TENSILE RESISTANCE OF WHEELED COMBINE HARVESTER

Lukas Benes, Petr Hermanek, Petr Novak
Czech University of Life Sciences Prague
benesl@tf.czu.cz

Abstract. This article examines the influence of tires depending on the tensile resistance of the combine harvester when low-pressure tires are one of the ways to respond to the increasing weight of self-propelled machines. Determination of the tensile resistance value is not simple, and it was necessary to modify the methodology of measuring. Tensile resistance determination was based on measurements of a drawbar pull. The drawbar pull was measured as follows. The combine harvesterJohnDeereS680i was to wed by a tractor. A pull dynamometer, from which the pulling force was read, was used as a tow bar. Measuring was carried out on the asphalt surface with maximum slope of 0.2º and a path length of 120 meters. The speed with which the combine harvester was pulled corresponds with the usual working speeds, by which the combine harvester moves on the land at the time of harvest. The variants of the measurement speed were 4, 6 and 8 km·h^{-1} and each variant was repeated two times. Therefore, we can observe a course of different values of the pulling force for the different speeds and thus the different tensile resistance. While operating the machine the bigger tensile resistance is reflected in higher work load of travel gear, increase of the power take from the engine unit and higher fuel consumption.

Keywords: combine harvester, tensile resistance, wheels, travel gear.

Introduction

For agricultural machinery more demands on performance are put [1]. Raper [2] reported that efficient mechanization in agriculture is a major factor underlying high productivity. Larger machinery is often related with timeliness, higher work rates, and lower labour requirements. The drawback of it is that larger machinery usually means increased machinery weight which increases the danger of soil compaction. Soil compaction affects the physical, chemical, and biological properties of soils and is one of the main causes of agricultural soil degradation [3].

Manufacturers of agricultural machines are trying to solve this problem by installing the belt units on the machines. The second way is using wide low-pressure tires with low pressure on the ground. Generally, an increase in tyre size is accompanied by a decrease in tyre inflation pressure to support a given axle load [4].

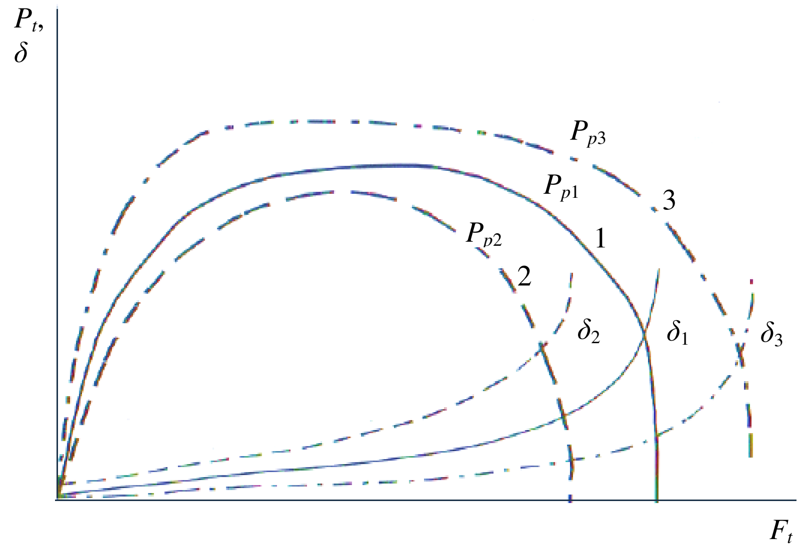

Fig. 1. **Influence ofgroundto potentialcharacteristics:** 1 – stubble; 2 – soil; 3 – asphalt surface; δ – wheelspin; P_p – potential pulling power; P_t – pulling power; F_t – tensile force [7]

The term low-pressure tire indicates that it has the ability to volumetric deformation. The volumetric deformation is dependent on the tire inflation pressure and load of the tire [5]. The concept of volume deformation is proposed to transfer the tire deformation characteristics on hard surface to that of soft terrain. The tire deformation has an effect on the tractive force, rolling resistance, torque, tractive coefficient, and tractive efficiency under different soft terrains [6]. Changes in these parameters can be easily observed in the change of the tensile force.Characteristics of thetensile force are influenced by ground.Bauer [7] discloses the characteristics of tensile force for various surfaces of ground in Figure 1.The influence oftire deformationis also reflectedin the change of the tensileforceat differentspeeds.

