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ASSESSING MAXIMUM LOADS WHEN SKIDDING WOOD UPHILL WITH TRACTORS

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Abstract

The results of measuring maximum loads on different slopes when skidding uphill with WOODY 110 cable skidder and adapted 4WD agricultural tractor AGT 835 are described in the article. Both tractors are very different and were chosen for the purpose of finding the limits of uphill skidding. Besides the slope, the pre-designated loads of different sizes and log orientation (butt-end or top-end forward) have been main variables. The trial was conducted on two concave shaped test skid trails in the forest. On the lower altitudes, the skid trails had small inclination, which slowly increased to 42% on the track where WOODY 110 was tested, and 27% where AGT 835 was measured. First the loads were skidded uphill with butt-end and then with top-end forward. The purpose was to choose too heavy loads, as we wished to stop tractors due to overload, but on different slopes. The proper load formation (butt-end forward if possible) in uphill skidding is most important on steeper skid trails. The dependency between maximum load and slope is linear. The calculated theoretical maximum load on horizontal surface enables us to make similar assessment for any other tractor weighing between 2 and 7 tons. For this purpose, John Deere 6220 and LIMB 80 LUXS adapted agricultural tractors for forest use were chosen and compared. The ratio between the tractor load on different slopes and tractor weight was calculated for all four tractors included in our comparison. Apart from the weight, tractor's engine torque (power) has the decisive influence on the load size. Maximum loads on different slope categories were calculated according to different engine powers.

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

UGOTAVLJANJE MAKSIMALNIH BREMEN PRI SPRAVILU LESA S TRAKTORJI NAVZGOR

Izvleček

Članek obravnava rezultate meritev spravila navzgor z gozdarskim traktorjem WOODY 110 in prilagojenim kmetijskim traktorjem s pogonom na štiri kolesa AGT 835 z mehanskim in hidrostatsko-mehanskim pogonom. Namen analize je bilo ugotavljanje maksimalnih bremen. Oba traktorja sta zelo različna in sta bila izbrana zato, da bi ocenili zmogljivosti traktorjev pri spravilu lesa navzgor. Poleg naklona vlake so bile spremenljivke še vnaprej določene velikosti bremen in njihove orientacije (z debelim oz. tanjšim koncem naprej). Meritve so bile opravljene v gozdu na dveh testnih vlakah konkavne oblike. Vlake so imele v spodnjem delu majhen naklon, ki se je pri vlaki za WOODY 110 povzpel na 42 % in na 27 % na vlaki, kjer je bil merjen AGT 835. Bremena so bila vlečena navzgor z debelim in v drugem poskusu s tankim koncem pri traktorju. Namen je bil izbrati pretežka bremena za takšne naklone, da bi se traktor zaradi preobremenitve zaustavil pri nekem naklonu vlake. Pokazalo se je, da je pri spravilu navzgor pravilno oblikovanje bremena (če je mogoče, z debelim koncem naprej) najpomembnejše na zelo strmih vlakah. Odvisnost največjega bremena in naklona vlake je linearna. Izračunano teoretično, največje breme na horizontalni podlagi omogoča oceno za katerikoli traktor, ki tehta med 2 in 7 tonami. V ta namen smo izbrali za spravilo lesa prilagojena kmetijska traktorja John Deere 6220 in LIMB 80 LUXS. Za vse štiri traktorje smo izračunali razmerje med največjim bremenom in težo traktorja. Na velikost največjega bremena poleg teže traktorja odločilno vpliva navor (in moč) motorja, zato je za različne kategorije terena izračunana odvisnost med največjim bremenom in močjo motorja.

Ključne besede: traktor, spravilo lesa, največji naklon, največje breme

INTRODUCTION
UVOD

Since the beginning of the sixties, tractors have been the most frequent choice of timber skidding mechanisation in Slovenia. Many types, forms, adaptations and modifications have been known and developed during this period (Krivec, 1967, 1979, Rebula, Košir, 1988). Despite the fact that timber forwarding in connection with mechanised cutting is rapidly increasing, the forestry tractors still remain central means of mechanised wood extraction. In some of the already published reports (Marenče, 2000), the necessity or need for a thorough investigation of tractors, their technological testing and comparison have been described. In this article we focused on the limits of uphill skidding with tractors and combined results of field testing and theoretical calculation. The purpose of this article is to discuss a question of maximum loads and maximum slopes of tractors when skidding uphill on different slopes.

