Study of the operation of the Mounty 4000 machine in logging in mountainous conditions in Bulgaria

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Abstract. The article presents the results of a study of the process of operation of the Mounty 4000 machine in mountain conditions. The main goal of the research is to establish production rates for harvesting when using Mounty 4000 machines in mountainous areas. The need for research in this direction is due to the lack of such data in the current regulations, as well as in the scientific literature. To study the operation of the Mounty 4000, a passive production experiment was carried out in the mountainous regions of Bulgaria. The obtained data on the rates of output and operating time of the Mounty 4000 allows you to make scientifically based decisions in the selection of effective technical means from a large number of alternatives for forest harvesting technologies in mountainous areas.

1. Introduction

In many countries where there are mountain forests, suspended cable systems of various designs are widely used. The cost of one installation varies from 100 to 250 thousand US dollars, which is inaccessible for forestry enterprises in the Russian Federation [1]. Therefore, now we need to focus on our own designs of installations, continue to search for new ones, because it is they who provide nature-saving technologies in the conditions of mountain forests.

In some countries, for example, Austria, along with the use of rope suspended installations, timber is lowered from the mountains using lightweight portable pipe trays, which also ensure high preservation of undergrowth and do not damage the soil. In Canada and Sweden, balloons are used for skidding timber, and in the Caucasus mountains – helicopters. This trend in the development of skidding technology is associated with the fact that ground skidding in mountainous conditions does not fully ensure the safety of the forest environment. In addition, the construction of roads in the mountains is not only expensive, but also ecologically not always expedient [2, 3].

It is believed that the use of balloon-type aircraft for skidding in mountainous conditions will increase in the future. This will make it possible to normalize the process of obtaining valuable timber and restoring forests with the main species without disturbing the forest environment, especially soils [4]. The problems of air skidding of wood are dealt with in the USA, Canada, Sweden, Italy, France,
Germany, and Norway, where large reserves of valuable wood are found in remote mountain forests. Special attention is paid to technology, which ultimately affects the economic side of mountain logging.

Wood harvesting in mountainous conditions differs in many technical, technological and organizational issues. This is primarily due to the terrain, which significantly reduces the productivity of work in the main operations of the technological process and even restricts the use of certain types of equipment when performing them. In addition, mountain slopes increase energy and labor intensity of production. At the same time, the high ecological sensitivity of mountain forests presupposes the use of environmentally friendly approaches in the design of logging operations [5]. As a result, the cost of harvesting is increasing. The costs of skidding timber from tractors and machines increase especially sharply, which, in addition, cause significant damage to the environment, and are also limited in use by the steepness of the slope of 15...20 degrees. Most of the ropeway installations allow you to develop areas with large slopes of the terrain (up to 30 degrees), the percentage and degree of damage to all forest components as a result is much lower, while mobile self-propelled installations are not inferior to most tractors in terms of productivity. In this regard, given the depletion of forests in areas with gentle (10 degrees) and sloping (11...20 degrees) slopes, the use of mobile self-propelled rope installations for skidding timber can become a significant and promising direction for the development of logging enterprises in mountainous areas. This is confirmed by the research of Ph.D. Bondarenko A.V. [6], where it was established that the use of a mobile rope installation at logging separately or together with a tractor allows, relative to the operation of a skidder alone, to reduce energy consumption by 12...17%, as well as damage to trees, grass cover and soil of the cutting area by 10...12%.

Mobile rope installations can be used for both clear and non-clear felling. According [7], installations for clear felling are designed, as a rule, for skidding bundles of timber with a volume of 1 to 5 m³, have a capacity of 40 ... 60 m³. Non-clearcutting machines are designed for skidding individual trees, logs, and assortments from a stand without damaging the growing standing forest. In this case, the volume of the pack is within the range of up to 1 m³, the capacity is limited to the range of up to 20 m³.

Today, a modernized version of the ML-43A is presented on the Russian market from mobile rope installations. In addition, in the Caucasus, the universal installations LL-31 and ML-59 developed with the participation of the Maikop VPKIlesmash are being tested with the ability to operate according to a single-span and multi-span scheme. Of the foreign mobile rope installations, the following companies attract attention: Madill (Canada), Tajfun (Slovenia), Larix, (Czech Republic), and Konrad (Austria) [8-9].

