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Effect of driving wheel type on drawbar pull of tractor

Vplyv typu hnacích kolies na ťahovú silu traktora

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Abstract

This paper is focused on the possibility of increasing the drawbar pull of agricultural tractor on the soil and grass-covered surface. From our perspective, we have chosen one available and the cheapest way, i.e. steel boots for tyres of small tractors, and this was compared with a newly developed system of auto-extensible blades next to the wheel. The tractor with steel boots and auto-extensible blades reached a higher drawbar pull on average by 70 % in comparison with tyres.

Keywords: tractor tyres, wheel equipped with auto-extensible blades, steel boot, force sensor

Abstrakt

Príspevok je zameraný na možnosti zvýšenia ťahovej sily poľnohospodárskeho traktora na pôde a zatrávnenom povrchu. Z nášho pohľadu sme si vybrali jeden dostupný a najlacnejší spôsob, a to oceľové návleky na pneumatiky pre malotraktory, a ten sme porovnali s novo vyvinutým systémom automatického vysúvania lopatiek vedľa kolesa. Traktor s oceľovými návlekmi a automaticky vysúvacími lopatkovými kolesami dosiahol vyššie ťahové sily v priemerne o 70 % v porovnaní s pneumatikami.

Kľúčové slová: traktorové pneumatiky, automaticky vysúvacie lopatkové koleso, oceľový návlek, snímač sily

Detailed abstract

Merania boli uskutočňované v októbri roku 2012 pri priemernej pôdnej vlhkosti 22 % na pôdnom type černozem s priemernou objemovou hmotnosťou 1,33 g.cm^{-3}. Pôda bola po zbere uhoriek a bola pomerne vlhká napriek suchému počasiu. Meranie ťahovej sily bolo zabezpečované meracou a záznamovou technikou Hydac 2020.

Meranie ťahovej sily, resp. brzdenie malotraktora Mini 070 bolo realizované malotraktorom T4K10 postupným pribrzďovaním až do 100% preklzu hnacích kolies. Automaticky vysúvacie lopatkové kolesá boli vyvinuté na Katedre dopravy a manipulácie pre zadné hnacie kolesá traktora MINI 070. Ich veľkou výhodou je, že sa nemusia demontovať z traktora pri prejazde po ceste a taktiež to, že sa automaticky vysúvajú pri preklze hnacích kolies traktora. Opätovné sklopenie záberových lopatiek nastáva pri spätnom chode traktora. Traktor nemusí byť vybavený prídavnými závažiami, lebo tie do určitej miery nahrádzajú lopatkové kolesá.

Ťahové sily traktora boli porovnané tiež pri meraniach s pneumatikami a oceľovými návlekmi. Zariadenie na zvýšenie ťahovej sily, umiestnené na obvode kolesa, ako sa odborne návleky nazývajú, umožňujú vďaka dokonalejšej adhézii s podložkou lepšie využiť výkon daného stroja a tým zvýšiť jeho ťahovú silu na pôde.

Merania boli uskutočňované na dvoch povrchoch a to na pôde a na tráve. Elektrický signál zo snímača sily typu EMS 150 bol zazanamenávaný digitálnou záznamovou jednotkou HMG 2020. Snímač sily je zapojený medzi brzdiaci traktor T4K10 a meraný traktor MINI 070 prostredníctvom reťaze.