METHODS
METODE

TRACTORS IN COMPARISON
TRAKTORJI V PRIMERJAVI

The comparison is based on field testing of WOODY 110 and AGT 835 tractors. During the test we also measured – for other purposes - loads on the wheels, torque, slip and some

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Fig. 1: AGT 835 with basic forestry equipment and measuring instruments during the test

Slika 1: AGT 835 z osnovno gozdarsko opremo in merilnimi inštrumenti med testom

other technical parameters, with methods that have already been discussed (Horvat, 1996, Marenče, 2000, Jejčič et al., 2001, 2003, Šušnjar, 2005, Tomašič, 2007). Tractors from field testing could have been hardly more different: cable skidder WOODY 110 (Košir 1997, 1999, 2000, Košir, Krč, 2000) on the one hand, and adapted super light agricultural tractor AGT 835 (Marenče, 2005, Marenče, Košir, 2006) on the other hand. Both tractors are made in Slovenia: WOODY 110 comes from VILPO Ltd., while AGT 835 is manufactured by AGROMEHANIKA Co. As we compared two very different tractors, one being only conditionally applicable for forest work (Figure 1) owing to its small dimensions and light equipment, and the other expensive and purpose built forestry cable skidder (Figure 2), we could determine the limits (load in relation to the slope) where other tractors for forest use could be found. Characteristics of the tractors in comparison are shown in Table 1.

Fig. 2: WOODY 110 cable skidder during test at the stopping point

Slika 2: Zgibni traktor WOODY 110 na točki zaustavitve med testiranjem

The comparison of WOODY 110 with cable skidders for full tree skidding on world wide scale shows that WOODY is one of the smaller cable skidders. The first prototype was originally developed in the mid-eighties for the purpose of thinning and selection cuttings on steep or otherwise sensitive terrains in mountainous regions of Slovenia (Košir, 1997). We should stress that small AGT 835 is a dwarf within the scope of international market.

WOODY 110 tractor is hydrostatically driven and remotely controlled (Košir, 2000). The tractor is designed as classically steering frame skidder, but with hydrostatic-mechanical transmission and could be produced with various attachment and size options. One of them is also a possibility of complete remotely controlled tractor steering. Many are used in Slovenia, Austria, Germany and Switzerland. AGT tractors are mainly devoted to the light agricultural work and can be found on farms for light work or on small-scale farms with limited agricultural and forest work. The standardised adaptation of this tractor for skidding timber has not yet been done. For the purpose of our testing we constructed provisional adaptation with safety cabin and frame, front blade and attached winch (pulling force: 1 x 30 kN). AGT 835 tractors are manufactured with classic (mechanic) and hydrostatic-mechanical transmission. Both versions were tested.

We also put into comparison two adapted forestry tractors: the well known John Deere 6220 and the adapted tractor LIMB 80 LUXS, which is produced in Slovenia by LIMB Co. and is relatively new on the market. This tractor has been presented to international public during forestry fairs, but we have very limited experience with this new machine. Until now it has only been tested by one forestry enterprise in Slovenia, but with encouraging experience. Characteristics of the tractor are promising and within the expected range of forestry tractors in Slovenia. John Deere 6220 has been in operation since 2005, while LIMB 80 LUXS has been recently adapted for forestry use and put in operation. Until now, both tractors have been studied for the purpose of time studies only.

The adapted John Deere 6220 and LIMB 80 LUXS have both mechanical transmissions with 16 + 16 and 24 + 24 gears. Optimal working ranges of the tractor engines are (data of the producers): for AGT 835 between 2100 – 3000 rev/min, John Deere 6220 between 1200 - 2200 rev/min, LIMB 80 LUXS 1400 - 2200 rev/min and for WOODY 110 between 1400 – 2200 rev/min. AGT 835 had – for testing only – a single Krpan drum winch (1 x 3000 daN) attached, which is probably too powerful for the tractor of this size; both adapted tractors had built-in double-drummed remote-controlled Igland 6002 pronto (2 x 6000 daN) winches. In this version, WOODY 110 has double-drummed remote-controlled Igland 2H (2x7000 daN).

FIELD TESTING
TERENSKO TESTIRANJE

The basic plan was to choose the concave shape of skid trail and to drag different loads uphill until the tractor stalled owing to too heavy load. Heavier load would mean lesser slope. The relative shape of both skid trails is displayed in Figure 1. We can see that the shapes of both skid trails are mainly concave, but the skid trail for WOODY 110 was stee-

Table 1: Some technical characteristics of the tractors in comparison

Preglednica 1: Nekatere tehnične značilnosti primerjanih traktorjev

	AGT 835	John Deere 6220	LIMB 80 LUXS	WOODY 110
Weight with equipment* / *Teža z opremo** (daN)	2010	6216	4886	7006
Length / *Dolžina* (mm)	2900	5150	4456	5400
Height / *Višina* (mm)	2100	2700	2575	2750
Width / *Širina* (mm)	1250	2150	2060	1940
Engine / *Motor*	Lombardini LDW 1503	JD 4045 TL 272	Perkins 1104C-44	Perkins 1004-40T
Torque (Nm – rev/min) *Navor (Nm – obr/min)*	99 – 2100	374 – 1200	294 – 1400	403 - 1400
Power (kW – rev/min) *Moč (kW – obr/min)*	26,4 – 3000	66,0 - 2200	60,0 - 2200	76.5 - 2200
Tyres: front/rear *Gume: spredaj/zadaj*	7.50 X 16	320/70R 24 /16,9 R30	320/70R 24 /16,9 R30	14.9/13- 28 PR12

* Basic tractor, cabin (safety frame), attached or built-in winch with wire rope, front and rear blade, wheel chains, chokers.

