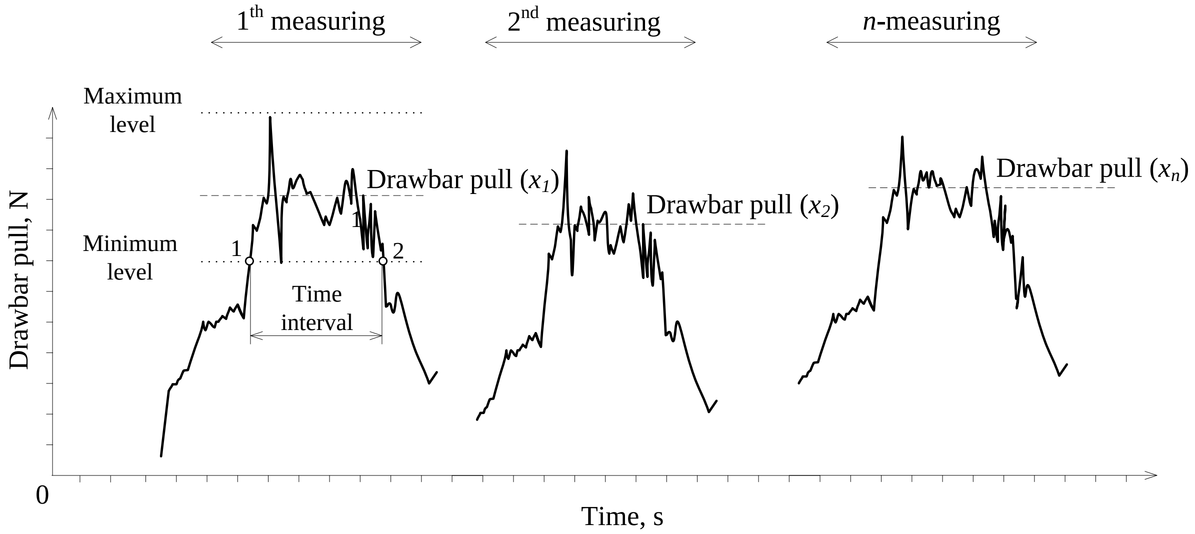

Fig. 3 Methodology of drawbar pull calculation.

RESULTS AND DISCUSSION

Fig. 4 and 5 show the measured courses of drawbar pull during the seven measurements on the cultivated soil. When the tractor was stopped, the driving wheels were slipping at 100% wheels slip. In this moment, the drawbar pulls reached the maximum values. The mean values were calculated and marked by broken lines in graphs.

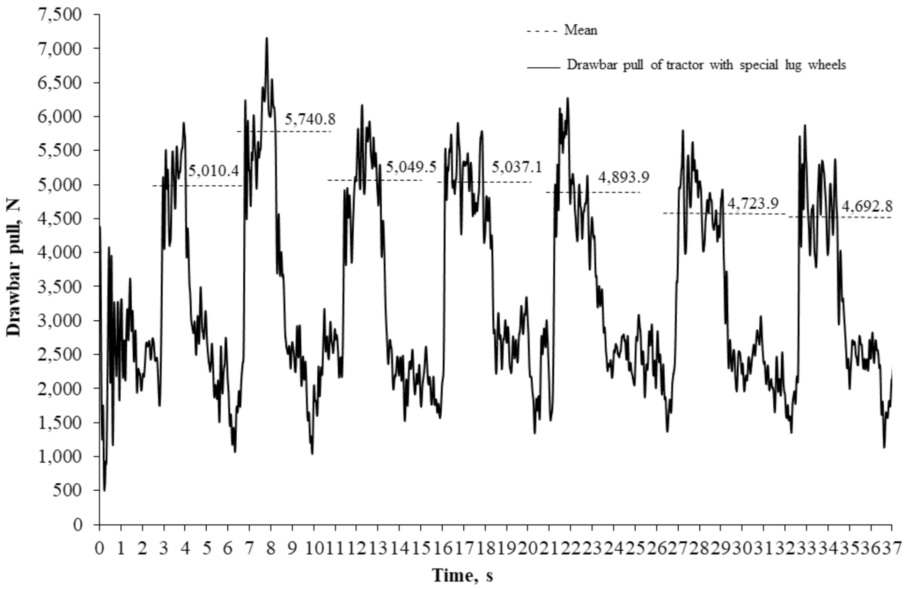

Fig. 4 Drawbar pulls of the tractor with the special lug wheels.