Podľa už prezentovaných výsledkov možno konštatovať, že najlacnejšie a najefektívnejšie zvýšenie ťahovej sily možno dosiahnuť prostredníctvom oceľových návlekov, ktoré sú komerčne vyrábané rôznymi firmami. No zároveň ich nedostatkom ostávajú dva faktory a to, že nemajú takmer žiadnu samočistiacu schopnosť a pomerne rýchlo sa zanášajú a po ďalšie, že pri prejazde po tvrdom podklade je značný výskyt porúch prevodového systému malotraktorov a preto ich treba ešte na poli demontovať. V druhom variante, ktorý sa dá použiť aj u ťažších traktorov je výhodou lepšia samočistiaca schopnosť lopatiek kolesa a taktiež to, že sa dajú sklopiť jednoduchou jazdou vzad. Následne po dokončení práce a po príjazde na dvor ich však treba dôkladne očistiť, najlepšie tlakovou vodou, lebo po zaschnutí hliny sa zamedzí vyklápaniu lopatiek. Treba však poznamenať skutočnosť, ktorá hovorí v prospech návlekov, a hoci to, že šípové lopatky mali rovnakú záberovú plochu ako lopatky výsuvného lopatkového kolesa, ale pri výsuvných lopatkových kolesách zaberali aj pneumatiky a predsa mali porovnateľné výsledky ťahovej sily. Ťahové sily na druhom prevodovom stupni boli takmer o 3% vyššie, čo však platí iba na pôde a tráve, ale nie na pevnom povrchu, kde je vyšší súčiniteľ adhézie.

Traktor s oceľovými návlekmi a automaticky vysúvacími lopatkovými kolesami dosiahol o dve tretiny vyššie ťahové sily v porovnaní s pneumatikami.

Introduction

The testing of tractors used in agriculture is continuously increasing because these machines directly influence the results of agricultural production (Hujo et al., 2012 a).

Agricultural tractors are losing a lot of energy by the slip of driving wheels. To reduce the tyre slip, tractors are loaded with a heavy weight, which increases the drawbar pull but excessively increases soil compaction and tyre wear on a hard surface (Semetko, 1998; Semetko, 2004). Nowadays, diesel oil and petroleum products belong to the most used fuels. Unfortunately, fossil fuels are non-renewable and exhaustible sources of energy (Müllerová et al., 2012). The increase of tractor drawbar pull influences the fuel consumption and emissions of exhaust gases.

To increase the drawbar pull and to reduce the soil compaction, some manufacturers recommend variable tyre inflation. Tyres are deflated to a pressure of 50 kPa on the soil, and when moving on the road, they are inflated again to the required pressure. This method is mainly based on research results, which show an average decrease of contact pressure on the soil at an inflation pressure of 6 psi by about one-third in comparison with tyres inflated to 18 psi, Figure 1 (Schuler et al., 2000).

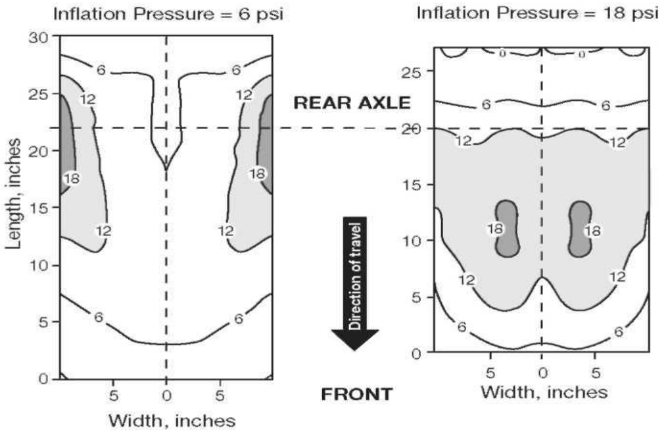

Figure 1: Pressure process in psi of the identical tyre with different filling pressures (Schuler et al., 2000)

Negative effects of soil compaction have been observed for several years at the Department of Transport and Handling. Possible solutions are presented in two variants, which were compared by us in terms of drawbar pull. The first option consists of wheels equipped with auto-extensible blades developed at the Department of Transport and Handling, and the second are steel boots that are used successfully on small tractors today.

Materials and Methods

Wheels equipped with auto-extensible blades

Wheels equipped with auto-extensible blades have been developed at the Department of Transport and Handling for the rear driving wheels of a tractor MINI 070. Wheels equipped with auto-extensible blades were designed according to the works published by Sloboda et al. (2008) and Jablonický et al. (2012). A big advantage is that they do not have to be removed from the tractor when passing on the road and also that they are automatically extended when the tractor driving wheels are slipping. Re-folding of driving blades occurs with the reverse movement of the tractor. The tractor needs not be equipped with additional load weights because they are replaced by wheels equipped with auto-extensible blades. Wheels equipped with auto-extensible blades are mounted to the wheel disc, and according to Figure 2 a, b, they consist of the following parts.