** Osnovni traktor, kabina (varnostni lok), vgrajen ali priključen vitel z jekleno vrvjo, prednja in zadnja deska, kolesne verige, verige za vezanje.*

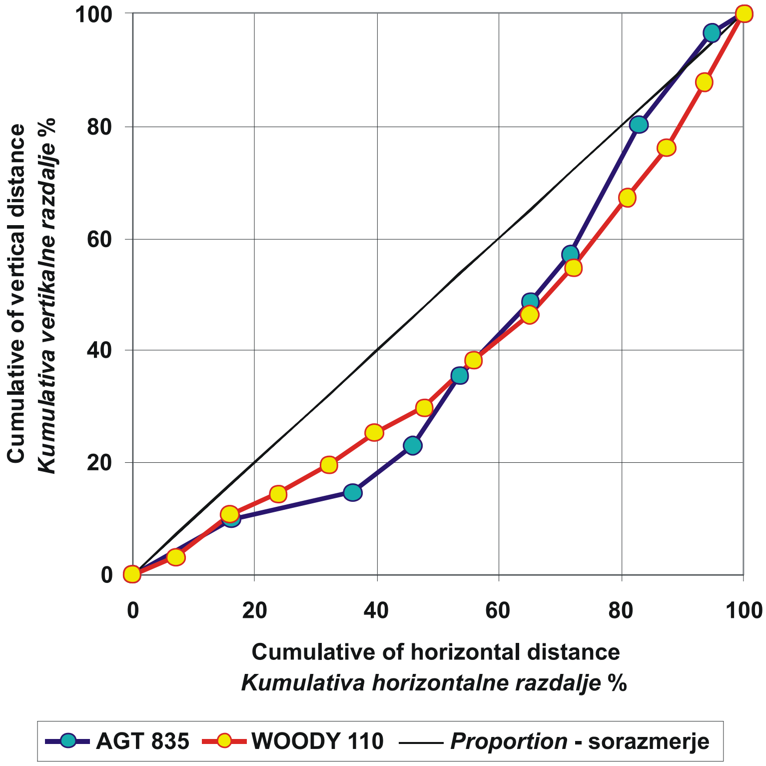

Fig. 3: Skid trails in the trial – cumulative horizontal distance and cumulative vertical distance in %

Slika 3: Vlaki v poskusu – kumulativna horizontalna in vertikalna razdalja v %

per (42%) and to our knowledge very close to the estimated working range of this type of tractors. This type of skid trail can be found in some places of the Karst area or in the Alps. The skid trail for AGT 835 was less steep and is typical of the central hilly region of the country. Each skid trail was divided in several segments (Table 2) according to the slope and surface conditions.

Loads consisted of 4 pieces of 8 m long fir logs when skidded with WOODY 110, but of different sizes and orientation (see Table 3) and one 8 m spruce log (also of different size and orientation) when skidded with AGT 835. Loads were weighed afterwards beside the truck road.

When dragging loads on rough surface, the friction coefficient is very important. Low friction coefficient can enable tractor to move heavier loads, but it can also have a significant impact on the slip (greater slip means lower pulling force). The result of the change in friction coefficient is therefore not always predictable. We measured the friction coefficient (between the skid trail surface and fir logs under bark) every testing day. The friction coefficient was not changing significantly (average 0,54) owing to the steady dry weather.

CALCULATION OF MAXIMUM LOAD
IZRAČUN NAJVEČJEGA BREMENA

According to Macmillan (2002), we calculated drawbar force on horizontal ground as a difference between horizontal force and rolling resistance (Bekker, 1960). The calculation of maximum load on horizontal ground went this way:

Table 2: Slope (%) characteristics of relative skid trail categories

Preglednica 2: Relativne kategorije odsekov vlak in nakloni (%)

	Average / *Povprečje*		Minimal / *Najmanjši*		Maximum / *Največji*	
Category / *Kategorija*	AGT 835	WOODY 110	AGT 835	WOODY 110	AGT 835	WOODY 110
Moderate uphill / *Blago nagnjeno*	6,3 < 10%	14,6 < 20%	3,0	10,0	8,0	19,9
Steep / *Strmo*	15,3 10 – 20%	24,6 20 – 30%	11,0	24,1	18,0	25,1
Very steep / *Zelo strmo*	24,0 20%<	36,8 30%<	21,0	30,8	27,0	42,2

$F_d = F_h - R$
$F_h = (2.q.T_e / D) *(1 - \delta)$

Where:
D = tyre diameter (m),
F_d = drawbar force (kN),
F_h = horizontal pulling force on the wheels (kN),
R = sum of resistances (kN).
q = transmission ratio (-),
T_e = engine torque (kNm),
δ = slip (-).

