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TECHNICAL PARAMETERS DYNAMICS OF WOODY 110 CABLE SKIDDER WITHIN THE RANGE OF STOPPING DUE TO OVERLOAD IN UPHILL WOOD SKIDDING

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Abstract

The article deals with uphill wood skidding with WOODY 110 skidder and the changes taking place in technical parameters: slip, torque, tractive forces, and weight distribution of a loaded tractor in the last three meters of skidding, which is defined as a range of stopping due to overload. The test was performed on a concave skid trail, where tractor loaded with 8 meter long fir logs stopped at the 32% incline. It stopped somewhat later when skidding with butt-end forward in comparison to skidding with top-end forward. The load weight with butt-end forward was 31.69 kN, whereas with top-end forward it weighed 33.53 kN. The measured speeds showed minute changes until the last meter, but decreased swiftly after stopping. Regarding some technical parameters, there were almost no changes at the end of stopping, two exceptions being the slip, which increased in the range of stopping, and the forward torque, which decreased in this range. The results showed that the hydrostatic transmission was efficient, considering that in a relatively well-controlled slip (the slip values increase only in the last three meters, which approximately equals the half of tractor's length) there was less ground damage.

Key words: cable skidder, slip, torque, speed, uphill skidding

DINAMIKA TEHNIČNIH PARAMETROV TRAKTORJA WOODY 110 V OBMOČJU ZAUSTAVLJANJA ZARADI PREOBREMENITVE PRI VLAČENJU LESA NAVZGOR

Izvleček

Članek obravnava vlačenje lesa z zgibnim traktorjem WOODY 110 navzgor, in sicer spremembe tehničnih parametrov: zdrsa, navora, vlečne sile in razporeditve teže traktorja z bremenom v zadnjih treh metrih vlačenja, ki smo ga imenovali območje ustavljanja zaradi preobremenitve. Poskus je potekal na konkavni vlaki, kjer se je traktor, ki je bil obremenjen s štirimi osemmetrskimi jelovimi hlodi, zaustavil pri naklonu 32 %, ko je vlačil les z debelim koncem naprej, in nekaj prej, ko je vlačil les s tankim koncem naprej. Breme je pri vlačenju z debelim koncem naprej tehtalo 31,69 kN, pri tankem koncu naprej pa 33,53 kN. Merjene hitrosti so skoraj do zadnjega metra pokazale majhne spremembe, nato pa so ob zaustavitvi hitro upadle. Pri nekaterih tehničnih parametrih prav tako skoraj do konca zaustavitve ne prihaja do bistvenih sprememb. Izjema je zdrs, ki v območju ustavljanja naraste, in navor spredaj, ki v tem območju upade. Rezultati kažejo, da je hidrostatski prenos učinkovit, saj z razmeroma dobro kontroliranim zdrsom (vrednosti zdrsa narastejo šele v zadnjih treh metrih, kar je enako približno polovici dolžine traktorja) prispevajo k manjšim poškodbam tal.

Ključne besede: zgibni traktor, zdrs, navor, hitrost, vlačenje lesa navzgor

INTRODUCTION
UVOD

After the early period of introducing adjusted agricultural tractors (KRIVEC, 1967), there has been a great improvement made in Slovenia after 1970, with the introduction of cable skidders. In the beginning, they often had single drum winch, but they were soon replaced by cable skidders with double drum winches (KRIVEC, 1979). The domestic machine industry adapted itself to the market possibilities and demands. Apart from agricultural tractors, the silvicultural skidders were developed in local workshops as well. Tractors used today in forest work differ very much according to their technical features. The difference is mostly in size, weight, engine power, forestry upgrade, and transmission of tractive wheel forces to the forest ground (KOŠIR, 1997, KLOBUČAR, KOŠIR, 1999, TOMAŠIĆ, 2006). Due to the above-mentioned differences, they are appropriate for work in various working and social conditions (REBULA, KOŠIR, 1988). This research focuses on Woody 110 cable skidder, which is suitable for work in difficult working conditions and has already been described in expert and scientific literature (KOŠIR, 1997, KOŠIR, LIPOGLAVŠEK, 1999, KOŠIR, 2000). Many viewpoints of studying this tractor have also been published, e.g. measuring methods description or time study (MARENČE, 2000, KOŠIR, KRČ, 2000), but the tractor was on the whole best presented in the PhD thesis (MARENČE, 2005).

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In many previous studies (SEVER 1980, 1984, MARENČE 2005, MARENČE, KOŠIR 2006), the values of numerous technical parameters, their features and interconnections, arising in different working conditions, have been studied. The majority of previous research projects were based mainly on comparisons of technical parameter values, at work in different working conditions – it was established that the longitudinal incline of skid trail and the load size had the biggest influence on work difficulty. Another point of interest were also the interconnections between the incline and load, focused mainly on the heaviest possible load at certain skid trail incline (KOŠIR, MARENČE, 2007) and on skid trail incline at the determined load size.

