Ecologically sound means of primary timber transportation in complicated forest usage conditions

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Abstract:
The primary timber transportation is one of the most essential operations in the timber logging technological process. Application of caterpillar skidding machinery on this operation, especially in the mountainous harvesting conditions, leads to considerable damage to the top soil layer. In the Ukrainian National Forestry University has proposed the prospective design of the equipment (cable-skidding system (CSS)) for the development of cutting areas under unfavourable forest usage conditions (patent of Ukraine № 45009 from 26.10.2009). The system operating is based on the principle of combination of a highlead cable logging system and skidder's abilities. The necessity of the guylines mounting on the frame support of the CSS to ensure its stability during the harvesting process and also the optimal shape of the inclined tower of the frame support have been substantiated. The results of the experimental researches of driving tractor stability during its performance have been introduced in the article.

Keywords: skidding, cable-skidding system (CSS), frame support stability, guylines, hauling line

1 Introduction

As it is known, the primary timber transporting is one of the most important operations in the timber logging technological process. And if some basic operations with the purpose of their execution facilitation, implementation of full mechanization and partial automation and increasing of productivity can be transferred from the cutting area to the landing or timber yard, the operation of timber skidding is necessarily present during logging operations on site. Taking into consideration technology and machinery which are used, it is possible to estimate the financial and technical conditions of timber harvesting enterprise.

Most problems arise during extracting timber in complicated forest usage conditions (mountain's relief, marshlands) and also during non-clearcut harvestings (selective, shelterwood harvestings, thinning of young and middle-age stands, etc.), especially in terms of causing ecological damages to the environment. It is known that in Ukraine at present more than 85% of all timber is extracted by tractors (Mahura 2009), most of them on crawler tracks, that cause significant damage to the upper soil layer and mechanically damage the residual stands.

On steep terrain in the Ukrainian Carpathians, almost 80% of yarding utilizes tractors -- caterpillar tractors (50%) or wheeled skidders. Horse logging represents about 10% of skidding, gravity systems (using sluiceways, skidways, etc.) represent 5% and cable systems make up to 5% of the harvested timber). Skidders are used on the slopes up to 25^0 and cable systems on the slopes between $15\text{-}35^0$. Average length of skidding is about 1.5-2.0 km, but in some cases can be as long as 4-5 km (Mahura 2009, Bybljuk 2004).

Unfortunately, cable systems, which are recommended as alternative means of timber extracting in complicated forest usage conditions, are not always used by forest enterprises in Ukraine (Kudra 2004). First of all, it is explained by their lack, mainly, because of their expensiveness. This causes the fact that a large majority of timber are skidded by tractors, sometimes even with violation of Ukraine's existing timber extracting rules (Adamovsky 2008).

2 Materials and methods

Taking into account problems, which were mentioned above, and with the purpose of their, at least, partial solutions, Department of Forest Engineering designed and proposed cable-skidding system (CSS,) which includes a rigging that consist of the main (hauling) and haulback lines (cables) with portable blocks and frame support of pyramidal structures, that is mounted on the driving tractor (Figure 1) (Kyy 2009).