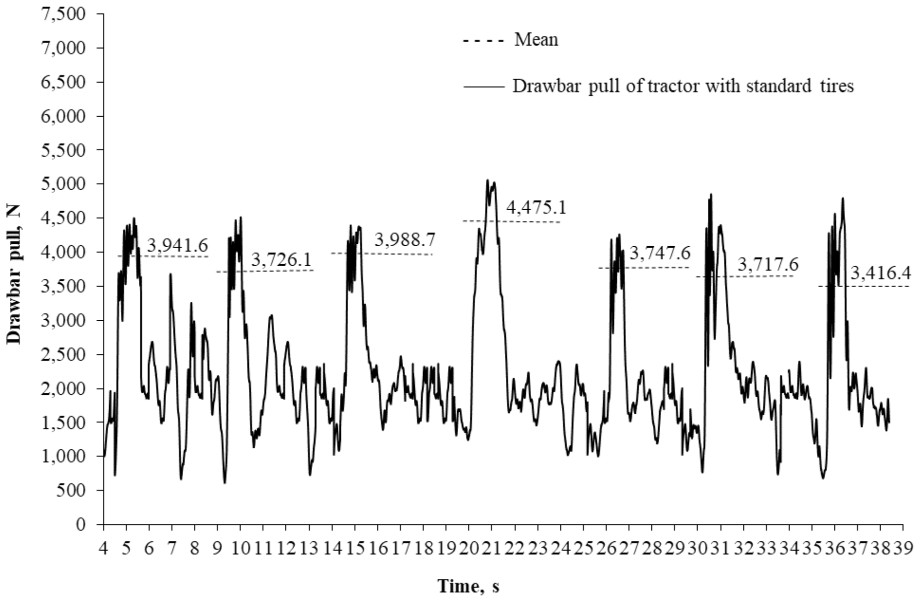

Fig. 5 Drawbar pulls of the tractor with the standard tires.

Tab. 1 shows the calculated values of drawbar pulls, and 95% confidence intervals (*CI*). Considering 95% confidence interval, Fig. 6 shows the statistically significant differences 23.1% between standard tires and special lug wheels.

Tab. 1 Data of drawbar pulls (N) of tractor with different driving wheels.

Wheels type	Drawbar pull N							*X* N	*CI* N
Standard tires	3,941.6	3,726.1	3,988.7	4,475.1	3,747.6	3,717.6	3,416.4	3,859.1	608.3
Special lug wheels	5,010.4	5,740.8	5,049.5	5,037.1	4,893.9	4,723.9	4,692.8	5,021.2	645.8

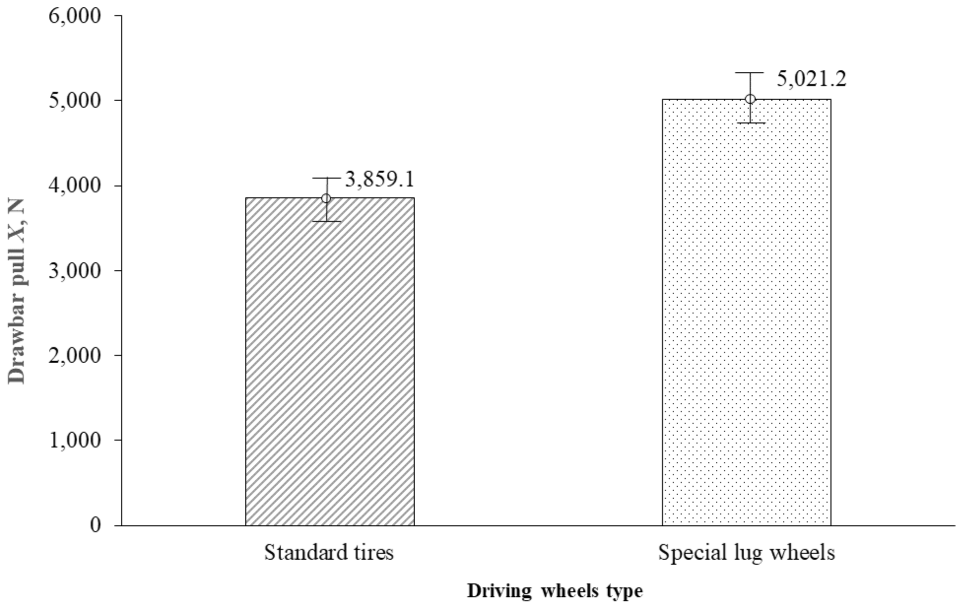

Fig. 6 Comparison of special lug wheels and standard tires.

Battiato and Diserens (2013) present in their work that, although the tractor developed higher drawbar pull both when tire inflation pressure was decreased and wheel load was increased, only the decrease in tire pressure produced improvements in terms of coefficient of traction, tractive efficiency, power delivery efficiency, and specific fuel consumption, while the only significant benefit due to the increase in wheel load was a reduction in the specific fuel consumption at a tire pressure of 160 kPa and a slip of under 15%. *Gee-Clough et al. (1977)* presents the tractive performance of tractor depending on tire inflation, too. When comparing these results with those obtained in our study, we improved the tractor performance using the special lug wheels. In this case the wheel load and tire inflation do not be changed. Traction performance tests were presented by *Turner et al. (1997)* to compare two different rubber belt tractors with two similar radial tire equipped mechanical front wheel drive tractors. Three different test methods were used in both tilled and untilled clay loam soil. The optimized systems showed only small differences in overall performance and efficiency in good traction conditions. This was also where both types of vehicle showed their best power delivery performance. Belted tractors showed their greatest benefit when operated at worse traction conditions in soft or loose soils. Similarly, the special lug wheels improved the traction performance of the test tractor, too.

CONCLUSIONS

The tractive performance affects effective usage of an engine power because a lot of energy is lost between the driving wheels and ground. The transformation of engine power to drawbar pull is a problem relating older and modern tractors, too. The paper presents the design, practical application and tests of special lug wheels to improve the tractive performers of the small tractor. The special lug wheels can be used not only in case of special agricultural conditions (rise grooving) but also in case of all tractors in all difficult tractive conditions. The tests of special driving wheels showed high potential of special lug wheels because the statistically significant increase in drawbar pull reached 23.1%.
The next interest will be aimed at automatization of lugs extension and influence of the special lug wheels on fuel consumption because the lower wheel slip improves this factor.

ACKNOWLEDGMENT

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