In none of the previous studies, a more detailed analysis of measured technical parameters reactions in the most extreme working conditions has been carried out (MARENČE, 2005) – i.e. at the time when tractor cannot move the load due to too extreme operating demands. In the test, working conditions were represented by the incline and skid trail surface (muddiness, rockiness, humidity, friction coefficient). During the test, the skid road surface did not alter, therefore the reason for differences between the individual tractor stops was too great longitudinal terrain incline, as well as the load size and orientation. In this research, the point of interest was the action just before the tractor stopped, in particular the relations between tractive force on the surface, tractive force on the winch, and wheel slip. Therefore, the point of interest was the actions in the last few meters of skidding on the skid trail, when the tractor speed was decreasing and the tractor finally stopped. In this article, not only the average values of certain longer sections, already included in the previous studies of this research field (HORVAT 1996, MARENČE 2005, KOŠIR et al. 2005, ŠUŠNJAR 2005), are analysed, but also the dynamics of working with the machine at its maximum capacity. The answers to these kind of questions are not important only from the viewpoint of establishing the capacity or utilization of different working means in extreme working conditions, but also as a whole representation of technical tractor analysis in uphill load skidding. These findings are especially interesting for the working machine, chosen in this research, which should be, due to hydrostatic transmission more environmental-friendly (KOŠIR, 2000). It is important to know whether its technical parameters are acceptable to the environment also in the most difficult working conditions, i.e. just before the stopping due to overload.

METHODS
METODE

Woody 110 tractor, manufactured by VILPO LLC, special forest cable skidder and is used for wood skidding in most difficult working conditions. The typical working area of this machine are steep or otherwise difficult skid trails, heavy loads and longer skidding and bunching distances. In the last decade, many Slovenian forestry companies and a number of companies abroad efficiently have used this type of machine

Fig. 1: Woody 110 tractor at a standstill, with the equipment for measuring technical parameters and the fifth wheel

Slika 1: Traktor Woody 110 ob zaustavitvi z opremo za merjenje tehničnih parametrov in petim kolesom in forest production. It is its technical features, already described during previous research (KOŠIR 1997, 2000, KOŠIR, LIPOGLAVŠEK 1999), and by which it differentiates from previous forestry mechanization in Slovenia, that make it a suitable subject of our research (Figure 1). Design engineers of the tractor wished to produce a small but powerful tractor, which would be able to perform in difficult terrain (especially inclines, ground capacity) and stand (prevalent thinning) conditions. With its 7 tons of weight, 220 cm width, 52 cm clearance, and possibility of using different pneumatic tyres, WOODY 110 is a good choice. The remotely controlled winch and the possibility of total remote control of the tractor only increase the usability of this machine.

On the typical Karst limestone terrain, the skid trail was 200 m long and of a concave shape, with the biggest incline of 43%. It was divided with profiles – according to the incline – into several sections. The tractor stopped at the part of the skid trail with an average incline of 32 %. The last three meters of the tractor's gradual stopping before its complete stop were named the range of stopping. When analysing data, the main attention was paid to the skidding process of the last three meters. After the last profile was passed, the tractor with the butt-end of the load forward drove for another 16 m, whereas with the opposite load orientation, the distance was 7 m. On these two short skid trail sections, all the measurements were analysed.

On this short section – range of stopping – several parameters were analysed: momentary tractor moving speed, torque on the wheels, horizontal tractive force on the winch, weight distribution on the axles, and slip on the wheels. Due to a more detailed analysis and data comparison, the section was divided into one meter long parts – thus the action in the last stage of skidding, when the gradual decrease of machine speed and its final stop took place owing to the too difficult working conditions, was presented.

In this research, only the skidding of 4 m^3 load was included. Nevertheless, the different load orientations (with the butt-end and top-end forward), and uphill skidding were also considered. Different load orientations were exempted from the research for the purpose of their reciprocal comparison, considering that this had already been done during previous research (MARENČE, KOŠIR, 2006), thus the aim was to use two uphill skidding examples to show the changes of technical parameters of the tractor, which would likely appear in conditions of this particular kind. The load consisted of four 8 meters long fir logs with bark.

The technical parameters data were recorded by applying the measuring chain and portable computer. The required equipment was installed on the tractor. The detailed description of data accumulation and the measurement equipment has already been described (MARENČE 2000, JEJČIČ et al. 2001, MARENČE, 2005).