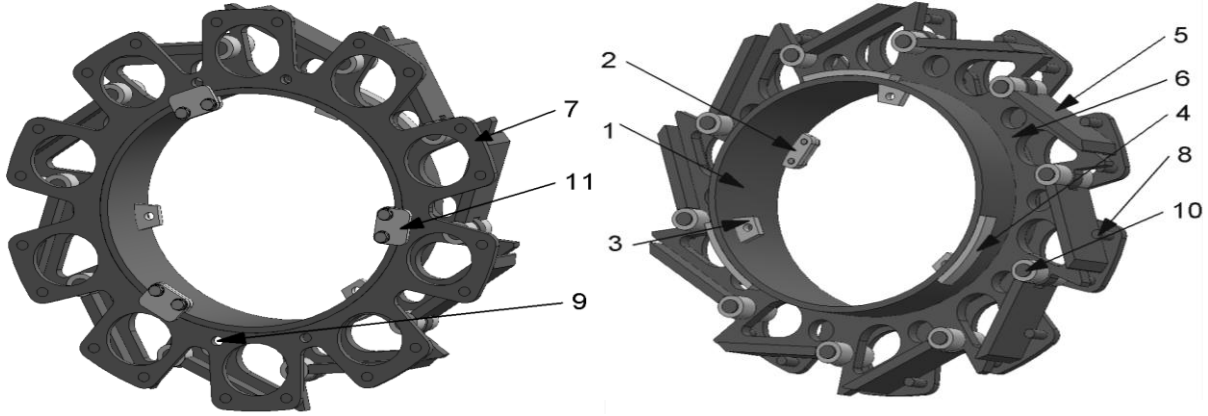

Figure 2 a, b: Wheels equipped with auto-extensible blades

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

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 disc for the control of blades (7). The blade control disc contains on its circumference twenty pressed guide pins by means of which blades move into the extended and retracted positions. On the other side of the blade control disc, there are four locking holes (9) to fix the position of blades in the retracted position. Three buffer plates (11), attached by six screws to the locking tabs (2), fix the blade control disc on the support tube.

Steel boots

A mechanism for increasing the drawbar pull, located at the periphery of the wheel, is professionally called a boot. Because of better adhesion with a pad, it allows us to better use the machine power and thus increase its drawbar pull on the soil. In Figure 3, boots consist of the following parts:

Figure 3: Steel boots: 1 – traction strip, 2, 3 – strips, 4, 5 – clamping with two clamping screws with M10 nuts

When installing the boots on wheels, the tractor must be lifted on the corresponding wheel side. This is the main disadvantage when comparing with the previous system. It consists of two strips (2), crossed according to the perimeter of the wheel tread. It is the perimeter measured on an unloaded tyre. At the end of rims, there are welded two perpendicular strips (3) with two holes for fastening screws (4). Traction strips (1), bent at an angle of 120°, are welded to rims vertically, in symmetrical intervals.

Figure 4: Wheels equipped with auto-extensible blades and steel boots mounted to the tractor rear wheels

Tractor loading during the measurement of drawbar pull

The drawbar pull measurement of the tractor Mini 070 is performed by means of a tensometric force sensor marked as 150 EMS, as shown in Figure 5. The force sensor is connected between the loading tractor T4K10 and the measured tractor MINI 070 through a chain, Figure 6. Measurements were performed on two surfaces – the soil and grass. A digital recording unit HMG 2020 (Hydac GmbG, Germany) was used to record electrical signals from the force sensor. A description of HMG 2020 is presented in the work published by Kosiba et al. (2011).