When operating timber harvesting machines of the manipulator type in mountainous conditions, their stability decreases due to the roll of the supporting-rotary devices of the manipulators. Comparative analysis of new designs of automatic levelers of manipulator platforms showed that their use will increase productivity and reduce the safety of logging operations in mountainous conditions [10-11]. Also, the stability of a logging machine with a manipulator is affected by inertial forces arising when lifting and lowering a load, including when the rotary part of the manipulator rotates. To limit the limiting fluctuations in the pressure of the working fluid when the piston of the hydraulic cylinder stops in intermediate positions when lifting or lowering the load, a hydromechanical damper has been developed. For the hydraulic drive of the column rotation mechanism, a hydropneumatic damping device has been developed which dampens dynamic loads and swinging of the load when the rotary column stops in intermediate positions, while accumulating braking energy, and then returns it back to the system, i.e. there is a process of energy recovery [12].

When cutting in the mountainous regions of Bulgaria, private logging companies have started using Austrian-made Mounty 4000 machines since 2018, which are mobile cable installations on a car chassis, additionally equipped with a manipulator with a Woody H50 processor head. Currently, in the current regulatory documents of 2007, as well as in the scientific literature, there is no information on the results of work on the primary transportation of wood - the Mounty 4000 machine. The existing equations for predicting the operating time of rope installations in our case are not applicable, since they were obtained for other equipment natural and production conditions.
The purpose of the research is to obtain the standard performance of the Mounty 4000 machines in the mountainous regions of Bulgaria.

2. Materials and methods
To investigate the operating time and output of the Mounty 4000 in mountainous conditions, a passive production experiment was carried out from March 2018 to May 2020, at 8 different ropeway work sites with three workers (feller, choker, operator).

All employees had many years of experience in logging. The research was carried out in the south-central part of Bulgaria near the town of Smolyan, where spruce, white pine and fir dominate the plantation. After the installation of the cable car route, the felling of trees was carried out next to it, and then after the skidding, trunks were cut from branches and crosscutting with the help of a processor head. On all 33 routes of the Mounty 4000 rope systems, two rope systems were used: a carrying and traction rope for skidding. Due to the fact that it was not possible to carry out the measurements in full due to the need for a long observation period, data were obtained on 300 cycles of operation with a maximum path length of up to 500 m, and measurements were carried out at each of ten fifty-meter sections of the path. Thus, 30 cycles were recorded at each site. Table 1 provides information on the length and slope of each rope line, the type of felling and average data on the volume of harvested wood. The total volume of harvested wood is 10.564 m³, with an average shift capacity of 37.0 m³.

| Observation site          | Date      | Number of tracks | Average diameter, cm | Average track length, m | Terrain slope, % | Cabin type | Average shift capacity, m³/cm | Workpiece volume, m³ |
|---------------------------|-----------|------------------|----------------------|-------------------------|------------------|------------|-------------------------------|----------------------|
| Staryy pik 163 o          | 02 April 2018 | 3                | 18                   | 480                     | 60               | Forced     | 9.8                           | 174                  |
|                           |           |                  | 22                   | 490                     |                  | 90 %       | 26.7                          | 534                  |
|                           |           |                  | 23                   | 450                     |                  |            | 27.4                          | 521                  |
| 163 m                     | 04 August 2018 | 2                | 24                   | 500                     | 46               | Forced     | 41.0                          | 504                  |
|                           |           |                  |                      | 450                     |                  | 60 %       | 472                           |                      |
| Dimovski liv 194 k        | 14 June 2018 | 4                | 30                   | 450                     | 50               | Forced     | 35.8                          | 1773                 |
|                           |           |                  |                      |                          |                  | 100%       |                               |                      |
|                           | 04 May 2019 | 14               | 28                   | 480                     | 62               | Forced     | 52.03                         | 5004                 |
|                           |           |                  |                      |                          |                  | 100%       |                               |                      |
| Pamporovo 3123 p          | 02 April 2020 | 5                | 21                   | 350                     | 48               | Thinning 20% | 40.0                          | 982                  |
|                           |           |                  |                      |                          |                  |            |                               |                      |
| Kremen 191 t              | 05 June 2020 | 3                | 49                   | 300                     | 34               | Group-gradual 30% | 24.0                          | 250                  |
|                           |           |                  |                      |                          |                  |            |                               |                      |
| 190 n                     | 07 August 2020 | 2                | 21                   | 350                     | 32               | Thinning 20% | 40.1                          | 350                  |