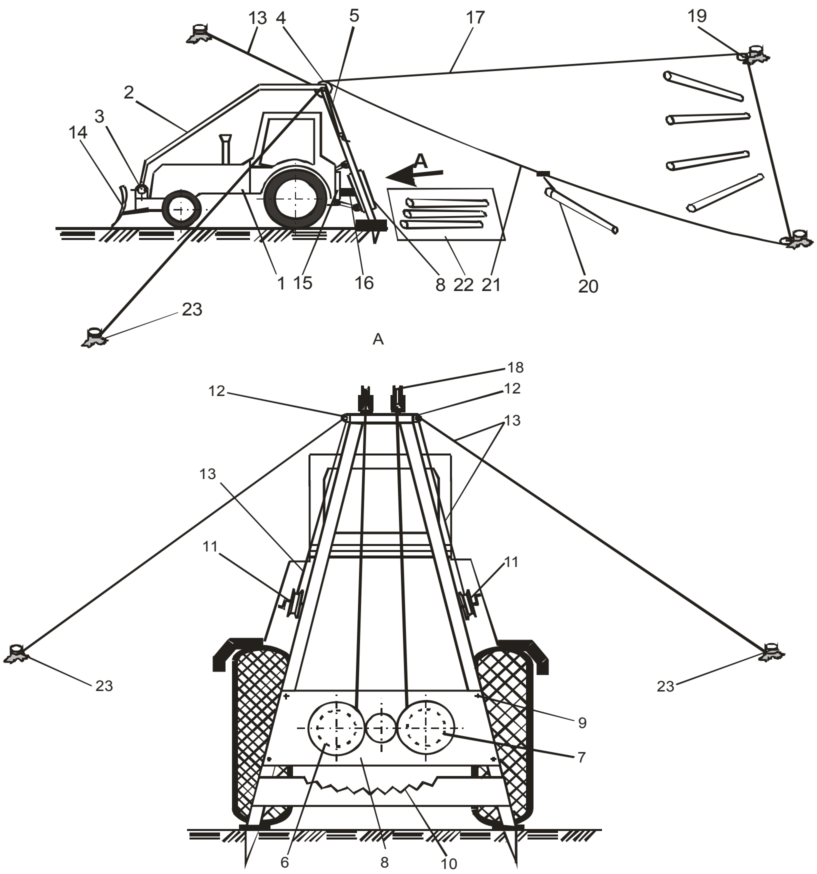

Figure 1: Scheme of the cable-skidding system

1 - base tractor; 2 - protective fencing; 3, 4 - joints; 5 - inclined yarding tower; 6, 7 - winch drums; 8 - slab; 9 – fixing bolts; 10 – notched bracket; 11 – hand winches; 12 – blocks; 13 – guylines 14 – blade; 15 – reversible reducer; 16 – cardan transmission; 17 - haulback line; 18 - guiding block; 19 – bypass blocks; 20 – skidded log; 21 - hauling line; 22 – pile of logs (landing); 23 – stumps

As may be seen from the scheme, proposed system structurally is similar to the construction of the mobile cable systems. However, the essential difference lies in the fact that cable rigging, along with a driving winch, that is mounted on the A-shaped yarding tower, can be easily removed from the tractor. In that case, the system functions like a common skidding tractor, while a protective fencing with the A-shaped tower simply serve as a protection during riding a tractor in the woods.

As it is clear from Fig. 1, during the operation of the proposed cable-skidding system on the primary transportation of timber, it necessarily must be fixed by guylines with the purpose of increasing its stability. It is logical to assume, that the efforts which will arise in the guylines, depend not only on a maximum load in a hauling line, but also on the position of guylines and angels of their attachment, both vertical and horizontal.

In addition, as theoretical research has shown (Kyy 2010), that the shape of the inclined skidding tower also has an essential significance for working conditions of the CSS. Thus, the trapezoidal inclined tower, leads to the rising of an additional twisting moments (torques), which cause the turning of the driving tractor around respective axes. Instead, using the inclined tower of a triangular shape (A-shaped mast), when the direction of the efforts that arise in the guylines and hauling lines virtually intersect at one point, prevent the additional twisting moments. So, we can state the expediency of using in the proposed design of CSS the inclined tower of triangular shape (A-shaped mast).

An appropriate cable rigging can be developed depending on the tractor tractive category, that will have an impact on technological parameters of the proposed system, including productivity, skidding distance, the area of timber collection, and more.

One of the most simplest schemes of cutting area transport development by cable-skidding system, as it seems to us can be as following (Figure 2).