Current knowledge of draught force could be a useful tool in many ways. The results can be used in routine practice to compare the energy performance of travel gear of self-propelled machines, verification of technical changes on machines and verification of agronomical measures [8].

Materials and methods

Field measurements took place in Veltruby in Central Bohemia. In affiliated company of the agricultural company ZOD ZálabíOvčáry. The measurements were taken on the 3rd of December 2013.The combine harvester was dragged on the asphalt surface.During the measurement it was slightlyrainyandthe ambient temperaturearound2 °C. The measured section was 120 meters long with an average incline of 0.2 degrees.

To measure the tensile draught force the combine harvester John Deere S680i without a header was used. The weight ofthe machinewas 18600kg and the type of tires and their pressures are given in Table 1. The combine harvester ravel gearwas decommissionedby usingdisconnectingaxle shaftsdue to mechanicalresistance of the gearboxanddifferential.

Table 1

Parameters of tires

Parameter	Front tires	Rear tires
Maker	Firestone	Goodyear
Dimensions	900/60 R32	620/75 R26
Pressure	0.15 MPa	0.30 MPa

Fig. 2. **Measuring set, from left: pulling tractor John Deere 7930, measuring instrument, pulled combine harvester John Deere S690i without header**

For actual measurement a measuring instrument of draught force developed in collaboration of the Czech University of Life Sciences and BEDNAR FMT ltd. (formerly Stromexport) was used. As a pulling tractor means John Deere 7930 served. The combine harvester was dragged back in order to facilitate connection of the measuring equipment (Fig. 2).

The basic part of the measurement apparatus was a strain gauge load cell S-38 with measuring range up to 200 kN. The load cell was necessary to be placed into a steel cage so that the forces were applied only in tension or compression. Bending of the load cell may cause its destruction. The load cell was calibrated on a stationary workplace. Calibration was carried out on the tensile testing machine ZDM 50t. The data from the load cell were sensed every 2 s into the laptop which was situated in the cabin of the tractor [9]. The measuring equipment was complemented by hinges for mounting between a pair of machines (Fig. 3).

Fig. 3. **Measuring equipment between combine harvester and tractor**

The measurements were made for alternative speeds 4, 6 and 8 km·h^{-1}. These speedssimulate normalrange of operatingspeeds, whichcombine harvestermoves onthe land atwork.The set of machines accelerated to the desired speed. Constant speed was kept at a constant valueafter reaching. The measurements were supplemented by GPS position sensing. The evaluation used data from the defined measuring path. This path was characterized by steady conditions of measurement.For eachspeedalways tworepeats were carried out.

Results and discussion

The calibration results and the calibration curve can be seen in Figure 4. Linear dependence of the measuring apparatus output frequency on the tensile force was proved. The resulting linear dependence was used as calibration equation for draught force calculation [9].

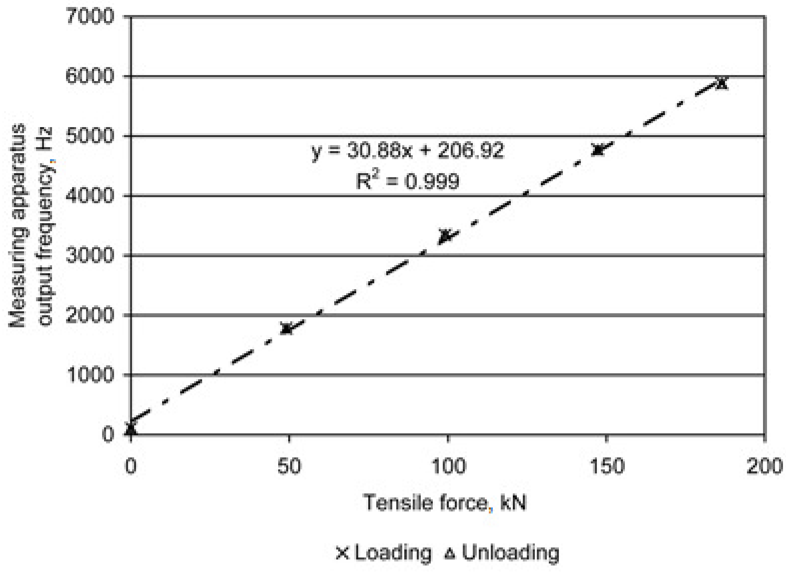

Fig. 4. **Dependence of measuring apparatus output frequency on tensile force, load cell calibration curve**