The fifth wheel was applied for establishing the distance driven on the whole skid trail as well as this short section (Figure 2). In general, the appliance of the fifth wheel for measuring the driven distance on forest skid trails is rather dubious (MARENČE 2005). This kind of measurement can be especially difficult and incorrect owing to the uneven skid road sections; in these cases, the fifth wheel, due to its own construction, does not follow the center of the skid road width,

Fig. 2: Fifth wheel used on the front part of the tractor

Slika 2: Peto kolo, nameščeno na prednjem delu traktorja and thus error in measurements can occur. In our example, the measured distance was short and straight – the comparison of the same distance measured with a meter shows that use of the fifth wheel for measuring the distance driven in such condition was accurate and correct enough.

RESULTS
REZULTATI

In the analysis of technical parameters on this short skidding section we tried to establish whether there were any changes of parameters at the stage, when the tractor totally stopped due to too difficult working conditions. The analysed values are shown in the average estimates calculated separately for each driven meter of this section.

The moving speed of the tractor at this section of stopping gradually decreased, due to great – extreme longitudinal incline (Figure 3). The moving speed decrease tendency was present throughout the whole drive in this section, but it was more explicit in the last two meters, when the speed greatly decreased, and the tractor stopped.

When driving uphill and with the longitudinal incline of 32 % with butt-end forward, the average tractor speed was around 3 km/h at the beginning of the measured range. When the momentary tractor moving speed is decreasing until a total stop, the values of technical parameters are changing. Apart from the moments and tractive forces, the slip is also important, showing the effective force transmission from the wheels to the ground surface (ŠUŠNJAR, 2005), and thus the damage of the ground, which is at the tractor stopping intere-