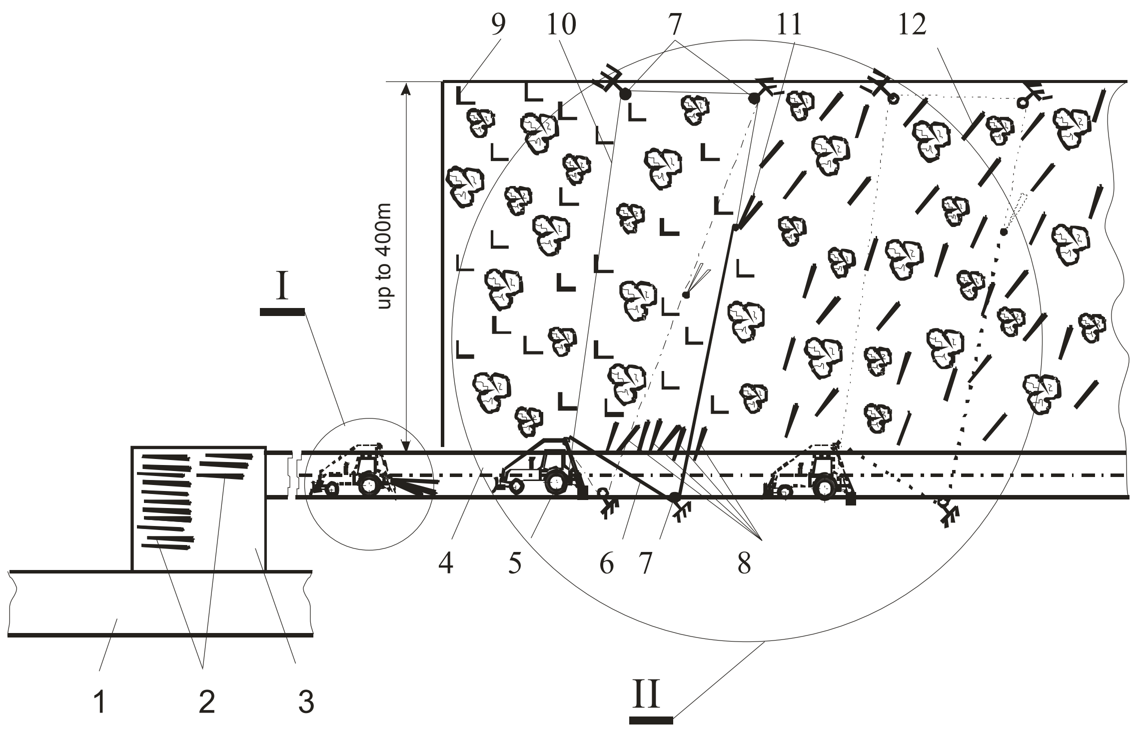

Figure 2: Technological scheme of primary timber transporting using CSS

I – utilizing CSS as a common skidding tractor; II – utilizing CSS as a mobile highlead skidding unit; 1- haul road; 2- piles of logs; 3 - landing; 4 - skid trail; 5 - driving tractor of CSS; 6 -hauling line; 7- portable blocks; 8 - logs skidded along the skid trail; 9-stumps; 10 -haulback line; 11 - pile of logs being skidded; 12 - logs.

As we can see, at the beginning, skidding of prepared logs to the skid trail take place (position II). At that stage driving tractor 5 does not leave the skid trail, but is placed on it. Using the haulback line (cable) and portable blocks, hauling line 6 is delivered to the place of logs collection and after hooking them on, the logs are moved to the skid trail, as it shown on fig. 2, II. Supposedly, the logs are to be skidded, and with the purpose to prevent their digging into the soil, it is advisable to insert into the front butt-end of the log a special plastic spherical or cone-shaped tip. Portable blocks should be made of aluminium or duralumin-ium alloys and be equipped with simple, easy and environmentally safe fastenings to the stumps or butts of growing trees. Recommended diameter of haulback line should be within 6...8 mm, as it is used only for delivering hauling line to the place of timber collection. It should be noted, that the simplicity of the proposed system construction, on our opinion, lets a possibility for a quick placing and removing of a driving tractor into the most appropriate position, so that almost every stem was pulled to the skid trail using a new route on a fresh soil, or at least a number of logs that are moved by one route was reduced to a minimum.

Such technological scheme almost will not affect the condition of cutting area top soil, and prevent mechanical damages of residual trees.

As it was mentioned, driving tractor, because of its system constructive features, can be quickly mounted or removed to the required place. At the same time it doesn't enter into the cutting area, but remains only on the skid trail. As a result, during the timber extraction from the forest to the skid trail using a cable, it is necessary to ensure stability of the driving tractor, i.e., to prevent its overturning under the action of loading, that exert in the hauling line (cable).

Usually, during the mounting of such systems (mobile cable systems), the guy lines are installed to ensure the stability of the yarding tower. However, their installation takes some time, though not significant. But if often remove the driving tractor, the total time of guy lines installation will accordingly increase, that impact on reducing overall system performance.

The question is, whether the proposed CSS can be used without installing guylines to the driving tractor and if it is possible – in which cases?

Let driving tractor (Fig. 3), is based on ground by wheels in points A_1, B_1, B_2, A_2 . A-shaped yarding tower BB_1B_2 is installed in such way, that its plane makes with the horizontal plane XOY angle γ . The guy lines BM_1, BM_2 will be considered to be absent, and let us suppose, that in the hauling line BM emerged an effort $T' = T'_X$, under which the stability of the driving tractor is lost and the tractor starts to turnover, i.e., to rotate around axis OX.

