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Kratki znanstveni članek
Short communication

Measuring the limits of uphill timber skidding with a WOODY 110 forestry tractor

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Abstract

The paper deals with the test results of uphill skidding of wood with a WOODY 110 cable skidder. The aim of the study was to find the limits of uphill skidding in relation to load size, log orientation and the slope. The trial was prepared on a test track of concave shape in the forest and with pre-designed loads of different sizes. The loads were skidded uphill once with butt-end and then with top-end forward, until the tractor stopped because of the slope. The results show that butt-end forward skidding is more efficient. The difference between maximum loads at specific maximum slopes is almost constant (0.53 t). Proper load formation (butt-end forward if possible) is more important when skidding on steeper slopes.

Key words: forestry, tractor, skidding, maximum slope, maximum load

Merjenje mejnih sposobnosti pri spravilu lesa navzgor z gozdarskim traktorjem WOODY 110

Izvleček

V članku obravnavamo spravilo lesa navzgor s traktorjem zgibnikom WOODY 110. Cilj študije je bil iskanje mej spravila lesa navzgor v odvisnosti od velikosti kosa lesa, orientacije bremena in naklona terena. Poskus smo pripravili v gozdu na testni vlaki konkavne oblike in z vnaprej pripravljenimi bremeni. Bremena smo vlačili enkrat z debelim, enkrat s tankim koncem naprej, dokler se traktor ni zaustavil zaradi prevelikega naklona. Rezultati so pokazali, da je spravilo z debelim koncem naprej učinkovitejše. Razlika med maksimalnimi bremeni pri nekem naklonu je bila skoraj konstantna (0,53 t). Pravilno oblikovanje bremena (debeli konec naprej) je pomembnejše, kadar spravljamo les navzgor na večjih naklonih terena.

Ključne besede: *gozdarstvo, traktor, spravilo, maksimalni naklon, maksimalno breme*

1 Introduction

1 Uvod

In Slovenian forestry, tractor skidding prevails. In addition to adapted wheeled agricultural tractors, adapted tracked tractors and special forestry tractors are used. Special forestry tractors – cable skidders – are used only by various kinds of forestry enterprise, while private forest owners use only agricultural tractors of different sizes and adaptations for forest work. Among the various types of skidder, the WOODY tractor is important, since it was designed and made by the Slovenian Slovenj Gradec forestry enterprise in the eighties (KOŠIR 1997), and later reconstructed and further developed by the VILPO enterprise (KOŠIR 1999, KOŠIR / KRČ 2000). The tractor is hydrostatically driven and remote controlled (KOŠIR 2000). The latest model is the WOODY 110, and it comes in various attachment and size options. There are many in use in Switzerland, Germany and Austria, as well as nine already in use in Slovenia. The tractor was tested in 2000 and later under controlled conditions. This paper gives some of the results, which can be used for estimating the skidder's capabilities when skidding heavy loads uphill.

2 Methods

2 Metode

The purpose of the trial was to determine the limits of uphill skidding in relation to load size, log orientation and slope, under conditions as near as possible to average conditions in forestry. The basic features of the tractor are shown in Table 1. The tractor was equipped with a remote controlled winch with a pulling force of 70 kN. The whole tractor was remote controlled, but neither of these options was relevant to the trial. For test purposes, we chose a skid road of concave shape. The skid road was divided into

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14 segments on the basis of the changing slope (Table 2). In addition to other variables (JEJČIČ et. al. 2001, 2003, MARENČE 2000, ŠUŠNJAR 2005) we also measured the time and recorded the whole operation with a video camera.

The loads were composed of four 8 m long spruce logs of different sizes (Table 3) and orientations (butt-end of logs on tractor and top-end forward) - (MARENČE 2005). The loads were prepared before the trial in such a manner that the volumes, measured as usual in forestry, were as close as possible to 2, 3, 4, 5 and 6 m^3 under bark. The loads were weighed at the roadside after the trial. The tractor dragged the load in an uphill direction until it stopped because of slip or choked transmission.