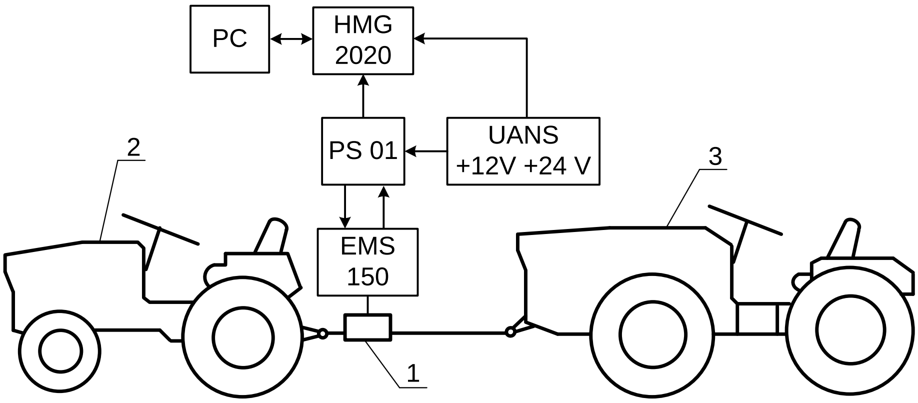

Figure 5: Connection diagram of drawbar pull measurement of Mini 070

1 – drawbar pull sensor EMS 150, 2 – measured tractor Mini 070, 3 – loading tractor T4K10, HMG 2020 – digital recording device, UANS – universal battery source, PC – personal computer, PS 01 – junction box

Figure 6: Measurement of drawbar pull

The drawbar pull measurement of Mini 070 is arranged chronologically in the following points:

- connecting the tractor T4K10 to the MINI 070’ s hitch by the chain, which is connected to the force sensor of drawbar pull;

- preparing the measuring device HMG 2020 for measuring;

- measuring the maximum drawbar pull while loading the tractor T4 K10 up to a 100 % slip of the Mini 070’ s driving wheels;

- measurements carried out on the soil and grass, with different versions of driving wheels (tyres, wheels equipped with auto-extensible blades, steel boots) in the first and second gear.

Table 1: Specifications of the tractor Mini 070

Year of manufacture	1989	
Construction weight	310 kg	
Driving speed at rated engine speed 3,600 rpm	1st gear	1.53 km*h^{-1}
	2nd gear	2.72 km*h^{-1}
	3rd gear	4.96 km*h^{-1}
	4th gear	14.40 km*h^{-1}
Clutch	Dry, single plate, with direct mechanical shutoff	
Engine	Petrol, four-stroke, air-cooled Briggs & Stratton	
	Number of cylinders	1
	Displacement	400 cm^3
	Max. performance / rotation speed	8 kW / 3,600 rpm

Table 2: Specifications of the tractor T4K10

Year of manufacture	1966	
Construction weight	820 kg	
Engine	Two-stroke, air-cooled diesel	
	Number of cylinders	1
	Displacement	900 cm^3
	Max. performance	10 kW

Results and Discussion

The obtained results presented in Figure 7 show the curve of the maximum drawbar pull in the first gear on the soil and grass. Figure 7 shows only the selected time period of two seconds, which represents an increase in drawbar pull and the culmination of its maximum value. The total measurement time of drawbar pull was 20 seconds. Drawbar pull begins when all measurements are at about the same level of 1,000 N corresponding to the pulling of released T4K10 in neutral. In the field of increased drawbar pull, there were recorded different characteristics given by the type of base and type of device to improve the transmission of drawbar pull. The highest oscillation of drawbar pull was observed when using the wheel equipped with auto-extensible blades on a grassy surface. In this case, the short-term increase of drawbar pull is given by the engagement of blades on a firmer grassy surface as opposed to the field surface. In case of tyres and steel boots, the increase of drawbar pull is smoother due to a more uniform arrangement of tyre contact surfaces and of boots' blades on the wheel circumference.