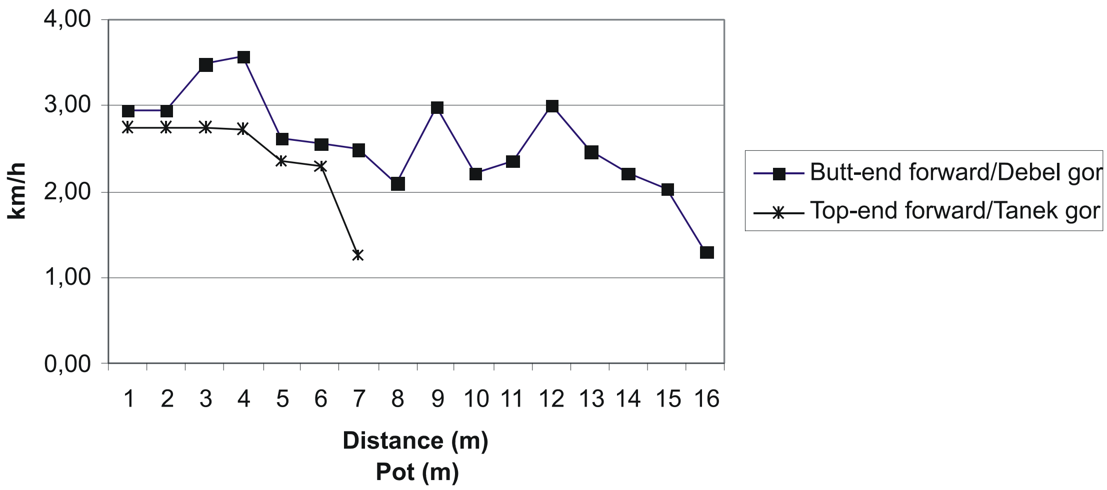

Fig. 3: Driving speed decrease before stopping

Slika 3: Zmanjševanje hitrosti vožnje pred zaustavitvijo

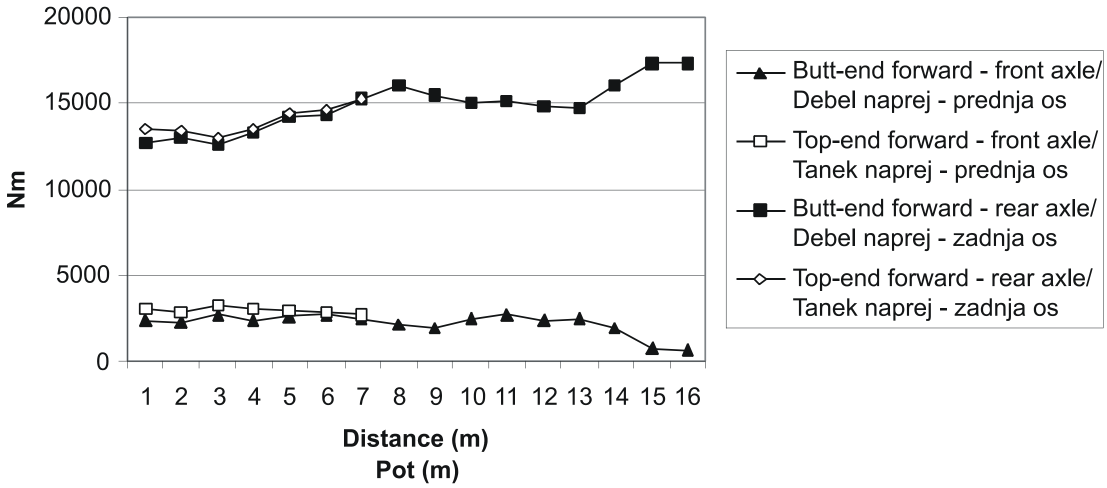

Fig. 4: Torque on wheels during skidding with butt or top-end forward

Slika 4: Navor na kolesih pri vlačenju z debelim in tankim koncem naprej

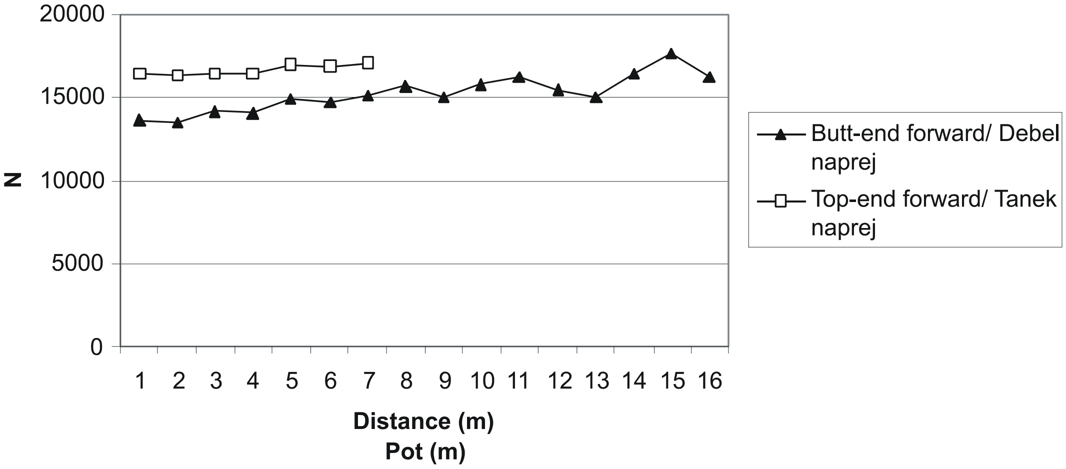

Fig. 5: Horizontal tractive force on the winch

Slika 5: Horizontalna vlečna sila na vitlu

sting, unknown, but important. Similar findings were established for the load orientation with the top-end forward. It has to be pointed out that due to different load orientation, but still of the same load size, the tractor stopping occurred earlier when skidding top-end forward. With top-end load orientation, the tractor stopped already at the 7th m of the driven profile 10 (in case of butt-end orientation only after the 16th meter). The feature of load orientation influence on skidding alone was studied during previous research, and thus it is not in the focus of this analysis (KOŠIR, MARENČE, 2007).

Torque on the wheels, when skidding with the butt-end forward is shown for the front and rear axle separately. Figure 4 shows that torque values on the front axle are decreasing, and increasing on the rear. These changes are minimal, but the biggest change is noted only in the last three meters of skidding. The torque on both axles, with top-end forward, changed minimally at this section. Similar to the skidding with butt-end forward, the noted change is decreasing on the front axle, and increasing on the rear. The changes are more evident during skidding with butt-end forward (Figure 4).

The horizontal tractive force on the winch, which carried the load when skidding uphill, did not change essentially; it was constantly increasing at a very low rate, but in the last meter, just before stopping, its value decreased (Figure 5). The force is expected to decrease at the end of skidding – the tension in the steel chain is in most cases retained, due to stop the tractive force is actually not needed, the load moving speed falls towards zero. The horizontal tractive force on the chain, when skidding with top-end forward, also did not change essentially, as did not when the tractor stopped (Figure 5). There is a greater horizontal tractive force required when skidding with top-end forward, as the minor part of the load weight is transferred to the rear part of the tractor.

