With skidder and load down the skid trail – does in this case a slip of the wheel also influence the forest ground?

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Abstract:
This report discusses the subject of downhill skidding – during downhill skidding there are totally different burdens on the machines and their dependence and connection are based on totally different principles. Therefore, this article does not deal with the problems of a machine overcoming difficult skidding conditions, but rather studies the wheel slip in the process of downhill skidding. By using a Woody 110 skidder, we skidded a load of 6m^3, comprising of four 8-meter lengths. These were skidded downhill – the longitudinal slope was the highest in the upper section, but slowly reduced in incline towards the truck road and reached its lowest value at the final, and lowest, point of measure. This kind of skidding causes the so called negative slip. This is the greatest on the steep sections of the skid trail; it decreases towards its lower section; whereas the values become positive on the gentle section. The necessary pulling force on the winch also increases by decreasing the longitudinal slope.

Keywords: skidder, downhill skidding, slip, pulling force

1 Introduction

In Slovenian forests the majority of timber is skidded with tractors. The operation of skidding is performed with various machines that have different work execution, technical features and also differ in their primary purpose (this is especially true for private forests where the owners conduct work on their own). The machines thus differ in their suitability or adequacy for forest work.

In numerous previous research works studying the skidding operation with tractors, various authors mostly dealt with actions and correlations occurring during the uphill skidding (Horvat 1996, Košir, 2000, Šušnjar, 2005). This is understandable since these operations cause the biggest burdens and impacts on the environment, especially the ground surface – furthermore, the uphill skidding is related to the capacity of individual machines and its adequacy for working in different conditions (Horvat, 1996, Klobučar and Košir, 1999, Tomašić, 2006).

Due to sustainable forest management and strict ecological restrictions the selection of suitable working means and technology is regarded as important. The selection does not refer only to the efficiency of the machine, but also considers its ecological suitability. When working in the sensitive forest environment, the numerous restrictions have to be taken into consideration – these dictate the use of suitable and adaptable working machines (Rebula and Košir, 1998). One group of such working machines are definitely also the new cable skidders that are apart from the adapted agricultural tractors regularly applied in difficult working conditions by Slovenian forest companies. One type of these cables skidders (Woody 110) was studied also in this research. The problems of working with this type of machine are profoundly discussed in the Ph.D. Dissertation (Marenče, 2005).

Timber skidding operation has various effects on the environment. Especially in difficult working conditions (steep terrain, skidding of heavy loads) a special care is necessary when applying heavy machinery. Technical parameters of the machine are those factors on the basis of which we estimate the suitability of the specific machine. In this regard several authors also emphasise the type of transmission (force transmission) from the tractor to the ground and the resulting different slip (Košir, 1997b, 2000, Jejčič, 2000 a, b, Macmillan, 2002).

With regard to technical parameters, this article mainly focuses on the relation between the wheel and the surface above which the tractor moves. When skidding up the skid trail these influences are expectedly higher. The higher tractive force is necessary, the torques on wheels are increased, and also the slip increases due to the slope of skid trail – however, this article studies this relation when skidding downhill, i.e. in all those cases when technically speaking the work does not represent many problems and is as such rarely discussed. In this article the focus is aimed especially at the slip of tractor wheels and necessary pulling force on the winch wire rope.

For a complex approach to timber skidding, it is not enough to be familiar with parameters occurring during uphill skidding – when skidding the same loads downhill there occur substantially different burdens, their dependence and connection is based on totally different laws. Thus the purpose of this article is to stress the importance and problems for downhill skidding operation, which is rarely a subject of study in our research works. We believe that the substantial and profound knowledge of actions occurring during downhill skidding is an important part of information about what actually happens during the timber transport. Similar information could be found also in some recent research projects (Mostafanezhad, 2006, Marenče and Košir, 2007, Šušnjar et al., 2010).

2 Methods

The measurements were conducted on Woody 110 cable skidder – the tractor is produced in Slovenia and due to its technical characteristics it is also regarded suitable for working in difficult, more demanding working conditions (Figure 1). The cable skidder was equipped with several measuring instruments – their description exceeds the extent, content, and purpose of this article. The measuring set applied on this tractor was already described in detail (Jejčič et al., 2001).