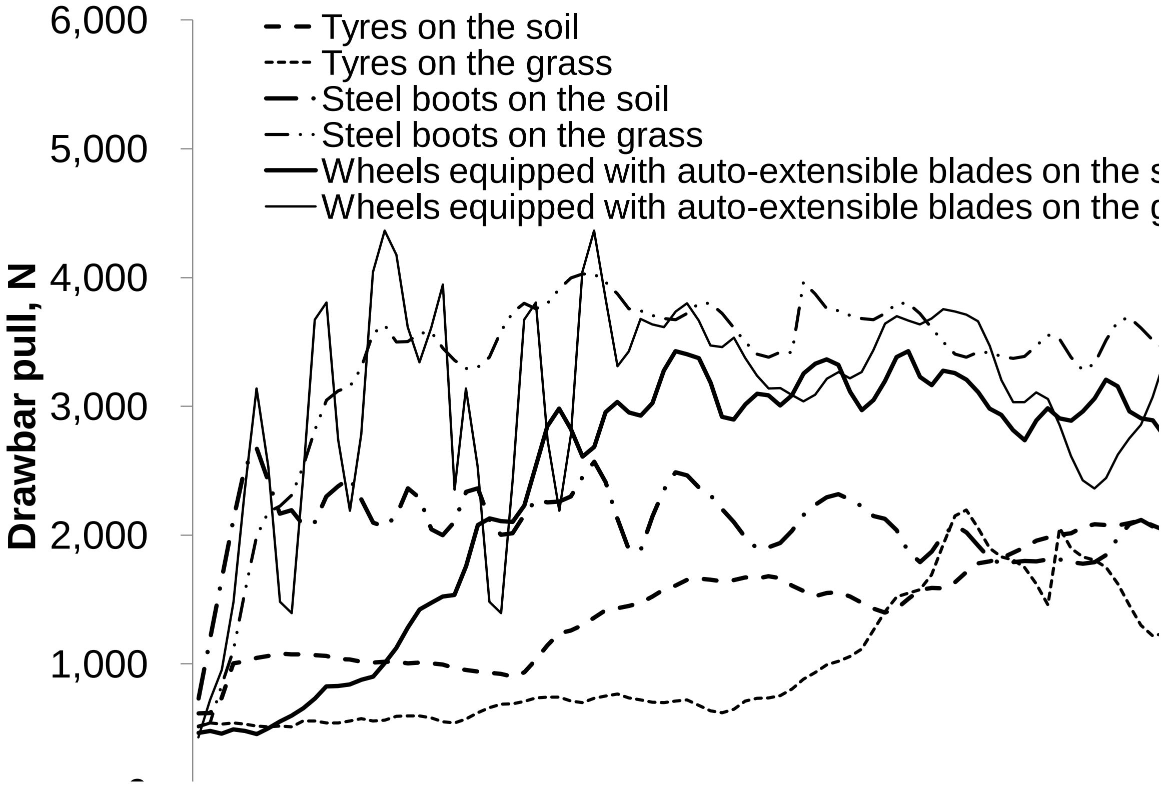

Figure 7: Course of drawbar pull of Mini 070 on the soil and grass

The obtained results presented in Figure 8 and 9 show the increase in drawbar pull of the wheel equipped with auto-extensible blades and steel boots in comparison with tyres. The values clearly show the increase of drawbar pull of both variants of metal wheels on average by 70 % in comparison with tyres. The tractor reached a higher drawbar pull in the second gear in all variants of driving wheels on average by 3 %. This increase is possible only on the soil and grass where engine power is better distributed on a yielding surface. In the first gear, the engine has a sufficient power for slipping of drive wheels; however, in this condition, it shows a lower drawbar pull in all cases. The maximum drawbar pull was achieved on the soil in case of steel boots and on the grass in case of auto-extensible blades. These findings confirm the theoretical basis for traction of wheel on a yielding surface. The higher the stiffness of the base, the higher drawbar pull is reached by the tractor when using the blade wheel, which needs a higher soil stiffness next to the wheel for reaching a higher drawbar pull. On the contrary, on the soil that is less compacted than a grassy surface, the tractor reaches higher drawbar pull with steel boots.