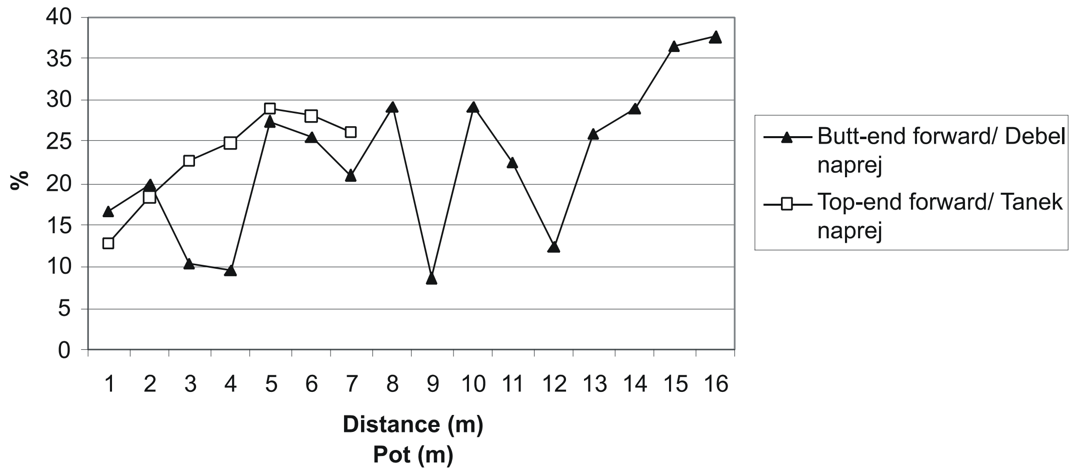

Fig. 6: Slip during skidding with both load orientations

Slika 6: Zdrs pri vlačenju z obema orientacijama bremena

Due to the importance of efficient force transmission from wheels to the ground, out of all technical parameters, the greatest attention in this research is focused on the **slip**. Due to its damaging effect, in this case on the soils, the slip has a bad influence on the environment (MACMILLAN 2002, MARENČE 2005). The numerous studies (JEJČIČ 2000 a, b, MARENČE, KOŠIR 2006) indicate that the working machinery with hydrostatic tractive force transmission is more suitable for the forest work, due to their smaller slips. Considerable data on uphill load skidding are at hand (MARENČE 2005, ŠUŠNJAR 2005). But there is no information on what is happening in tractor wheel - forest ground relation just before the tractor stops or whether the slip values essentially change at the extreme capacity of the machine.

The analysis indicates that at the gradual slip increase the tractor speed decreased. This increasing was small and more distinctive just before the machine stopped (Figure 6). The most important finding of the data analysis is the fact that during the final range of stopping, the essentially longer slip of wheels did not occur. In this situation, mostly due to hydrostatic transmissions and the appropriate electronic settings of tractor parameters, the slip on wheels did not occur. Great and sudden slip is usually a case with tractors using the standard mechanic transmission. The maximal slip was in this case around 38%. It can be seen that when skidding with top-end forward the slip increase caused speed decrease. During the last meters, compared to butt-end forward, it did not increase, but remained at the same level or even decreased slightly (Figure 6). The conclusion of analysis indicates that at the time when tractor stops, the slip is not essentially higher also when skidding with top-end forward. Hydrostatic transmission and machine settings prevent the wheels from rotating when tractor is not moving. Due to overload, the tractor simply stops. The slip does not significantly increase just before tractor stopping what could cause damage to the forest soils with lateral forces of rubber pneumatic profiles or chains. Excessive forces are, besides ground levelling due to pressure, the major reason for ground damages during wood skidding (DUNCAN, 2006).

Weight distribution of the tractor is on the horizontal surface and without load 62 % on the front axle and 38 % on the rear. When skidding on the slope and with load, this proportion changes drastically (KOŠIR *et al*., 2005), but it is a good measure for tractor stability (the balance is when front axle load equals zero during uphill skidding). In longitudinal direction, this stability is rarely jeopardized, as opposed to lateral stability. Lateral skid trail inclines were not included in our study, considering that the test skid trail was considered in this respect safe. In the range of stopping, the tractor stability was not essentially changed. The data indicate (Figure 7) that despite the great longitudinal incline of the skid trail around 20 % of total weight remained on the front axle of the tractor. The size of the load on the front axle is the result of the weight of the tractor and load, which is on its front part lifted, thus particularly burdening the rear part of the tractor. The weight distribution between the front and rear axles remained approximately the same, regardless of load orientation. The stopping occurred at the longitudinal skid trail incline of 32 %. When stopped, less than 20 % of the tractor weight with load remained on the front axle (Figure 7).