The sum of resistances in theory (Macmillan, 2002) comprises rolling resistance, skidding resistance against moving the load, resistance of transmission and slope resistance, which is in case of horizontal ground equal to 0. In our case, rolling and skidding resistance was taken into account.

$R = R_r + R_t$
$R_r = Q*f_r$ if travelling empty and
$R_r = (Q + Qb*b)*f_r$ when skidding loaded.
$R_t = 0$ when skidding empty and
$R_t = (1 - b)*Qb*f_t$ when skidding loaded.
$b = F_v / Q_b$

Where:
F_v = vertical force = part of the load hanging on the tractor (kN),
R_r = rolling resistance,
R_t = skidding resistance,
f_r = rolling resistance coefficient (f_r = 0,15),
f_t = friction coefficient (f_t = 0,54),
Q = weight of tractor (kN),
Q_b = weight of load (kN),
b = share of the load (Q_b) hanging on tractor.

During the trials, the vertical force F_v was measured and part of the load weight on tractor (b) calculated in this way. Total sum of resistances is therefore:

$$R = (Q + Qb*b)*f_r + (1 - b)*Qb*f_t$$

When tractor stops owing to too heavy loads drawbar force 0, while the theoretical pulling force with slip is equal to sum of all skidding resistances:

$F_d = 0$ and
$F_h*(1 - \delta) = R$

We can calculate theoretical load on horizontal ground from the above equations:

$$(Q + Qb*b)*f_r + (1 - b)*Qb*f_t = (2.q.T_e / D) *(1 - \delta) = F_h$$
$$Qb = (F_h - Q*f_r)/(b*f_r + (1 - b)*f_t)$$

The slip value was expressed as dependency on force applied to the ground surface. Under the same condition we therefore assumed that bigger load meant more slip. Our measurements (Marenče, 2005) truly proved this and the following regression equation for slip load dependency on even ground (average inclination ± 5%):

$$\delta = 2{,}4897*e^{3{,}5585*L}$$
R^2 = 0,7525, n = 29

Where L is a proportion between maximum theoretical pulling force, which can be achieved at optimal engine revolutions and the actual load:

$$L = Q_b / F_{hmax}$$

For this equation, data of all measurements were used, as statistically we could not have proved the differences among different tractors and load orientations. The rolling resistance coefficient was taken as an example for medium hard soils (Wong, 2001), and is slightly smaller than experimentally stated by Tomašić (2007). The transmission ratio was defined as a proportion between engine and wheel speed, and is therefore changing during the actual work. We took as an example machine speed of 3 km/h and engine speed (rev./min) according to the engine type (see Table 1) in engine speed range with maximum torque and maximum power (this range is between 1400 and 2200 rev./min for Perkins 1004-40T). We calculated pulling forces for these transmission ratios in the optimal range of each engine. Then, the maximum load (Qb) was calculated for both butt-end and top-end skidding.

RESULTS
REZULTATI

FIELD TESTING
TERENSKO TESTIRANJE

Basic results of the carried out measurements are shown in Table 3. From many combinations of dragging load uphill, only in one case the load for AGT 835 tractors was too heavy to overcome the slope. Loads and skid trail were chosen much better during the trial with WOODY 110, where tractor stopped in every movement, but with different loads and on different slopes (Table 3). Mechanical and hydrostatic-mechanical versions of AGT 835 were in this chapter treated as average of one case (differences are really small and can be neglected for the purposes of this article).

The load orientation proved to be an important factor as it has already been discussed by different authors (Samset, 1985, Horvat, 1996, Košir, Marenče, 2007). The situation with WOODY 110 is clearer, and more reliable conclusions can be drawn, while the trial with AGT 835 has shown only one comparable result.

CALCULATION RESULTS
REZULTATI IZRAČUNOV

All cases where tractors stopped owing to too heavy loads are shown in Figure 4. Loads at zero slope were not measured, but calculated as described in the previous chapter. This calculation serves as a good estimation of potential loads on even surface. The results differ slightly from the already published analysis of uphill skidding with WOODY 110 (Košir, Marenče, 2007), as the calculated theoretical values of skidding in horizontal terrain and comparison with two other tractors, which were not measured in the field, were also added to our comparison.

We see that the zero-load point for both tractors is, on average, at approximately 40% slope (AGT 835 Butt-end 43%, AGT 835 Top-end 41%, WOODY 110 Butt-end 41% and WOODY 110 Top-end 38%). This figure is close to practical experience of maximum uphill slope under similar conditions. We also see that butt-end orientation enables tractors to drag the same loads on steeper slopes or to drag heavier loads on the same slopes (Figure 4). The average difference when skidding with WOODY 110 is 6.23 kN (around 623 kg) in favour of butt-end skidding, while when skidding uphill with AGT 835 we could not prove the difference.