Figure 1 shows the structure of the MOUNTY 4000, the main feature of which is that the winch drive is hydrostatic. Both the operator and the choker in the cutting area can control the carriage from the radio remote control. A small internal combustion engine is installed in the carriage for active unwinding.
of the traction rope. Automation ensures that it stops at the cutting area at the necessary points of hook-on and uncoupling of the load, which are set by the operator. The speed is automatically reduced when passing the saddle.

![Machine device MOUNTY 4000](image)

**Figure 1.** Machine device MOUNTY 4000 (Konrad Forsttechnik).

A separate element is a manipulator with a working body - a harvester head, it provides delimming, bucking into assortments, which are stacked for loading onto forestry vehicles.

When taking measurements on site, we decided to collect data in such a way that it is traceable and meets the quality standard ISO 17025. For this, we created a system of forms for recording various data, a protocol for preparing field works. Measurements of individual methods of operations were recorded with an accuracy of 1 second. Assortments were measured in terms of diameter and length in centimeters and were counted without bark. Thus, data were obtained on 300 skidding cycles. The data were entered into tables and processed in the Excel program. The cycle time is also recorded with an accuracy of 1 second. In measuring working time, we took into account only the work of the machine, and not the work of individual workers.

### 3. Results

When studying the operations of felling trees and their skidding along 33 routes within two days, a shift capacity from 26.7 m³ to 58 m³ was observed and the average trip load on skidding when performing forced sanitary felling on windblow areas was 1.2 m³, when cutting care – 0.9 m³, when performing group-gradual felling – 1.4 m³. The average skidding distance was 181 m. The average skidding distance was 14 m.

In the case of group-gradual felling, half of the working time was spent on processing operations – felling, delimming, measuring and crosscutting, with only the tops of the trees being trimmed and sorted by the processor. Two 2 m timber assortments were counted as one 4 m timber assortment.
Table 2. Presents data from average daily wind area observation, thinning and group logging.

| Data                                               | Windfall areas | Thinning | Group-gradual felling |
|----------------------------------------------------|----------------|----------|-----------------------|
| Average number of work cycles per day, units       | 43             | 45       | 17                    |
| Average voyage load on skidding, m³                 | 1.2            | 0.9      | 1.4                   |
| Number of objects of labor for 1 skidding cycle, units | 5.5           | 6.4      | 2.9                   |
| The volume of the subject of labor, m³              | 0.22           | 0.14     | 0.48                  |
| Time of one cycle of work, min                     | 7.20           | 6.97     | 9.3                   |
| Average haulage, m³                                | 52.0           | 40.0     | 24.0                  |

The duration of the average cycle is 7.20 min ± 21 sec in windblow areas, and with thinning of 20% – 6.97 min ± 20 sec with a probability of 95% (α = 0.05), cycles with breaks were not taken into account (table 2).

From table 3 it can be seen that the visit time is 450 min. The total travel time to the site is 565 min. This time begins to be taken into account by the arrival of workers at the base in the morning and continues until they return in the evening.

As for observation during felling and skidding of wood, then during felling, fallen trees are immediately skidded, during skidding and processing the next tree or trees are laid, etc.

In cutting areas with very large trees, the whole team performs felling, delimbing, bucking and sorting of all parts with a diameter exceeding the upper limit for the processor of 50 cm, and the tops were transported uncut. These pieces are trimmed and sorted by the processor. The daily productivity in this case is small, about 20-25 m³ without bark.

Observations during the assembly of the ropeway noted that the travel time depends on the installation situation, the length of the route, the number of intermediate supports with saddle posts, the availability of suitable trees for anchors and supports, and the relief. The least amount of time is required to transfer the cable car to the adjacent fan-shaped track without an intermediate support and end mast - two and a half hours or 7.5 man-hours. Most of the time is required for the transfer of the cable car to a new area under development with the preparation of the parking lot with an excavator and movement on the roads. Moving for such a situation takes at least two calendar days. This is due to the use of a fan-shaped scheme for the development of a mountain slope, when the movement of the mobile machine itself is not required.