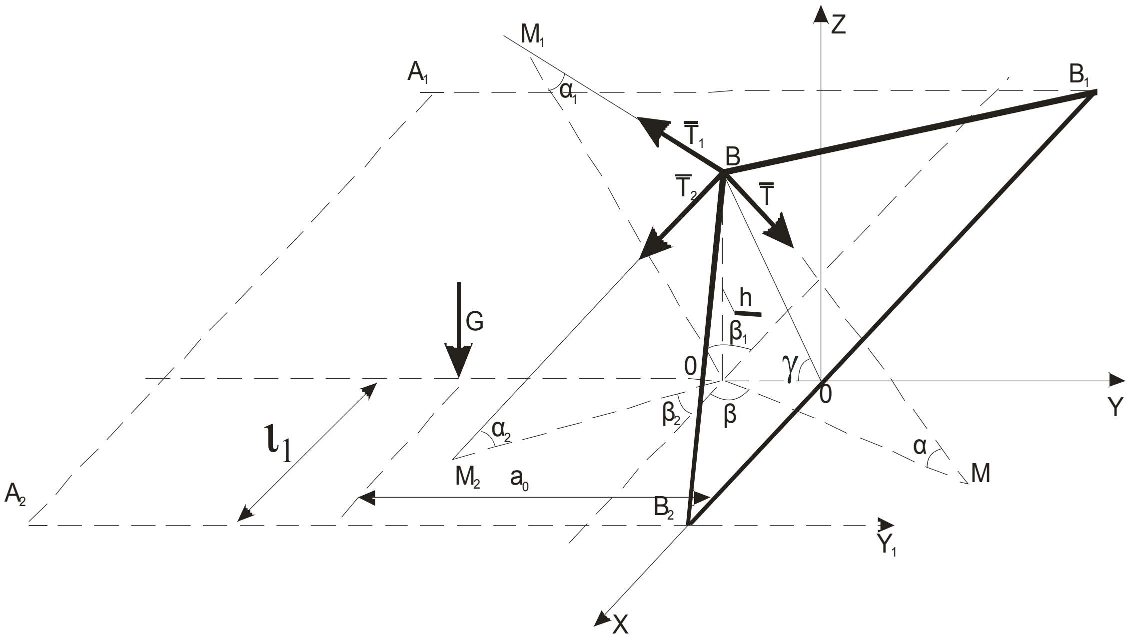

Figure 3: Scheme of the operating forces in the cable-skidding system during its work

Under the loss of stability is understood the case, when the supporting wheels begin to lift off the ground. In this case, at overturning the tractor around the axis OX, loss of stability is a detachment of supporting wheels off the ground in the points A_1,A_2.

Let make the equation of forces moments T' and G relatively to the axis OX

$$G \cdot a_0 + T_X^{/} \cdot \sin\alpha \cdot h \cdot \cos\gamma - T_X^{/} \cdot \cos\alpha \cdot \sin\beta \cdot h \cdot \sin\gamma = 0 \quad (1)$$

Whence

$$T_X^{/} = G \cdot \frac{a_0}{h \cdot (\cos\alpha \cdot \sin\beta \cdot \sin\gamma - \sin\alpha \cdot \cos\gamma)}, \quad (2)$$

Now, consider the case, when there is a danger of overturning the driving tractor around the axis B_2Y_1, i.e., when at the hauling line BM emerged the efforts $T'' = T_Y''$ under which, the supporting wheels are detached off the ground at the points A_1, B_1 and let write the equation of forces moments G and T_Y''

$$G \cdot l_1 + T_Y^{//} \cdot \sin\alpha \cdot l_1 - T_Y^{//} \cdot \cos\alpha \cdot \cos\beta \cdot h \cdot \sin\gamma = 0 \quad (3)$$

Whence

$$T_Y^{//} = G \cdot \frac{l_1}{h \cdot \cos\alpha \cdot \cos\beta \cdot \sin\gamma - l_1 \cdot \sin\alpha} \quad (4)$$

where, G - weight of the tractor; h - height of the block installation at the A-shaped yarding tower; l_1 and a_0 - respectively the coordinates of the tractor gravity forse center; variable values: α - angle between the hauling line and the horizontal plane (taking into account a considerable pulling distance relatively to the height of the block installation it has no significant effect on the value of T_1 and T_2); β - angle of timber package pulling relatively to the placement of the driving tractor