The graph in Figure5 shows that the tensile force values for the individual travel speed have similarvalues. Measuringat higher speeds (6 and 8 km·h^{-1}) is a problem ofhigh variance ofvalues.This is due toimpactsdue tothe inertiaduring the measurement. The sensor recorded these values and these are after processing, they appear as outliers and extremes.

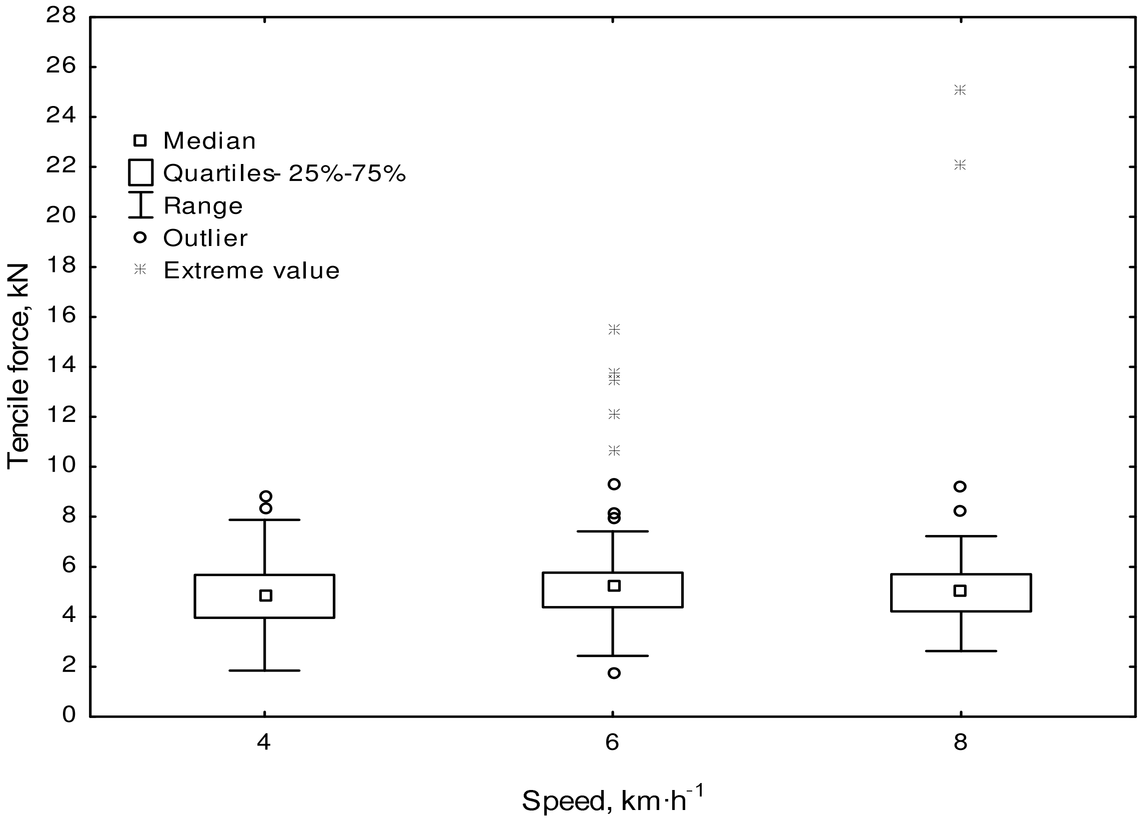

Fig. 5. **Dependence of tensile force on pulling speed**

This fact affects subsequent statistical evaluation with using of Fisher LSD test. The results of Fisher LSD test are given in Table 2. The Fisher's test confirms the assumption that among the values of the tensile resistance are not statistically significant differences. Nevertheless, in the average values of the tensile resistance a trend of gradual increase in the tensile resistance is visible.This trend is below the threshold of statistical significance.