As a result of the experiment, the goal of the research was achieved – data were obtained to substantiate the production rates and operating time of Mounty 4000 machines in the mountainous regions of Bulgaria, which will serve as an addition to the current standards.

The research carried out allowed us to obtain reliable results of the operation of the Mounty 4000 machine in the mountainous regions of Bulgaria. The results of this study will complement current regulations. The obtained data on the rates of output and operating time of the Mounty 4000 allows you to make scientifically based decisions in the selection of effective technical means from a large number of alternatives for forest harvesting technologies in mountainous areas [13-14]. The conducted research is of great importance in view of the fact that at a distance of 200-300 m from the forest road on steep sections, the available stock of timber for development has dried up. The development of more remote areas on very steep slopes is required. The use of the Mounty 4000 machine allows you to successfully solve this issue.
### Table 3. General structure of the working day at windblow areas and thinning areas (565 min).

| Components of working time during the day                      | Windblow areas (43 cycles), min | Thinning (45 cycles), min | Windblow areas, % | Thinning, % |
|---------------------------------------------------------------|---------------------------------|---------------------------|-------------------|-------------|
| **Work time**                                                 |                                 |                           |                   |             |
| The time of short periods of the skidding cycle (uncoupling the load, pulling the hook to the carriage, lowering the hook, lifting the load, waiting in front of the ramp, lowering the load) | 40.3                            | 42.1                      | 7.13              | 7.45       |
| Cargo formation time                                          | 174.9                           | 175.6                     | 30.97             | 31.09       |
| Time of movement of the carriage along the carrying rope       | 95.3                            | 95.8                      | 16.87             | 16.96       |
| Total running time                                            | 310.5                           | 313.5                     | 54.97             | 55.50       |
| **Out-of-cycle time**                                         |                                 |                           |                   |             |
| Preparatory and final time                                    | 45                              |                           | 7.97              | 7.97       |
| Organizational time                                           | 5                               |                           | 0.89              | 0.89       |
| Time to go to the place of work and prepare the tool          | 8.5                             | 5.5                       | 1.50              | 0.97       |
| Time for servicing equipment                                  | 11                              |                           | 1.95              | 1.95       |
| Time for servicing equipment and refueling it with fuels and lubricants | 69.5                            | 66.5                      | 12.30             | 11.77       |
| **Non-working hours**                                         |                                 |                           |                   |             |
| Violations of the loading process, etc.                       | 20                              |                           | 3.54              | 3.54       |
| Lunch break                                                   | 30                              |                           | 5.31              | 5.31       |
| Interruptions and short breaks between work cycles            | 12                              |                           | 2.12              | 2.12       |
| Personal time                                                 | 8                               |                           | 1.42              | 1.42       |
| Total non-working hours                                       | 70                              |                           | 12.39             | 12.39       |
| **Time outside the workplace**                                |                                 |                           |                   |             |
| Unused time                                                   | 5                               |                           | 0.89              | 0.89       |
| Travel time to the work site from the base of the enterprise and back | 110                             |                           | 19.45             | 19.45       |
| Total time                                                    | 565                             | 565                       | 100.00            | 100.00     |
4. Conclusion
The results of the study shows that the distance between the tracks, which in relation to the standards adopted in Bulgaria is 60 m, should be halved when leaving, and every second track should be abandoned when resuming. The time spent on the formation of the load should be reduced when performing strictly directed felling of trees, as well as from the transfer of maintenance to the preparatory and final time.

We also have demonstrated that the Mounty 4000 mobile rope machine with a Woody H50 processor (Mountain harvester) is highly productive and well adapted to mountain infrastructure, terrain and silvicultural approaches to work in Bulgaria and other countries of the world. Compared to traditional forest harvesting options based on mobile cable systems, the use of the Mounty 4000 allows you to increase the output of the entire system by 7...12%.

In the conditions of the Russian Federation, the use of Mounty 4000 mobile rope installations with a Woody H50 processor is not available to most enterprises today due to their high cost. Therefore, it is necessary to develop its forestry machine building, to look for new effective design solutions to improve mobile rope installations, because it is they that provide nature-saving technologies in mountain forests.

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