If to analyze obtained dependences (2) and (4) we can see that they include values, which could be considered constant: G - weight of the tractor; h-height of the block installation at the A-shaped tower; l_1 and a_0 - respectively the coordinates of the tractor gravity forse center; variable values: α - angle between the hauling line and the horizontal plane (taking into account a considerable pulling distance relatively to the height of the block installation has no significant effect on the value of T_1 and T_2); β - angle of timber package pulling relatively to the placement of the driving tractor. Obviously, that the change of the value of the angle β will have significant impact on the value of T_X' and T_Y'' - the critical values of efforts in the hauling line BM, the presence of which will lead to the tractor overturn around the axis OX or B_2Y_1, respectively.

Let make some calculations using obtained relations, assuming the basic parameters of the tractor MTZ-82 and analyze the effect of changing the angle β on the value of critical force in the hauling line. Thus, assume that the weight of the tractor G is equal to the unit and obtain the value of the critical force in the shares of the tractor weight.

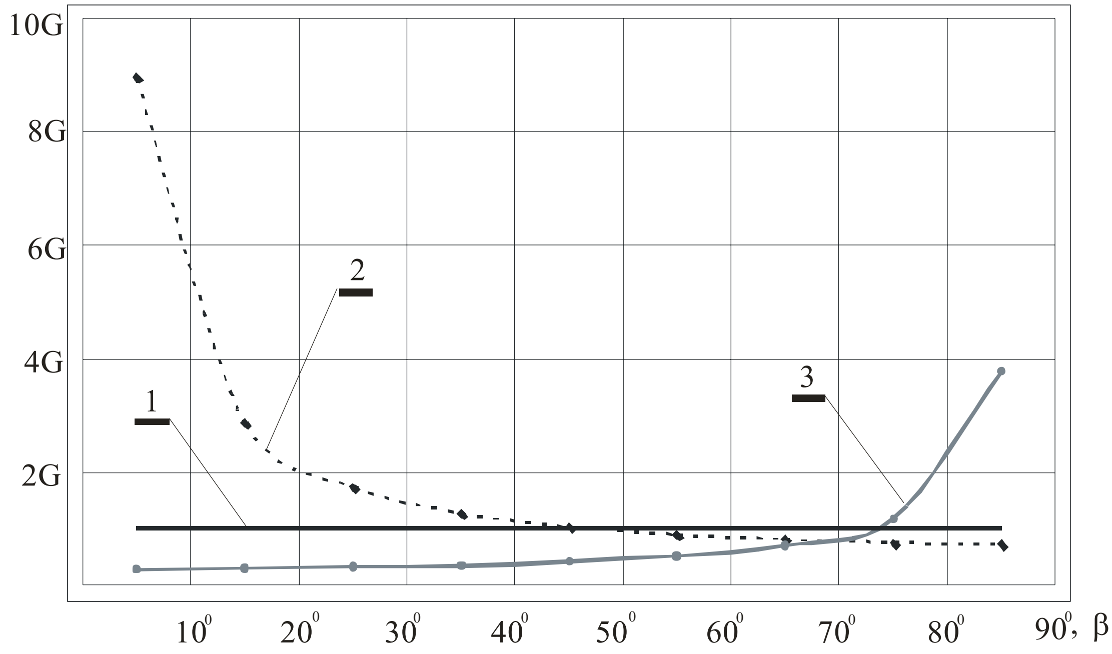

Figure 4: Effect of the angle β change on the value of critical force in the hauling line

1 - straight line, characterizing the weight of the tractor; 2 - graph of the critical force in the hauling line, that leads to the tractor overturning around the axis OX; 3 - graph of the critical force in the hauling line, that leads to the tractor overturning around the axis OY.

As it is seen from the graph (Fig. 4), during the timber skidding in the plane OXY (Fig. 3) by changing the angle β from 5^0 to 45^0, weight of the driving tractor ensures its stability and resistance to the overturning around the axis OX. However, it is in this value of the angle β there is the greatest threat for the tractor overturning around the axis OY. That is, the greater possibility of stability loss relatively to one axis, the greater stability of the driving tractor to the overturning around the other axis. It should also be noted, that during the performance of logging operations in the plane OXY, there is the greatest danger for driving tractor overturning around the axis OY. As it is seen from the graph, at the angle $\beta = 5^0$, the value of the effort that will lead to the tractor loss of stability relatively to the axis OY is equal $0{,}29G$.