Figure 1: Special forest cable skidder Woody 110

Its technical characteristics are presented in Table 1:

Table 1: Some technical characteristics of the tractor Woody 110

Weight with equipment (daN)*	7006
Length (mm)	5400
Height (mm)	2750
Width (mm)	2200
Clearance (cm)	52
Engine	Perkins 1004-40T
Torque (Nm – rev/min)	403 - 1400
Power (kW – rev/min)	76.5 - 2200

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

Such research and necessary measurements can be conducted on special and designed objects that provide comparable conditions as they occur in our everyday work. In this research we opted for another approach – in the actual working site we selected an object (skid trail) where regular forest production took place. In this way we wanted to achieve conditions similar to actual everyday working conditions – thus acquired results of measurements were therefore more authentic. Due to measuring devices and other equipment the tractor was somewhat wider, thus the appropriately wide skid trail had to be selected. This was also the only requirement for conducting this study that needed to be regarded when selecting the suitable skid trail.

220m long skid trail was approximately of a concave shape and slowly decreased towards the truck road. In this direction also the measurements analysed in this article were performed. In the upper section the longitudinal skid trail slope reached the highest values, in the downhill direction the slope decreased, and in the last, final section reached the lowest values (Figure 2):

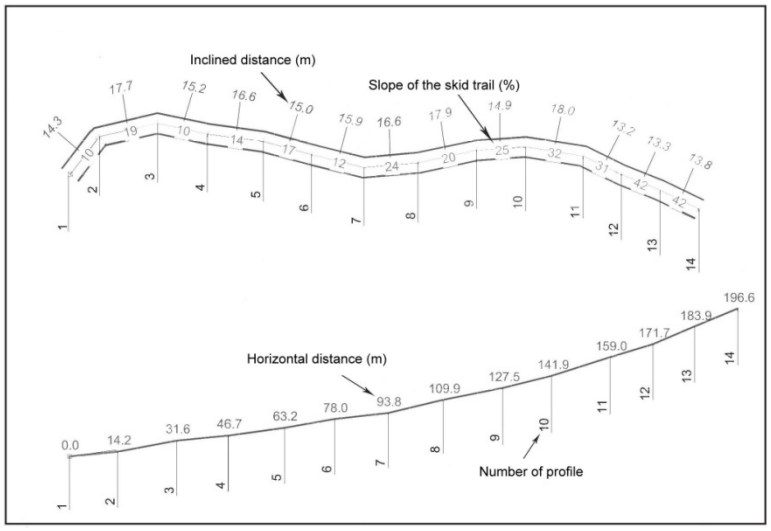

Figure 2: Selected skid trail – longitudinal slope and distances

By selecting this kind of skid trail we tried to encompass the whole range of longitudinal slopes on which timber skidding with tractor usually takes place. The whole skid trail was divided into several sections with different longitudinal slope. Thus the spans between 10 and 42 % of longitudinal slope were achieved. Especially for the purposes of simplifying the discussed problem we joined similar individual sections according to longitudinal slope. Thus we got three cca. 50 to 60 m long sections that are used in the article for analysing wheel slip and pulling force influence on tractor winch wire rope (Table 2).

The joined sections were designated according to their restricting profiles (14-10, 10-7, 7-3) representing longitudinal inclines above 30 %, 21 to 30 %, and up to 20 %.

Table 2: Joined sections on the skid trail

Name of joined section	Slope (%)	Length (m)	Total Length (m)
14-10	42, 42, 31, 32	13.8; 13.3; 13.2; 18.0	58.3
10-7	24, 20, 25	14.9; 17.9; 16.6;	49.4
7-3	10, 14, 17, 12	15.9; 15.0; 16.6; 15.2	62.7

Due to considerably poorer driving characteristics and driving in the curve this study did not consider the measured data between profile 1 and 3. All distances on the skid trail were in our case preliminary measured with measuring device, whereas during the skidding also the fifth wheel was applied. In our case this method proved itself as less accurate mainly due to horizontal curves on the skid trail and due to wheel construction. This was already discussed in detail (Marenče and Košir, 2009).

The load analysed in this research was adjusted to technical capacities of the selected tractor. We selected 6m^3 of load – it consisted of four 8-metre lengths of fir tree with bark, with a mass of 4729kg. The load was directed with butt end of timber in the driving direction and with its front part raised (Figure 3).

Figure 3: 6 m^3 load

During the force transmission from the tractor wheel to the ground, there normally occurs a certain slip. This happens frequently when driving across rough terrain and especially during the uphill skidding. In our case the skidding was executed on the constructed skid trail and mainly downhill skidding was analysed.

The slip can be defined in different ways. Košir (Košir, 1997a) defines it as:

$$\text{Slip} = \frac{(st - ss)}{st}, \qquad (1)$$

Where:

st – theoretically covered distance (m),

ss – actual covered distance (m).

During downhill skidding we applied instruments to measure the distance of individual wheel (Figure 4).