What these research results mean for practical work with different tractors on different skid trails etc. has already been partially discussed in the articles and papers (Samset, 1985, Košir, Marenče, 2007, Košir, et al. 2005). The possible practical use of results is easy to imagine, if the following is true:

1. first assumption is that 40% slope (with friction coefficient 0.54) is marginal (load is zero) for both tractors when skidding uphill, and
2. second assumption is that maximum load on horizontal surface is dependent upon the tractor weight and rolling

Table 3: Stopping points of different load orientations and sizes

Preglednica 3: Točke zaustavitve pri različnih velikostih in orientacijah bremen

Load orientation	AGT 835 Mechanical *AGT 835 Mehanski*			AGT 835 Hydrostatic - mechanical *AGT 835 Hidrostatsko-mehanski*			WOODY 110 Hydrostatic – mechanical *WOODY 110 Hidrostatsko-mehanski*		
	Load *Breme*	Max slope distance *Največja poševna razdalja*	Max slope *Največji naklon*	Load *Breme*	Max slope distance *Največja poševna razdalja*	Max slope *Največji naklon*	Load *Breme*	Max slope distance *Največja poševna razdalja*	Max slope *Največji naklon*
	kN	m	%	kN	m	%	kN	m	%
Butt-end forward *Debel naprej*	7,70	139,60	27	7,74	137,60	27	17.68	194.7	36.5
	6,57	No stop *Brez zaustavitve*		5,61	No stop *Brez zaustavitve*		24.30	184.3	31.5
	4,64			4,16			31.69	164.1	28.5
	2,20			2,36			39.58	153.8	22.5
							45.37	118.0	22.0
Top-end forward *Tanek naprej*	8,90	138,50	27	8,47	137,40	27	17.89	188.8	31.5
	6,74	No stop *Brez zaustavitve*		5,14	No stop *Brez zaustavitve*		23.83	183.1	31.5
	4,88			3,96			33.53	154.6	22.5
	2,56			1,92			36.33	154.1	22.5
							47.29	88.0	18.0

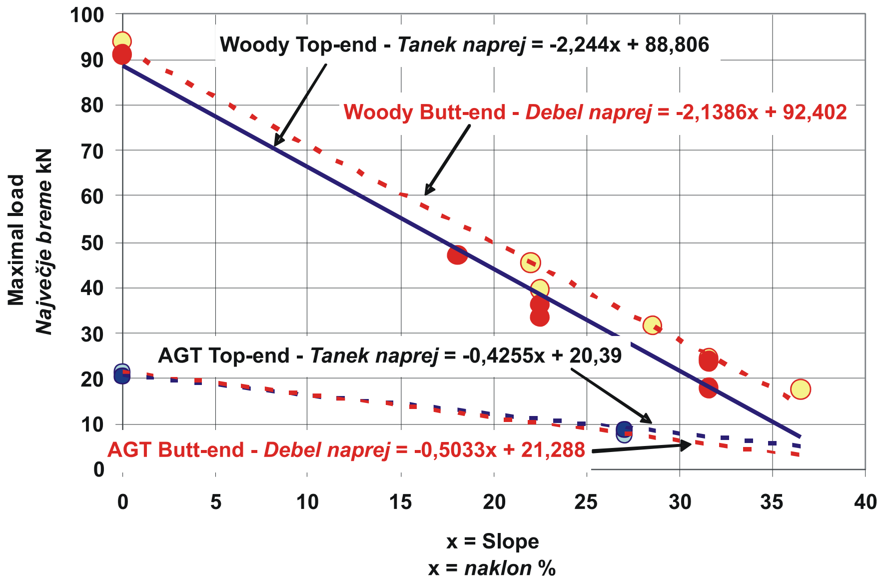

Fig. 4: Maximum loads in kN when skidding uphill with WOODY 110 and AGT 835 (average of both transmission options) – results of the trial

Slika 4: Maksimalna bremena v kN pri spravilu lesa navzgor z WOODY 110 in AGT 835 (povprečje obeh transmisij) – rezultati poskusa

resistance, machine maximum torque, transmission ratio and wheel's diameter, and

3. third assumption is that the dependence between slope and maximum load is close to linear, then we can easily calculate the behaviour of any other tractor on the slope under described conditions. Tractors were chosen (Table 1) also for the reason that they are important for Slovenian forestry today or they will probably be a subject of research in the nearest future (time studies, performance, analysis of idle times and repair etc.).

In Figure 5, the averages (but-end and top-end) for all tractors were calculated with average zero-load slope of 40% (absolute limit for average between top-end and butt-end orientations). The field between the lines for AGT 835 and WOODY 110 in Figure 5 tells us what kind of combination between tractor weight, slope and load can be expected. Obviously, a heavier tractor, as opposed to WOODY 110, would move the red curve up. We see that the choice between different sizes of tractors is broader at gentle slopes than on steep slopes, where absolute differences between tractors become small.