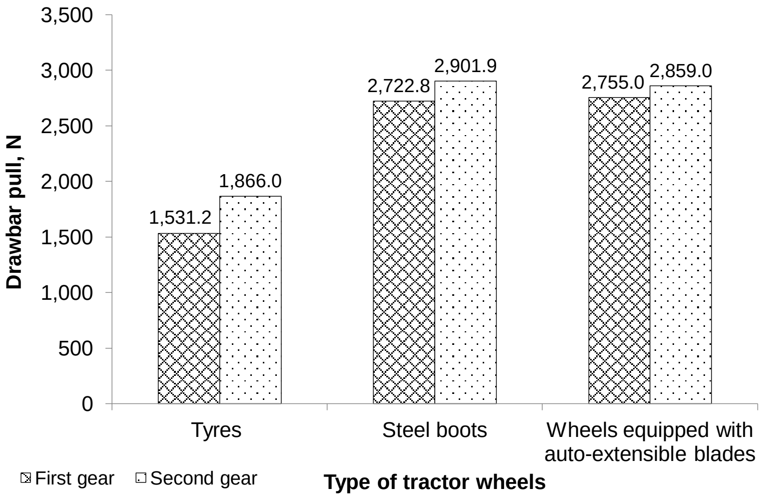

Figure 8: Maximum values of drawbar pull of Mini 070 on the soil

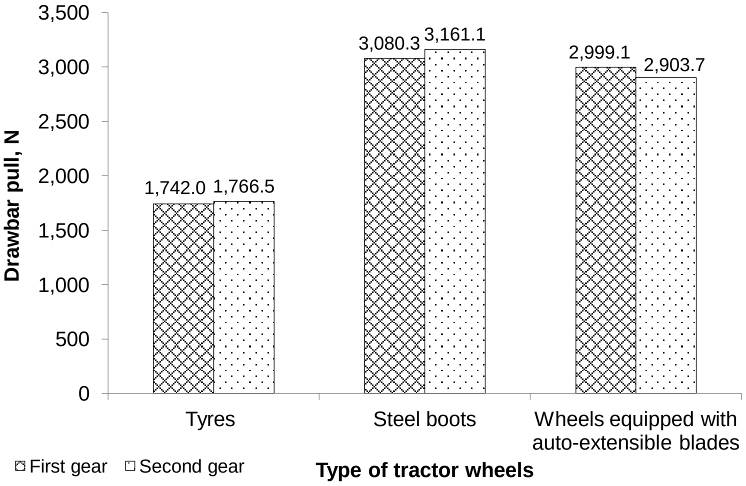

Figure 9: Maximum values of drawbar pull of Mini 070 on the grass

Conclusion

Measurements were carried out in October 2012, at an average soil moisture of 22 % on the soil type *Chernozem*, with an average bulk density of 1.33 g*cm^{-3}. The soil was after harvesting of cucumbers and was relatively wet despite a dry weather. The measurement of drawbar pull was performed by the measuring and recording equipment Hydac 2020. The measurement of drawbar pull, or the loading of the small tractor Mini 070, was performed by T4K10, by gradually loading up to 100 % slip of driving wheels, as shown in Figure 5 and 6. According to the already presented results, it can be concluded that the cheapest and most efficient increase of drawbar pull is by using steel boots manufactured by various companies. At the same time, there are two factors representing disadvantages, the first that steel boots have almost no self-cleaning ability and are muddy relatively fast, and the second one that when passing over a hard surface, there is a high incidence of failures of the transmission system of small tractors, and therefore they should be removed on the field already. In the second variant, which can be used even for heavier tractors, a benefit is in an improved self-cleaning ability of wheel blades and that they can be folded easily by riding backwards. Following the completion of work and upon arrival at yard, they must be thoroughly cleaned, preferably by water pressure, because drying clay may cause no-tipping of blades. Finally, the fact that speaks in favour of boots should be noted. Although V-shaped blades had the same traction area as extensible blades, with wheels equipped with extensible blades also tyres were engaged and still had comparable drawbar pull results.

At the present, the trend of tractor design is aimed at high universality and possibility to equip the tractor with various attachments (Hujo et al., 2012). Steel boots and wheels equipped with auto-extensible blades can be manufactured for various types of tractors wheels.

Acknowledgements

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