Obviously, during the timber skidding in the plane $O(-X)Y$ we will obtain a mirror image to the graphics shown in (Fig. 4) and then the greatest danger of the tractor overturning occur around the axis OX.

To establish the reliability of the obtained results of the theoretical studies it is necessary to conduct appropriate experimental researches. Thus, the best option – to conduct such researches on the real, industrial equipment, production of which requires substantial funds. Therefore, the authors limited themselves by creating an experimental laboratory unit, maximum closer to the real model (Figure 5). As we can see, the experimental model consists of the base 2, on which the frame support 3 is established. A block 7 is mounted on the frame support in such way, that it was able to rotate around a vertical axis. Hauling line 8 by one end is connected to the dynamometer's ring 5 and the other end through the block 7 is attached to the loading winch 4, which is attached to the cross-bar of the frame support 3. The guylines 6 by one end are attached to the rings of the dynamometers 1, which are fixed at the appropriate places on the basis, and by the the second end - to the top of the frame support. Thus during the loading of the hauling line 8 using the winch 4, in the guylines 6 will occur efforts, which will be fixed by the dynamometers 1. Dynamometer 5 will fix the value of the effort in the hauling line.

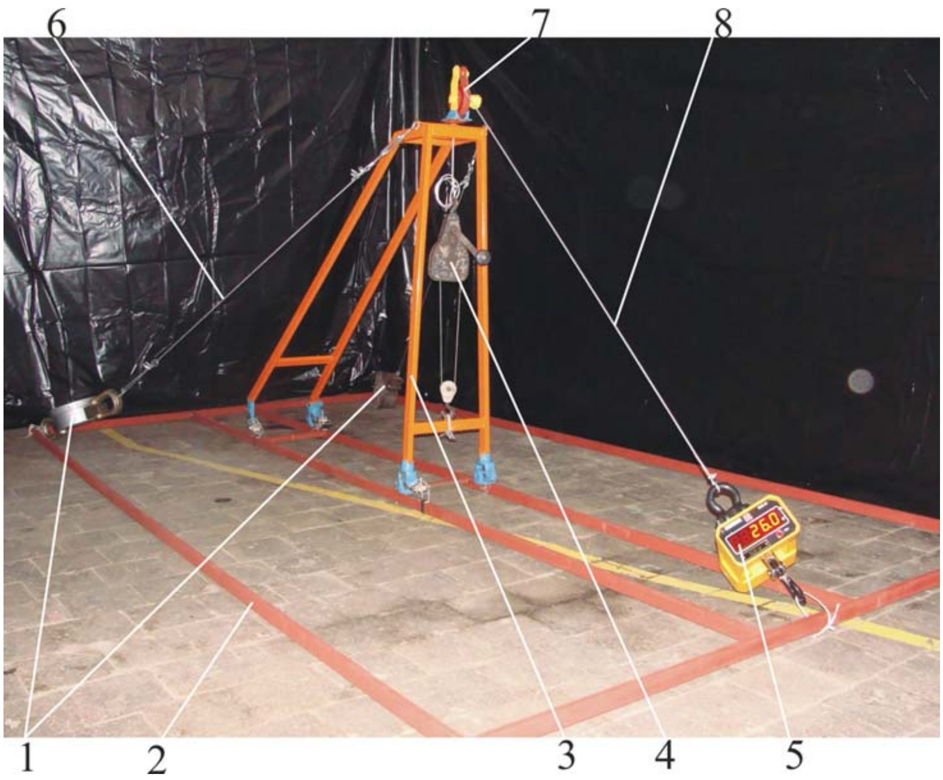

Figure 5: The experimental unit for the CSS driving tractor stability conditions determination: 1 - dynamometers installed on the guylines; 2 – base; 3 - frame support; 4 - loading manual winch; 5 – dynamometer installed on the hauling line; 6 – guyline; 7 – block; 8 - hauling line.