Figure 4: Measurement of the distance covered by individual wheel

The actual covered distance measured with meter was compared with theoretical distance (i.e. the distance with the included slip) which the individual wheel covers during the downhill skidding. The slip calculated in this way is shown in percentages.

Apart from the slip, also the data on pulling force is shown – i.e. the force in the winch wire rope with which the load is skidded. Due to additional requirements and for the needs of analysis the force in this research was divided into its horizontal and vertical component – in this article only its resultant is shown (Figure 5).

Figure 5: Measurement of pulling force in the winch wire rope

3 Results

3.1 Slip

When studying the wheel slip on the surface we normally refer to the driving dynamics of uphill skidding. In all cases the slip is in direct proportion with the longitudinal slope of the skid trail and the load size. Thus the wheel covers longer distance as the tractor actually makes – therefore we talk about the positive slip. The consequence of this occurrence is the removing of the ground – i.e. the type of damaging impact on the forest ground which apart from the already mentioned factors depends also from the type of surface and its humidity. However, the wear of tyres and smaller work efficiency due to slip are not discussed in this article.

In the title the question is raised: what are the relations during downhill skidding, since in our case we are not dealing with the longitudinal slope in the uphill direction – the load is skidded only downhill. How and especially to what extent the gravity comes to the assistance? For the whole study it is the most important that the smaller wheel slip means also the smaller damage to the ground.

The research showed that the features of tractor movement during downhill skidding are substantially different. Mainly there occurred the negative slip during the skidding of 6 m^3 load along the whole skid trail. Only in the lowest part, i.e. the lowest slope, the slip hardly occurred. The values are shown in the Figure 6 – according to different longitudinal slope, especially for front (first column) and back axle (second column).

In the upper, most steep skid trail section the slip was the most distinctive – the values were between 8 and 9 % - the slip was negative all the time. The influence of gravity on the slip length in the longitudinal slopes above 30 % is therefore obvious. During the skidding towards lower, less steep section, the slip decreased, but still remained in the negative values. At the end of the skidding trail, where the slopes were the smallest (up to 20 %), the slip was also the smallest and what is important – it attained the positive level for the first time. In such skid trail slope the impact of gravity is the smallest, but still present – and this is evident from the measured values. The slip values are minimum but positive for the first time. The significant differences between front and back axis were not established.

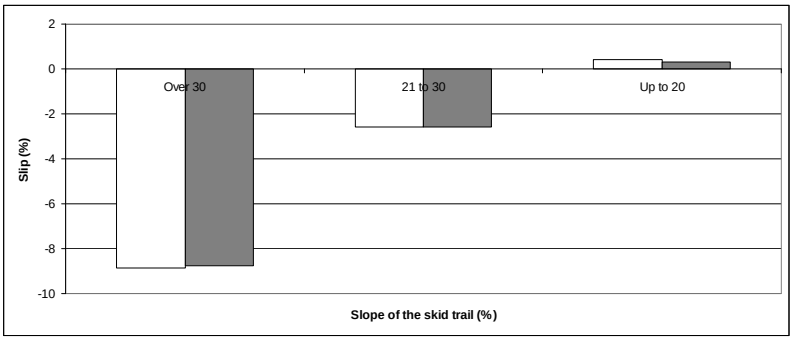

Figure 6: Slip of tractor wheel during downhill skidding

3.2 Pulling force

Apart from load size the biggest influence on the pulling force is attributed mainly to the slope of the terrain on which the load is skidded. Also the important impact of gravity needs to be mentioned. When skidding the load up the skid trail the same factors influence on the necessary pulling force – the difference being that during the uphill skidding in very demanding conditions sooner or later the limit is reached when skidding is not possible anymore due to load oversize or longitudinal slope. In all these cases there usually occurs the dilemma to what limit the tractor is capable to perform work and where is the point when due to technical limitations of the tractor this is not possible anymore. These have been already studied in the previous research works (Marenče and Košir, 2008). The studied problem is clearly totally different for the downhill skidding.

Pulling force values on the winch that are necessary for load movement are shown in Figure 7.