Table 1: Basic features of the WOODY 110 skidder

Preglednica 1: *Osnovne značilnosti WOODY 110*

Weight / *Teža*	5500 daN
Length / *Dolžina*	5400 mm
Height / *Višina*	2750 mm
Width / *Širina*	1940 (2000)mm with tyres / *s pnevmatikami* 14.9/13-28
Motor / *Motor*	PERKINS 1004-40T, 4 cyl. cil.
Power / *Moč*	76.5kW - 2200 rev/min o/min
Tyres / *Pnevmatike*	14.9/13-28 PR12
Drive / *Pogon*	Hydrostatic – mechanical, processor control / *Hidrostatični – mehanski, procesorska kontrola*
Winch / *Vitel*	IGLAND 2H, 2x7000 daN
Velocity / *Hitrosti*	0 - 17 , 0 - 30 km/h

Table 3: Load sizes

Preglednica 3: *Velikosti bremen*

Load orientation *Lega bremena*	Under bark *Brez skorje* m^3	Weight *Teža* kN
Butt-end forward *Debeli konec naprej*	1.66	17.68
	3.11	24.30
	4.07	31.69
	5.12	39.58
	6.10	45.37
Top-end forward *Tanki konec naprej*	2.37	17.89
	2.89	23.83
	4.13	33.53
	5.15	36.33
	6.14	47.29

For the purposes of further research and possible comparisons, we also defined the friction coefficient by dragging a known load parallel to the typical surface of the skid road.

3 Results

3 Rezultati

The friction coefficient was shown to be an average of 0.54, which is comparable with other studies (MARENČE 2005, SAMSET 1979). We measured the moisture of the soil surface over the course of the experiment, but the results showed very low variability due to the sunny weather during all measurements. The low variability of the friction coefficient means that the results of the trial can be fairly well trusted.

Basic data of the trial are shown in Table 4. The first point to be made is that the tractor failed to reach the top of the skid road in all cases, but it must be stressed that the maximum slope at the top was chosen on the basis of experience as a maximum for any kind of uphill skidding

Table 2: Skid road characteristics

Preglednica 2: *Značilnosti traktorske vlake*

Profile *Profil*	Slope *Naklon*	Horizontal distance *Horizontalna razdalja*	Height difference *Višinska razlika*	Cumulative slope distance *Kumulativna poševna razdalja*	Cumulative horizontal distance *Kumulativna horizontalna razdalja*	Cumulative height difference *Kumulativna višinska razlika*
	%	m	m	m	m	m
1 - 2	10	14.2	1.4	14.3	14.2	1.4
2 - 3	19	17.4	3.3	32.0	31.6	4.7
3 - 4	10	15.1	1.5	47.2	46.7	6.2
4 - 5	14	16.4	2.3	63.8	63.2	8.5
5 - 6	17	14.8	2.5	78.8	78.0	11.1
6 - 7	12	15.8	1.9	94.7	93.8	13.0
7 - 8	24	16.1	3.9	111.3	109.9	16.8
8 - 9	20	17.6	3.5	129.2	127.5	20.3
9 - 10	25	14.5	3.6	144.1	141.9	24.0
10 - 11	32	17.1	5.5	162.1	159.0	29.4
11 - 12	31	12.6	3.9	175.3	171.7	33.3
12 - 13	42	12.3	5.2	188.6	183.9	38.5
13 - 14	42	12.7	5.3	202.4	196.6	43.8

with tractors. The results are shown in Figure 1, and can be briefly summarised. Skidding with the butt-end to the front is more successful (HORVAT 1996) with the given physical properties of the skid road.