The primary purpose of our research was to analyse individual technical parameters changing during skidding work, where stopping of the tractor occurred, i.e. the range of stopping. The described analysis was by itself explicit enough,

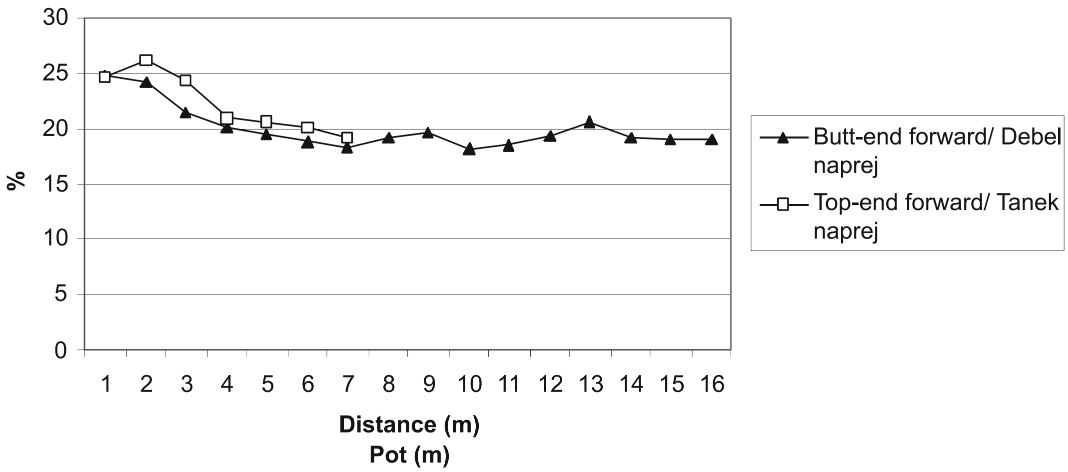

Fig. 7: Total weight distribution on front axle

Slika 7: Razpored skupne teže na prednji osi traktorja

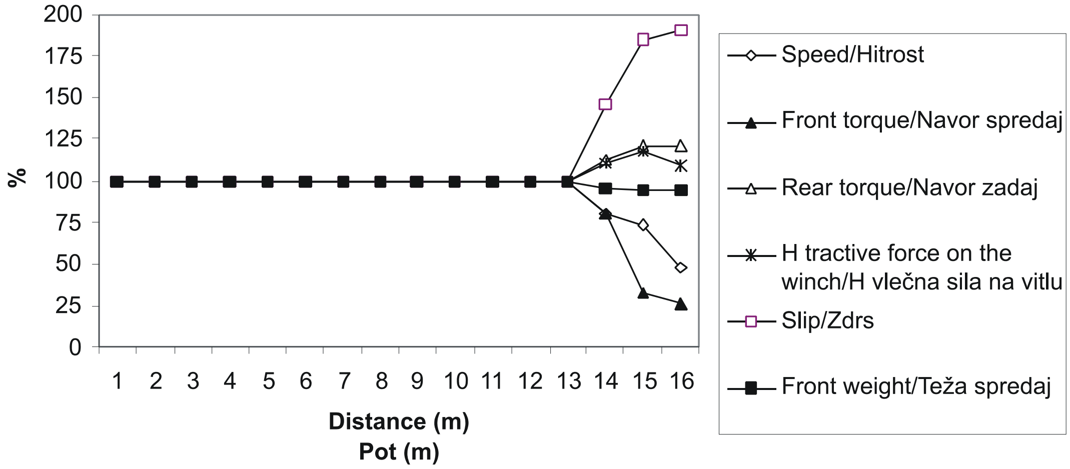

Fig. 8: Measured parameter values when skidding uphill with butt-end forward

Slika 8: Vrednosti merjenih parametrov pri vlačenju navzgor z debelim koncem naprej

but the point was to show the changes when dealing with technical parameters more simply on the same picture. The measured distance was thus divided into two parts:

1. the first part of the section, where the estimation was stated that essential changes with the majority of parameters had not occurred yet – variability of parameters values did not have specific tendency;
2. the second part clearly showed that greater differences occurred in the majority of measured technical parameters – range of stopping due to overload.

It was proven that the second part was around three meters long, which was less than the circumference of the tractor wheel - the distance of one wheel turn. With the purpose of comparing these two sections between themselves, the arithmetic means of values for all measured parameters were calculated for the first part of skidding, and then compared with the range of stopping values at the end of skidding and machine stopping. The last section of the skid trail – the range of stopping – was in case of both load orientations three meters long. In this section of the skid road, the greatest differences occurred. These were in the final stage of skidding conveyed in percents of deviation from average estimate from the first part, shown in Figures 8 and 9 with 100%.

The speeds of tractor on the skid trail indicate that in such difficult working conditions, expectedly, the speeds of uphill skidding are relatively small and that they are extremely decreased only just before stopping. Also in this last part, there are no essential changes in some technical parameters.