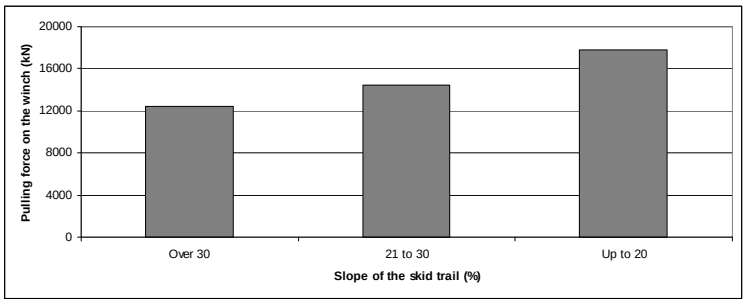

Figure 7: Necessary pulling force in the winch wire rope during downhill skidding

The results show that during the downhill skidding, the smallest pulling force is needed for moving the load in the steepest slope of the skid trail. To move the whole 6 m^3 of load approximately 12 kN of pulling force was necessary in the slopes above 30 %. In this case the impact of gravity is expectedly the highest due to high slope. During the downhill skidding the slope gradually decreases, consequently causing the necessary pulling force on the winch wire rope to increase – in the lowest, the least steep section it equalled approximately 18kN.

In this respect, the ratio between the loads mass which in our case equalled 4729 kg and the required force for moving the load this heavy is interesting. We establish that in the upper, the steepest part of the skid trail the pulling force for load movement of approximately 25 % of the total mass is necessary, whereas in the bottom, i.e. the least steep section, the force already equals 38 %. Usually we do not deal with similar relations between the abovementioned values during the downhill skidding since they do not represent special limitations and problems in the forest work. This is simply not regarded as a problem for the downhill skidding and setting the limits of the tractor. However, it is relevant during the uphill skidding when tractor simply cannot skid such a heavy load in steeper slopes.

4 Discussion, conclusion

Timber skidding is conducted at low speeds – the goal is to achieve high tractive forces and the smallest slip possible. In this way less energy is lost and also less damage to upper ground surfaces done. Mainly, these problems are dealt with for the uphill skidding. In the case of downhill skidding it has to be pointed out that impacts on the environment can also be different due to lower forces and slip. The importance of such research is to show the relation: tractor – wheel – ground. Despite the fact that this case does not deal with capacity limits of individual machines, such measurements show what actually happens during the downhill skidding. Does the slip actually occur and if it does what is its extent and type? The slip values are mainly negative – this means that all four driving wheels brake during the downhill movement due to gravity. The absolute values of the slip are decreasing respectively. It is necessary to emphasise that ground damages are not specifically analysed in this article – we can only infer about them according to the size of wheel slip. At the same time these values can be compared with the values of other similar researches – mainly in the case of uphill skidding where the values are usually higher. The gravity influences also on the required pulling force on the winch wire rope – for smaller slopes it is expectedly higher.

5 Summary

Different tractors are used for timber skidding in Slovenia. These machines are different in regard to their work execution, technical characteristics as well as their primary purpose. In previous research work on timber skidding the authors mostly studied the uphill skidding. This is expected and understandable because in this part of timber transport the biggest problems, machinery burdens and resulting damaging impacts on the environment occur.

In hard working conditions, bigger specialised forest tractors are used for timber skidding – in this article the cable skidder Woody 110 was studied. We monitored and analysed the slip of tractor wheels and necessary pulling force in the wire rope. For uphill timber skidding the higher tractive force is necessary, the torques on wheels are bigger, also the slip increases due to the skid trail slope – however, this article studies this relation when skidding downhill, i.e. in all those cases when technically speaking the work does not represent great problems. In all these cases there occur substantially different burdens on machines, their dependence and connection is based on totally different laws. This is why the importance and problems of downhill skidding is emphasised in this article.

The 6 m^3 load was skidded down the skid trail with Woody 110. The load comprised of four 8-meter long logs (fir tree in bark). The skid trail was of a concave shape, with the highest longitudinal slope in its upper part (above 30 %). Its slope gradually decreased and in the bottom section reached the lowest values (up to 20 %).

During downhill skidding the gravity is the factor that substantially influences on wheel slip as well as on the required pulling force. The values for both measured parameters were expectedly lower – lesser slip means also less damage to the ground. The article does not deal with the extent of damages – from the size of wheel slip we can in our case infer its influence on the forest ground. Moreover, these values can be compared to the values of other similar studies – especially to cases of uphill skidding. Along the whole skid trail the negative slip occurred – meaning that the tractor covered longer distance than its wheels. In the steepest part of the skid trail the slip was the most distinctive – the values were between 8 and 9 %, but all the time remained negative. Only in the lowest, least steep section the slip hardly occurred.

Apart from the load size, the slope on which the load is skidded has the biggest influence on the pulling force. However, also the importance of gravity needs to be mentioned. In the highest slope of skid trail (above 30 %) the smallest pulling force on winch wire rope was necessary to skid 6m^3 load – approximately 12 kN. During the downhill skidding the slope gradually decreases and consequently the required pulling force increases – in the lowest, least steep section it equals approximately 18 kN.

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