Table 4: Stopping points of different load orientations and sizes

Preglednica 4: *Točke zaustavitve pri različnih legah bremena in naklonih vlake*

Load orientation *Lega bremena*	Load *Breme*	Maximal slope distance *Največja poševna razdalja*	Maximal slope *Največji naklon vlake*	Height difference *Višinska razlika*
	kN	m	%	m
Butt-end forward *Debeli konec naprej*	17.68	194.7	36.50	40.85
	24.30	184.3	31.50	36.01
	31.69	164.1	28.50	30.04
	39.58	153.8	22.50	26.30
	45.37	118.0	22.00	20.65
Top-end forward *Tanki konec naprej*	17.89	188.8	31.50	37.34
	23.83	183.1	31.50	35.65
	33.53	154.6	22.50	26.49
	36.33	154.1	22.50	26.37
	47.29	88.0	18.00	14.13

For practical purposes, it is essential to evaluate the difference between the two load orientations. A calculation of linear regression (Figure 1) shows that the curves are practically parallel within statistical significance. This means that the tractor is capable on average of hauling uphill 0.53 t more when the orientation is butt-end forward (0.45 t on horizontal ground, 0.61 t on very steep slope). The explanation is clear – when the butt-end is oriented toward the tractor and lifted from the ground, the vertical load of the tractor is greater, and the required horizontal force when moving is smaller. The distribution of the weight between the front and rear axles of the tractor on the horizontal surface when empty is 57%:43%. When lifting the load on the rear axle, this proportion reaches around 50%:50% (horizontal ground) or 39%:61% (on slope) - (KOŠIR / MARENČE 2005), which enable very good exploitation of the driving forces.

The relative proportion between the orientation of the maximum loads driven uphill under different slopes can also be expected to increase according to the slope, since the absolute difference remains almost constant (Figure 2).

This would in practice mean that when skidding close to maximum skid road inclinations, greater attention needs to be paid to the load orientation (SAMSET 1985). This could be achieved by proper felling of the trees, and in certain cases also through the process of wood bunching. We would suggest that when skidding uphill, the fellers should fell the trees with the top away from the skid road whenever possible. Such a practice would increase the bunching distance. On the other hand, it would increase