Table 2

Results of Fisher LSD test

LSD test: Tensile force, kN α = 0.05000		
Speed, km·h^{-1}	**Tensile force, kN Average**	**1**
4	4.91	****
6	5.66	****
8	5.65	****

All values for the descriptive statistics are summarized in Table 3. From Table 3 it is seen that the measured values have a relatively high standard deviation and variance values. There is a vibration attachment of the measuring equipment especially at higher pulling speeds. This isprobably due tothe backlash in theattachmentof the measuring device.For further measurements it will benecessary to modifythe structureof the measuring equipment.

Table 3

Summary statistics used for tensile force for individual speeds

Speed	4 km·h^{-1}	6 km·h^{-1}	8 km·h^{-1}
Count	62	62	62
Mean	4.911	5.377	5.094
Median	4.876	5.248	5.038
Mode	multiple	5.637	4.762
Sample variance	1.968	7.043	12.501
Standard deviation	1.403	2.654	3.535
Minimum	1.848	1.783	2.625
Maximum	8.778	15.514	25.099
Skewness	0.390	1.962	4.489

Conclusion

Performing of the tensile test of the combine harvester has found that at operating speeds 4, 6 and 8 km·h^{-1} significant differences in the tensile resistance were not found. The average value of the tensile resistance at operating speed 4 km·h^{-1} was 4.91 kN. At speeds 6 and 8 km·h^{-1} the average values of the tensile resistance were higher and almost the same (5.66 and 5.65 kN).These results are important for comparison of measurements in real soil conditions, which will take place in the future. Similarly, for comparison with the tracked chassis combine harvester.The problemof measurementis highvariationof values, which impairs interpretation of the results. For further measurements it will be needed to changeattachment of measuring instruments.It is necessary toreduce the clearanceinthe connection between themachines. The results presented in this paper were also taken to serve verification of the possibility to measure the tensile resistance of combine harvesters.

Acknowledgement

This contribution has been drawn up on the basis of solution of the project 2015:31160/1312/3110 financed by the Internal Grant Agency of the Faculty of Engineering of the Czech University of Life Sciences Prague.

References

1. McPhee J.E., Aird P.L., Hardie M.A. etc. Theeffectofcontrolledtraffic on soilphysicalproperties and tillagerequirementsforvegetableproduction. Soil and TillageResearch, vol. 149, 2015, pp. 33-45.
2. Raper R. L., Arriaga F. J. Effectofvehicleload, transducerdepth, and transducer type on soilpressures. Proceedings of International conference“ASAE Annual International Meeting”, July 17-20, 2005, Tampa, United States, pp. 15.
3. HakanssonI., Voorhees W. B., Riley H. Vehicle and wheelfactorsinfluencingsoilcompaction and crop response in differenttrafficregimes. Soil and TillageResearch, vol. 11, 1988, pp. 239-282.
4. Ogunjirin O. A., Kamal A. R. Effect of Tyre Inflation Pressure and Speed of Operation on Tractor Tractive Performance during Tillage Operation. Proceeding of Nigerian Institution of Agricultural Engineers, vol. 21, 1999, pp. 199-208.
5. Barbosa L.A.P.,Magalhães P.S.G. Tire tread pattern design trigger on the stress distribution over rigid surfaces and soil compaction. Journal of Terramechanics, vol. 58, 2015, pp. 27-38.
6. Fan H., Zhao L. Mathematical model and experimental research of interaction between elastic tire and soft terrain. JournalofTsinghua University, vol. 37, 1997, pp. 110-114.
7. Bauer F., et.al. Tractors. First edition. Prague: Profi Press, 2006. 192 p. (in Czech).
8. Kroulík M. Technique in precision agriculture technology. Thesis submitted in fulfilment of the requirements for the associate professor. Czech University of Life Sciences Prague, 2013. (in Czech).
9. Novák P., Chyba J., Kumhála F. etc. Measurement of stubble cultivator draught force under different soil conditions. Agronomy research, vol. 12, 2014, pp. 135-142.