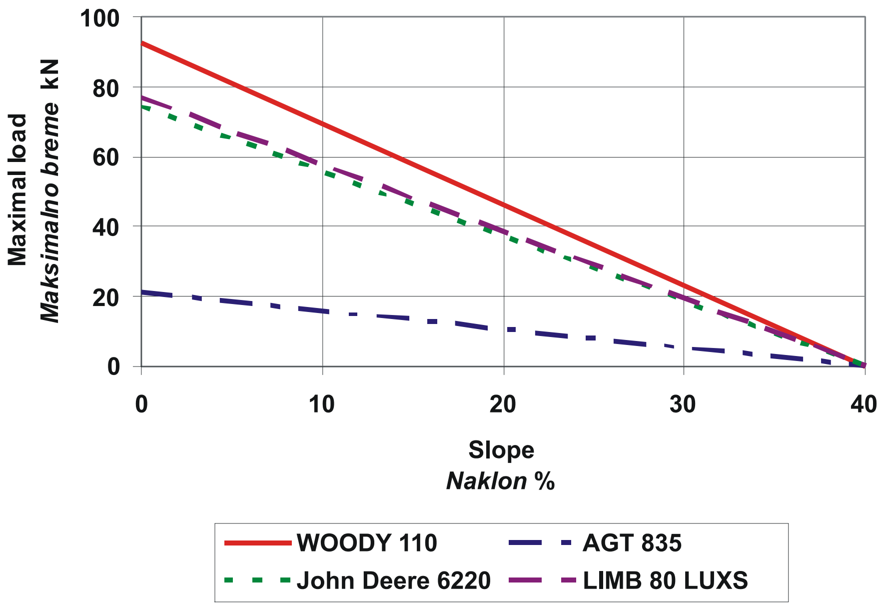

Fig. 5: Maximum loads in kN when skidding uphill – triangle for assessing limits

Slika 5: Maksimalna bremena v kN pri spravilu lesa navzgor – trikotnik za ocenjevanje mej

The relative difference between both load orientations when skidding with WOODY 110 is smaller on gentle slopes – let us say up to 15% – but grows with steeper inclination. When skidding on slopes close to the tractor's limits, the load orientation becomes more important. It obviously has an impact on the economy of skidding with a certain tractor. On the other hand, we know that optimal load orientation is a complex question of tractor's skidding economy. It also touches the question of directional felling, which is not possible everywhere, and bunching distance. In steep terrains, where tractor cannot move outside skid trails, the bunching distance is greater when logs are butt-end oriented. This is a fact, which opposes better efficiency of butt-end skidding. In practice, the optimal load orientation can therefore be rarely respected.

The dependency in Figure 5 can be turned around to find the answer to the question of how big a slope a certain tractor and chosen load can handle. We can also see that theoretical considerations and real experiment results can sometimes make useful combinations. Among all tractors, John Deere 6220 and LIMB 80 LUXS are most similar (engine, similar weight and transmission).

MAXIMUM LOAD AND ENGINE POWER
MAKSIMALNO BREME IN MOČ STROJA

The calculated maximum loads are shown in Table 4. This case is valid for described conditions and could not be generalised. Under different conditions (i.e. significantly different surface of the skid trail, friction coefficient, stoniness, rockiness, tractor chains, etc.), the result would be different. We think, however, that the method is worth developing through further testing.

Finally, we calculated weight of the load: weight of the tractor ratio (Table 4). These ratios have small variation and on the basis of Table 4 we can estimate the expected maximum loads under described conditions. There is, however – for practical purposes – an analysis to be carried out: what kind of relations we can expect between maximum and average loads taken from time studies when skidding uphill on different slopes.

Engine power and torque have direct impact on tractor performance. Both characteristics are, beside tractor weight, wheel diameter and slip, most influential and this is why the relations between engine power and maximum load under dif-

Table 4: Calculated maximum loads (tons) and weight of the load : weight of the tractor ratio when skidding uphill – average of butt-end and top-end skidding

Preglednica 4: Izračunana maksimalna bremena (t) in razmerje teža bremena : teža traktorja pri spravilu navzgor – povprečje obeh orientacij

Slope / *Naklon* %	AGT 835	John Deere 6220	LIMB 80 LUXS	WOODY 110
Weight of load in tons / *Teža bremena v t*				
0	2,1	7,4	7,7	9,3
5	1,8	6,5	6,7	8,1
10	1,6	5,6	5,8	6,9
15	1,3	4,6	4,8	5,7
20	1,1	3,7	3,8	4,6
25	0,8	2,8	2,9	3,4
30	0,6	1,9	1,9	2,2
35	0,3	0,9	1,0	1,0
Weight of load : Weight of tractor / *Teža bremena : teža traktorja*				
0	1,04	1,19	1,28	1,32
5	0,91	1,04	1,12	1,16
10	0,79	0,89	0,96	0,99
15	0,67	0,74	0,80	0,82
20	0,54	0,60	0,64	0,65
25	0,42	0,45	0,48	0,49
30	0,30	0,30	0,32	0,32
35	0,17	0,15	0,16	0,15