It should be noted, that the vertical posts of the frame supports 3 are fixed by hinges, and incline posts – are set freely on the base. Therefore, during the loading of the system, the efforts that are appearing in the hauling line will be transferred to the guylines. Besides of that, hauling line, same as the guylines, can be fastened in any point of the base, changing the horizontal and vertical angles of appropriate lines placement. Thereby, an imitation of hauling the timber package from various points in relation to the mounted driving tractor of the CSS is achieved . Weight of the tractor G was imitated by suspending the appropriate load to the top of the frame support. Weight of the tractor on the resulting graphs was taken as a one unit.

3 Results

Results of the experimental studies are presented on the graphs (Figures 6, 7). As may be seen from the Fig.6, there is a danger of the CSS driving tractor overturning around the axis OX (without presens of guylines), while lateral hauling a timber at the angle to the longitudinal axis of the tractor $\beta \approx 52^0 ... 90^0$ (Figure 6, curves 2, 3, are below of the strait line, characterizing the weight of the tractor).

Angle of lateral hauling within $\beta \approx 0^0 ... 51^0$ demands the installation of the guylines to prevent overturning of the tractor around the axis OX. This conclusion is confirmed by both theoretical calculations (curve 3, Figure 6) and obtained results of experimental studies (curve 2, Figure 6). It should be noted that the calculations was taken to the maximum possible, for this model of the driving tractor, volume of the timber package that is skidded.

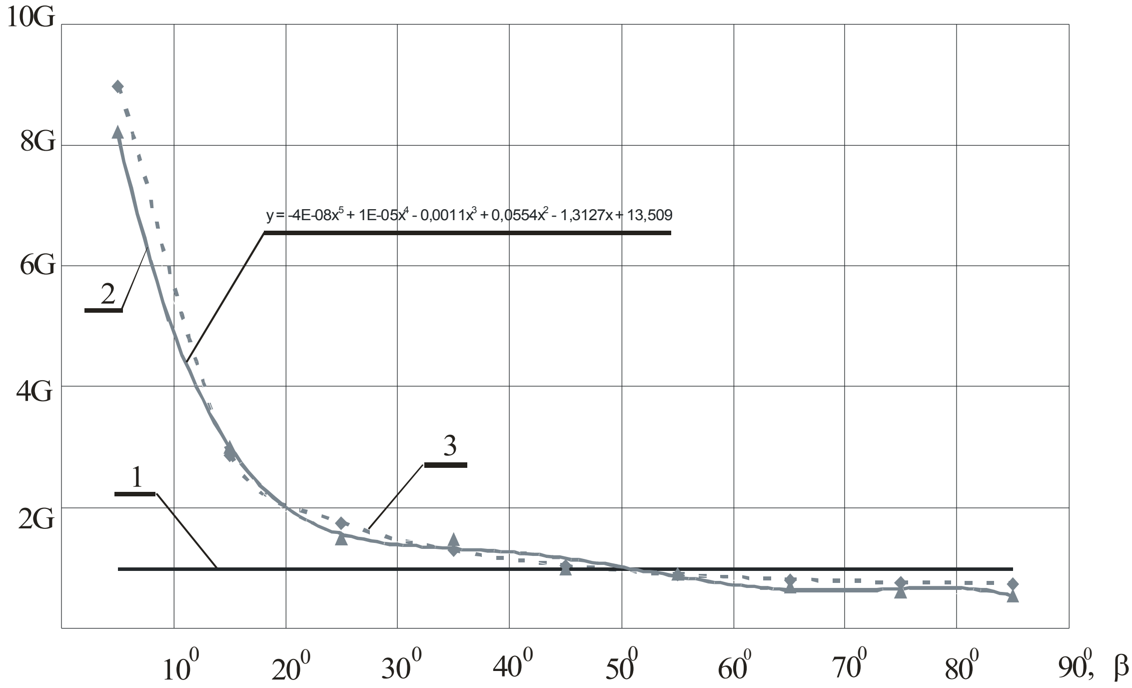

Figure 6: Change of the critical force value in the hauling line, that leads to the overturning of the tractor around the axis OX: 1 – line, characterizing the weight of the tractor; 2 – a graph of the critical force change in the hauling line, built on the experimental data; 3 – a graph of the critical force change in the hauling line, built on the theoretical dependence (2).