This is especially true for tractive force on the tractor's winch – it hardly changes at all. The longitudinal skid trail incline also hardly changes at the measured section, meaning

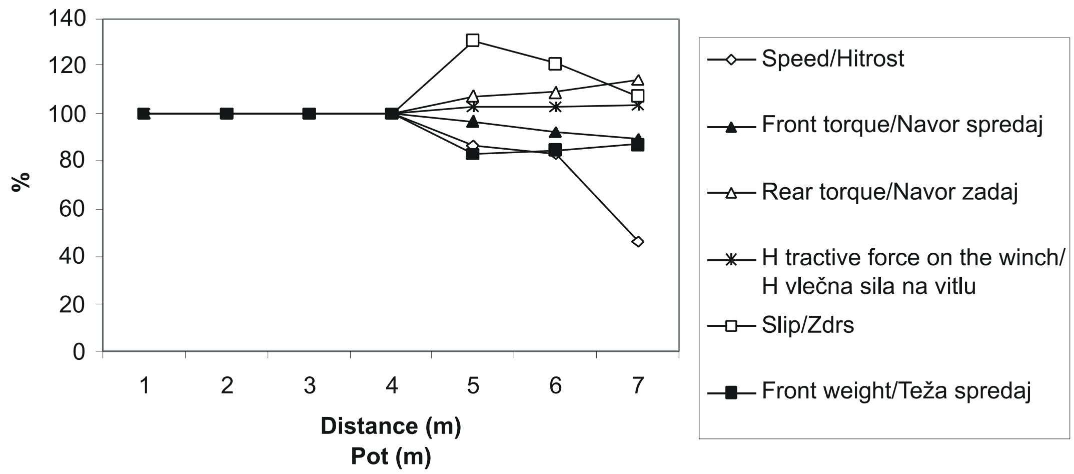

Fig. 9: Measured parameter values when skidding uphill with top-end forward

Slika 9: Vrednosti merjenih parametrov pri vlačenju navzgor s tankim koncem naprej that load orientation according to skidding means and skid trail is mostly constant as well. Just before stopping, the tractive force increased a little, and fell to zero when stopping.

Weight distribution between front and rear tractor axles alters only during different incline and load size and orientation (MARENČE 2005, KOŠIR, MARENČE, 2005). The measured skid trail section is short, thus the incline changes relatively little as well, which also holds true for weight distribution. According to the configuration of the skid trail, it would be expected that a gradual weight decrease on the front axle would occur. This has happened, but very minutely at the range of stopping due to its shortness. In our case, 20 % of weight remains on the front axle during stopping. Thus it has to be highlighted that when using such machine in very difficult working conditions, a total unloading of the tractor's front during stopping never occurs. Therefore, when using this tractor in the too steep terrain the tractor driver safety is not jeopardized due to lower stability.

The greatest differences during the extreme working conditions when skidding with butt-end forward occur during the torque and consequent wheel slip (Figure 8). At the end of skidding, a slight torque increase on the rear wheels occurs; at the same time, the torque on front wheels is greatly decreased. With such longitudinal incline and the load, which is lifted from the ground with its front part, the tractor carries much more load on its rear axle. Due to a better rear wheels grip, this torque can be better utilized. The same action – although less evident – is seen also when skidding with top-end forward.

Together with the torque, the wheel slip increases as well. It constantly increases within the range of stopping, but the main difference is seen in the last meters of skidding (Figure 8). The slip has increased during the stopping and reached the highest value at the same time. It has to be highlighted that when this type of tractor with load stops, the 100 % slip or on the spot wheel rotation never occurs, due to limited working conditions. (MARENČE 2005, MARENČE, KOŠIR 2006), as it happens to tractors using mechanic power transmission. The tractor stops due to too difficult working conditions, whereas the steering system of hydrostatic engine prevents the mere slip.

The analysis of all measured parameter values indicates that, despite the burden increase with the incline increase, the tractor is not influenced by it, until overload occurs during the last skidding meters. Then all the measured parameters fall to zero. The explanation of such functioning of the tractor's transmission shows that the hydrostatically-mechanic transmission is well adjusted and performs the tractor function and surface overload prevention.

DISCUSSION
RAZPRAVA

Until now we have performed tests mostly for agricultural, and rarely for forestry tractors. Although the theory of vehicle movement (also for military purposes) is well developed (BEKKER, 1960), similar studies are also rare in the scope of foreign scientific research. With regard to forestry machines, environmental care is given particular attention, i.e. studies of influence on forest soils (PORŠINSKY, 2005). This article deals with the study of behaviour of the selected technical parameters in the last section of uphill skidding when the tractor is already overloaded. In these last critical seconds of movement, the hydrostatical force transmission to the ground has to show its advantage. This has been confirmed by the obtained results.

The comparison with standard mechanic drive remains an open question, and due to the fact that the comparable tractor is not at our disposal, this question will remain unanswered. Considering the fact that similar analyses of small adjusted agricultural tractors AGT 835 with mechanical and hydrostatic transmission have been carried out, the future analyses perhaps will, at least partly, answer this question after all.

The goal of these studies is often to estimate the limits of reasonable and safe usage of the working means. Is it really necessary to push the machine to its limits?