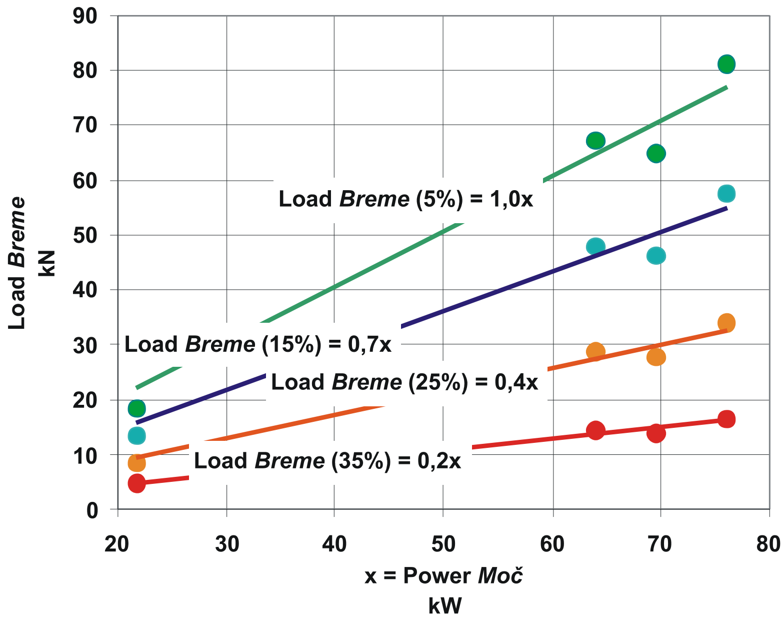

Fig. 6: Expected maximum loads in relation to slope category and engine power

Slika 6: Pričakovana maksimalna bremena v odvisnosti od kategorije naklona in moči motorja

ferent slope categories are shown. The slope categories in Figure 6 are: 0 – 10%, 11 – 20%, 21 – 30% and more than 30%. The curves in Figure 6 show averages for each category and for four tractors (calculated engine power is slightly different than in Table 1 as theoretical dependence between power and engine speed for tractor engines differs from commercial information). The linear equations in the figure can be used for fast estimation of maximum load on certain slope category for uphill skidding, i.e. if we have tractor of 50 kW, maximum load of some 3,5 tons can be expected when skidding uphill on the slopes between 10 and 20%.

DISCUSSION AND CONCLUSIONS
RAZPRAVA IN ZAKLJUČKI

The article deals with continuous development of the method of tractor testing, which should be, as much as possible, close to the actual situation in mountainous regions. At the same time we have had in mind that this kind of testing is expensive, demands specific equipment and staff and is time consuming. This means that – when testing for practical applications – the number of measuring parameters should be kept at minimum and the goal should be defined very clearly indeed (Marenče 2005, Košir et al., 2005, Šušnjar, 2005). In this article it was established that engine characteristics and machine weight play an important role in comparison, as well as load orientation, but this has already been stressed earlier (Samset, 1985, Košir, Marenče, 2007). The combination between testing in the field and theoretical considerations is obviously most economical and accurate enough for practical use.

If we wish to perform this kind of simplified test under different circumstances, we should have the skid trail of a proper shape (concave is very practical) and pre-designed loads, which have to be chosen in such a way that tractor would be stopped at different slopes. Our experience has given us the following recommendations as far as maximum load is concerned : tractor weight relation (this is valid for both tractors): on small slopes (0 – 10%) load / weight ratio should be between 0.6 and 1.3, on moderate slopes (10 – 20%) load / weight ratio should be between 0.8 and 1.0, on steep terrain (slopes between 20 and 30%) the ratio is between 0.3 and 0.6, and on very steep terrain (slopes over 30%) between 0.15 and 0.3. All this is true for described conditions. Just a simple change in the surface quality of the skid trail or in tractor equipment (i.e. chains) could cause different outcome of the trial. Meanwhile, we can recommend using tractors with greater weights and greater engine torques, when skidding uphill is frequent, and where stand conditions allow formation of greater loads.

We also suggest that when performing time studies of new tractors and techniques, simple test of maximum load when skidding uphill should be implemented with simplified method. What we need to know in such a case is, apart from tractor's characteristic weight of the load (that can be weighed or established in standard forestry way), the maximum slope and characteristics of the skid trail. In the future, this would enable enough reliable (economical) comparisons. Apart from such technical testing, only the calendar time structure and standard times would be needed to evaluate a tractor's economical competitiveness.

The novelty in this contribution lies in the fact that we put together two very different tractors with joined results from observations, and with theoretical approach made a comparison in the range where field observations have not been made. We also have to stress that during last few years, the significant improvement in measurements has been documented (Šušnjar, 2005, Tomašić, 2007). That gives us a hope that we shall greatly improve our knowledge, experience and intuition.

POVZETEK

V prispevku smo se osredotočili na meje vlačenja lesa - z različnimi traktorji zgolj pri vlačenju navzgor. Podatke terenskih meritev smo dopolnili z vrednostmi iz tehničnih kalkulacij. Z njimi smo želeli odgovoriti na vprašanje, kolikšna največja bremena lahko dosegamo v različnih vzdolžnih naklonih ob vlačenju lesa navzgor.