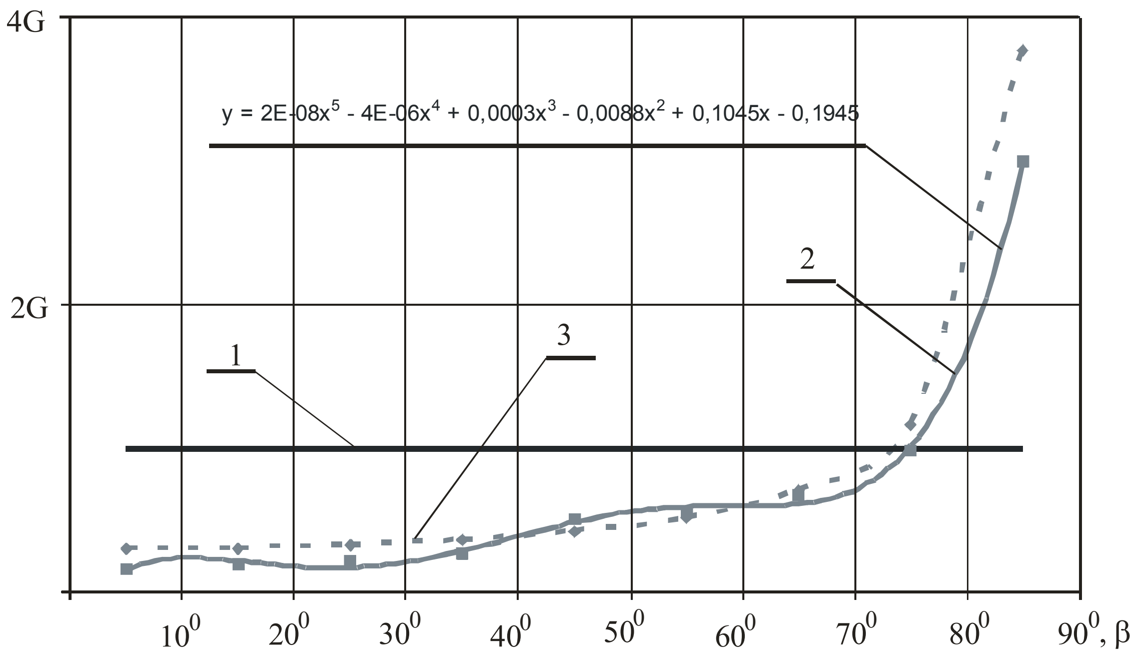

Figure 7: Change of the critical force value in the hauling line that leads to the overturning of the driving tractor around the axis OY: 1 - straight line, characterizing the weight of the tractor; 2 - a graph of the critical force value change in the hauling line, built on the experimental data; 3 - graph of the critical force value change in the hauling line, built on the theoretical dependence (4).

Shown on the Figure 7 graphics, built by both the theoretical dependence (curve 3) and the results of experimental studies (curve 2) clearly show that the danger of the overturning of the driving tractor (in the case of absence of the guylines) around axis OY (curves 2,3 are above of a strait line 1) arises while an angle of a lateral hauling is $\beta \approx 75^0 ... 90^0$, and while an angle of a lateral hauling is within $\beta \approx 0^0 ... 74^0$ the stability of the driving tractor to the overturning around the axis OY is provided by its weight. From the results of the theoretical studies, that were confirmed by the results of experimental researches, it is seen that in the absence of the guylines, if stability of the driving tractor to the overturning around the axis OX is ensured due to its weight, there is a danger of its overturning around the axis OY, and vice versa. This lets us to claim, that when hauling (skidding) the timber (the maximum possible package for this model of the tractor) within $\beta \approx 0^0 ... 90^0$, based on the conditions of its stability (resistance) to overturning, it is necessary to install the guylines.

4 Conclusions

1. The above suggested construction of the cable-skidding system (CSS) (patent of Ukraine № 45009 from 26.10.2009), is one of the prospective directions for the creation and development of the equipment for the primary timber transportation under unfavourable (complicated) forest usage conditions.

2. The most rational shape of the inclined mast design 5 (Figure 1) is not the trapezoidal one, but in the shape of triangle, at the top of which is mounted a guiding block and directions of the forces T, T_1, T_2 have common point of intersection on the guide block.

3. The results of theoretical (Figure 4, curves 2,3) and experimental (Figure 6, curve 2; Figure 7, curve 2) researches have shown that during the process of the lateral hauling (skidding) of the timber at an angle $\beta = 0^0 ... 90^0$ to the longitudinal axis of the driving tractor it is necessary to mount the guylines in order to avoid overturning (ensuring stability) around the respective axis.

5 References

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