SUMMARY

The WOODY 110 cable skidder belongs to the category of cable skidders with double-drum winch, and has been in use for heavy load skidding on difficult terrains since 1970. The tractor is of Slovenian production and is used with a total remote control. The article includes some of the results that have not been published in this form to date. It deals with uphill skidding, the change of technical parameters, in particular slip, torque, tractive force, loaded tractor weight distribution just before stopping in the last three meters of skidding. This was named the range of stopping due to overload.

The test was performed on limy surface and on concave skid trail, where tractor loaded with four 8 m long fir logs (volume 4.07 and 4.13 m^3) stopped on 32% incline, while

skidding with butt-end forward, and somewhat less, when skidding with top-end forward. When skidding with butt-end forward, the load weighed 31.69 kN, whereas with top-end forward the weight was 33.53 kN.

The measured speeds did not change much until the last meter – but they constantly decreased, and swiftly decreased during stopping. Also with some other technical parameters, the essential differences did not occur almost till the end of stopping. For example, the torque slightly increased on the rear wheels, and slightly decreased on the front wheels. The exception was the slip increasing in the range of stopping. The measurements of horizontal tractive force on the winch chain, where the load was hung, showed that it was almost constant or slightly increased in the range of stopping when skidding with butt-end forward.

The analysis of the measured parameter values shows that although load increases with incline increase, the tractor is not influenced by it, until overload occurs during the last meters of skidding, or at the last turn of the wheel. Then all the measured parameters fall to zero. The explanation of such performance of the tractor's transmission indicates that the hydrostatically-mechanical transmission is well adjusted and that it performs the function of tractor and surface overload prevention. It is important as the results of various studies indicate the great responsiveness of forest ground to levelling and cross forces, transmitted from wheel ribs to the ground. With mechanical transmission, these transmissions are more difficult to control, thus causing more ground damages.

POVZETEK

Zgibni traktor WOODY 110 spada v kategorijo zgibnih traktorjev z dvobobenskim vitlom, ki so jih po letu 1970 začeli uporabljati pri spravilu težkih bremen in na težkih terenih. Traktor je domače izdelave in je v celoti daljinsko krmiljen. Članek predstavlja del rezultatov, ki doslej v tej obliki še niso bili objavljeni. Obravnava vlačenje navzgor, in sicer spremembe tehničnih parametrov: zdrsa, navora, vlečne sile in razporeditve teže traktorja z bremenom tik pred zaustavitvijo v zadnjih treh metrih vlačenja. To območje smo imenovali območje ustavljanja zaradi preobremenitve.

Poskus je potekal na apneni podlagi in na konkavni vlaki, kjer se je traktor, ki je bil obremenjen s štirimi osemmetrskimi jelovimi hlodi (prostornina 4,07 in 4,13 m^3), zaustavil pri naklonu 32 %, ko je vlačil les z debelim koncem naprej, in malenkost prej, ko ga je vlačil s tankim koncem naprej. Breme je pri vlačenju z debelim koncem naprej tehtalo 31,69 kN, pri tankem koncu naprej pa 33,53 kN.

Merjene hitrosti so skoraj do zadnjega metra pokazale zelo majhne spremembe, vendar stalno upadanje, nato pa so se ob zaustavitvi hitro zmanjšale. Pri nekaterih tehničnih parametrih prav tako skoraj do konca zaustavitve ne prihaja do bistvenih sprememb. Navor npr. nekoliko naraste na zadnjih kolesih, medtem ko na prednjih kolesih upade, vendar le za malenkost. Izjema je zdrs, ki v območju ustavljanja močneje naraste. Meritve horizontalne vlečne sile na vrvi vitla, kjer visi breme, so pokazale, da je ta skoraj konstantna oz. da pri vlačenju z debelim koncem naprej v območju ustavljanja za malenkost naraste.

Analiza izmerjenih vrednosti parametrov kaže, da traktor kljub večanju obremenitve z večanjem naklona tega ne čuti, dokler ne pride do preobremenitve v zadnjih metrih vlačenja oz. pri zadnjem obratu kolesa. Tedaj se vsi merjeni parametri zmanjšajo na nič. Razlaga takšnega vedenja traktorske transmisije kaže na to, da je hidrostatsko-mehanski prenos dobro naravnan in da opravlja funkcijo preprečevanja preobremenitev traktorja in podlage. To je pomembno zato, ker rezultati raznih študij kažejo na veliko občutljivost gozdnih tal na zbijanje in na strižne sile, ki se prek reber pnevmatik prenašajo na tla. Pri mehanskih transmisijah so ti prenosi sil na tla težje obvladljivi, zato so praviloma tudi poškodbe tal večje.

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