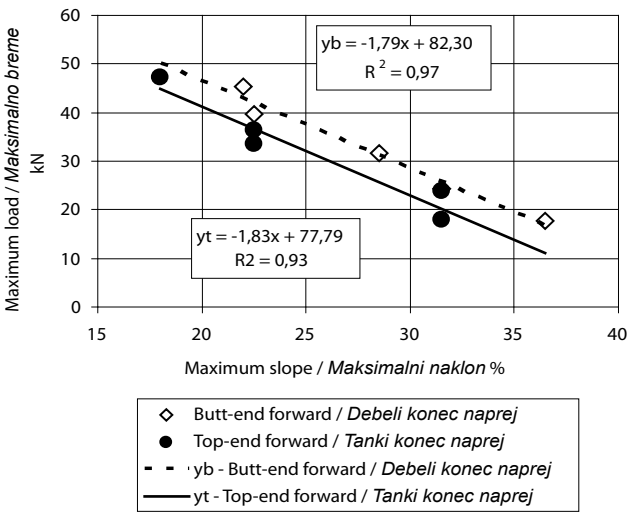

Figure 1: Maximum loads in kN when skidding uphill

Slika 1: *Maksimalna bremena v kN pri vlačenju navzgor*

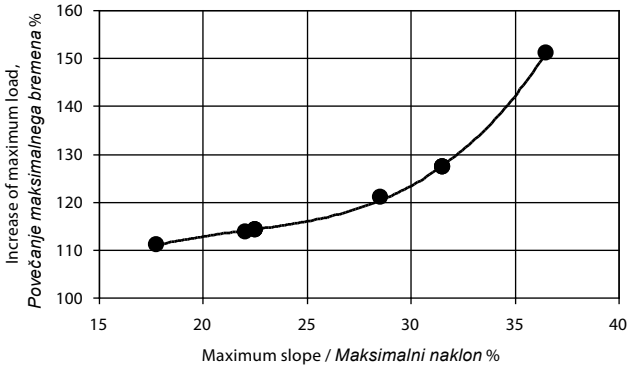

Figure 2: Relative proportion between the orientation of the loads

Slika 2: *Relativna razmerja med legama kosov lesa v bremenu*

the tractors' loads. Over short skidding distances, it would not greatly affect the overall skidding efficiency, but on extreme slopes or over greater skidding distances, this practice would obviously show better results. Proper time studies (SAMSET 1985) of actual production need to be carried out to compute the marginal distances and slopes where the load orientation is crucial.

A practical conclusion from Figure 2 is that the importance of the load orientation increases with slope when skidding uphill. This has important consequences for instructions related to directional felling performed by woodcutters. Butt-end forward can only be done when the cutter fells the tree at the proper angle away from the skid road. On the other hand, this means that the bunching distance is greater than when the cutter fells the tree toward the skid road. Which of the two is better economically, still needs to be calculated.

As already mentioned, we also measured the time of each journey. The differences between trials were not great, but when we calculated how much time was spent dragging separate loads, it was shown that load orientation had no impact on skidding speed. Larger loads need less time, and vice versa, but larger loads cannot be dragged up such steep slopes and the slope distance is similarly smaller. That also means that the dragging speed was slower with larger loads. Computed relations between speed, slope and loads of different load orientations are shown in Figure 3. Maximum speeds when skidding different load orientations are the same, but when skidding top-end forward, the maximum speed is achieved with a smaller maximum load than with butt-end forward. The speed increasingly lessens with load sizes over 30 kN. Differences between the speeds of skidding different load orientations also increase, which affects the overall performance of tractor skidding and its economy.

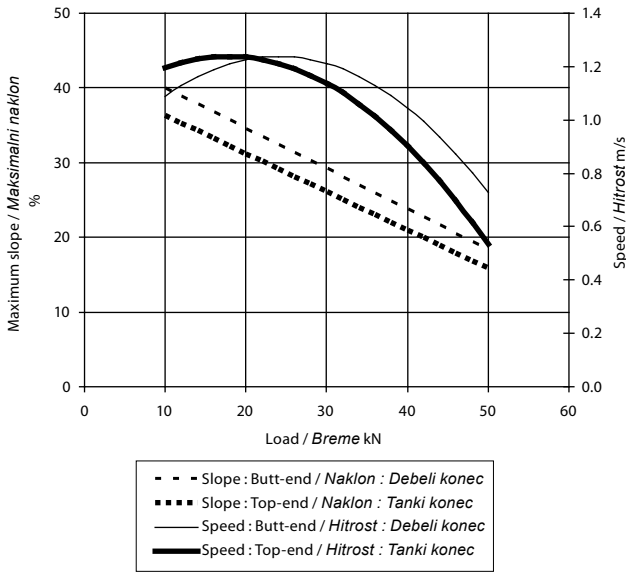

Figure 3: Speed of skidding loads uphill according to load size and corresponding maximum slope

Slika 3: *Hitrost vlačenja bremen navzgor glede na velikost bremena in odgovarjajoči največji naklon vlake*

4 Discussion

4 Razprava

Measuring tractor technical performance when skidding wood is new in Slovenian forestry. The first tests show significant differences between usual methods of skidding. The test track was chosen in a real forest and the whole experiment was oriented toward simulation of real skidding conditions. This may also have affected the results, with rather greater variability of the measured parameters. On the other hand, the experiment was designed in such a way as to achieve results that can be more easily understood by average users in forestry. Similar tests will have to be carried out in the future on other types of tractor and on different substrates in order to achieve more reliable results. It is also important to connect the results described in this article with the behaviour of other measurable variables, such as axle load, torque, slip and pulling forces (KOŠIR / MARENČE 2005, MARENČE 2005, ŠUŠNJAR 2005).

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