Podatki, ki smo jih analizirali, so rezultat terenskih meritev traktorjev Woody 110 in AGT 835. Glede na njune tehnične lastnosti, opremo in namen bi težko izbrali bolj različna traktorja. Prvi je gozdarski zgibnik in namenjen zgolj delu v gozdu, drugi pa zaradi slabših tehničnih karakteristik in lažje opreme le pogojno uporaben tudi za gozdno delo. Na osnovi obeh izbranih traktorjev smo postavili meje, znotraj katerih so z bremeni ob različnih vzdolžnih naklonih različni traktorji, ki jih lahko uporabljamo pri delu v gozdu.

V primerjavo smo vključili še dva prilagojena kmetijska traktorja: John Deere 6220 in LIMB 80 LUXS, od katerih je prvi že dolgo znan, drugi, izdelan v Sloveniji, pa je na trgu razmeroma nov in z njim še nimamo veliko praktičnih izkušenj.

Na vlaki konkavne oblike in z naraščajočim vzdolžnim naklonom smo vlačili različno velika bremena do točke, kjer se je traktor zaradi prevelikega bremena oziroma vzdolžnega naklona zaustavil. Vlaka za vlačenje s traktorjem Woody 110 je bila bolj strma kot v primeru vlačenja s traktorjem AGT 835 – v obeh primerih izbrana glede na tehnične zmožnosti obeh traktorjev. Vlako smo glede na njen vzdolžni naklon razdelili na več odsekov.

Tudi velikosti bremen smo prilagodili obema traktorjema: vlačili smo različno velika bremena, in sicer s traktorjem Woody 110 vedno štiri kose jelke dolžine osmih metrov, s traktorjem AGT 835 pa le en kos smreke dolžine osmih metrov. Vsa bremena smo ob koncu meritev tudi stehtali. Izbira vlake in bremen v primeru vlačenja s traktorjem Woody 110 je bila primernejša kot v primeru manjšega traktorja AGT 835. V prvem primeru se je namreč zaradi pretežkih razmer traktor vedno zaustavil, kar je bil tudi naš namen, pri vlačenju s traktorjem AGT 835 pa le v primeru največjega bremena v najbolj strmem delu vlake.

V analizi rezultatov smo uporabili različne podatke; osnovnim terenskim izmerjenim podatkom pri obeh traktorjih smo s pomočjo kalkulacij dodali teoretične vrednosti vlačenja z njima tudi v ravnini, vse skupaj pa primerjali še z dvema drugima traktorjema.

Rezultati testa kažejo, da pri obeh traktorjih pri vlačenju navzgor vzdolžni naklon okrog 40 % ponazarja mejno vrednost. (pri tem breme znaša 0 m^3). Rezultat je zelo blizu vrednostim, ki jih poznamo iz vsakodnevnega dela v podobnih delovnih razmerah. Tudi orientacija bremen z debelejšim delom naprej omogoča vlačenje večjih bremen ob enakem naklonu. Pri vlačenju s traktorjem Woody 110 znaša ta razlika okrog 6,23 kN.

Na podlagi analiziranih podatkov lahko preprosto izračunamo, kako se posamezni traktorji vedejo v različnih vzdolžnih naklonih. Območje med vrednostmi, ki jih predstavljata traktorja Woody 110 in AGT 835, nam nakazuje, kakšne kombinacije med maso traktorjev, vzdolžnim naklonom vlake in velikostjo bremena lahko pričakujemo ob uporabi različnih strojev. Izbira je lahko mnogo širša pri delu na manjših naklonih, medtem ko so razlike med traktorji na težjih terenih neprimerno manjše. Izbrani traktorji v raziskavi sestavljajo pomemben delež v današnji gozdni proizvodnji, poleg tega bodo v bližnji prihodnosti tudi predmet različnih raziskav s področja gozdnega dela.

V rezultatih je prikazano tudi razmerje med maso bremena in maso samega traktorja. Na tej osnovi lahko preprosto ocenimo velikost bremen, ki jih lahko vlačimo v izbranih delovnih razmerah – v nadaljevanju pa tudi, kolikšno je maksimalno breme ob izbrani moči motorja traktorja in vzdolžnem naklonu vlake.

Novost v prispevku je tudi sam metodološki pristop – v raziskavo smo vključili dva po tehničnih značilnostih zelo različna traktorja. Pri obeh smo opravili terenske meritve, jih analizirali in jih dopolnili z računsko pridobljenimi podatki za

vse tiste točke, kjer meritev nismo opravili. Tovrstne raziskave s tako drago mehanizacijo so vedno zelo zahteven raziskovalni projekt. S takšnim pristopom in kombinacijo različno pridobljenih podatkov lahko tudi sami bistveno prispevamo k večji racionalnosti pri izvedbi tovrstnih raziskav.

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