Modernization of mini-tractor for wood skidding

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Abstract. The work was carried out in three directions: changing the rotation system of mini-tractor, installing remote control of the winch and improving the trailer. The modernization of the mini-tractor in all directions was successfully completed, and the research results were patented. Testing of the improved mini-tractor in real working conditions confirmed our expectations. Replacing the rotary mechanism with steering, installing the driver's seat significantly reduced operator fatigue when wood skidding. Remote control of the winch reduced the time of wood loading on the trailer by 1.7 times compared to the option without using it. The total time to perform entire technology cycle from cutting trees to loading them on the trailer, skidding and unloading is decreased by 19.4%. Changing the design of the trailer allows to exclude the turn of the tractor train along the skidroad with penetration into the forest and facilitate the loading of harvested timber.

1. Introduction

Forests occupy 46.6% of the Russia territory. This is 21% of the area of total forests in the world. Forests grow in different climatic conditions, have different species composition and economic purpose. Russian forests have a significant impact on the formation of the Eurasia climate. Growing healthy and sustainable forests includes mandatory and timely care for them at a young age. At the same time in the process of cuttings the necessary conditions are the high preservation of the remaining part of the stand the ground cover and the upper soil horizons [1]. This requires light equipment that can reduce environmental damage [2]. Therefore, one of the important and promising areas of forestry in Russia is the creation and use special means of small mechanization when carrying out thinning.

Such equipment is constantly being modernized and is widely used in other countries for thinning forests [3] in young-growth forest stands and other forestry operations where the use of other equipment is dangerous [4], unprofitable [5] or has a negative impact on the natural environment [6]. In our country creation and using means of small-scale mechanization of cuttings is still being carried out at the level of creating and testing of experimental units, studying their operational characteristics and their impact on the natural environment. One of these studies with an experimental mini-tractor at the thinning (accretion cutting) in homogeneous and natural forests was being carried out for several
years. Analysis of the results of the mechanism using on thinning allowed to find reserves and propose solutions to improve its technical characteristics.

Creating a new product where new ideas would be implemented is a difficult and long process. One way to improve the equipment productivity, operating and maintenance conditions is modernization. The design changes and the installation of additional equipment on the experimental mini-tractor will allow to develop and apply technologies to use it most effectively for thinning. Thus, the purpose of the study is to increase the productivity and improve operating conditions of a mini-tractor for wood skidding.

2. Materials and methods
The object of the research was a mini-tractor MTR-1 which is an analogue of the mini-skidders Iron Horse IH 2055/2090 Pro (Sweden). Working in real conditions revealed some inconveniences in operation and relatively low productivity of the mini-tractor when wood skidding. First of all, driving a mini-tractor when walking and loading the harvested wood on a trailer are very tedious operations. In addition, the mini-tractor with a trailer has a large turning radius. This has a significant effect on its productivity during selective cutting in a dense forest stand and during cutting using skidroads.

The mini-tractor modernization was carried out in three directions: changing of design and turning system, changing of the trailer design and installing the remote control of the winch. The first two tasks require a technical solution and the third task is a development, manufacture and installation of special equipment on a mini-tractor. All design, engineering and assembly work was carried out by workers and teachers of the Ural State Forest Engineering University (USFEU) on the own training base. In real conditions, chronometric observations to determine the time spent on cutting, bucking, loading, transporting and unloading one transport package were carried out. A separate study to determine the efficiency of the winch remote control was done. Ten times at the same distance, the time of skidding and loading of logs on the trailer was measured. After that all the same operations without remote control were performed.

The obtained results were processed in the Statistics 6.0 program. All three directions of the mini-tractor modernization are interconnected and solve a complex of tasks to reduce labor costs when operating a mechanism, increase its productivity and preserve of the forest environment in the process of wood skidding during forest cutting.

3. Results and discussion
As already reported before designing and creating our mini-tractor we had experience working with a mini-skidder that was operated in walking regime. As a result of the experiment was concluded that this way of this equipment driving leads to operator fatigue, increase of probability to get hurt and as a result – productivity decline. The way out of this situation was obvious: it was necessary to install a driver's seat on our prototype. At the same time, it became necessary to change the way of driving the mini-tractor: the pedal for regulating the engine speed and the lever for switching the direction of movement (forward – neutral position – backward) were installed. The winch was installed in the back of the mini-tractor and the device for its control was placed under the driver’s seat. The driver's seat is protected by a protective shield (figure 1). In appearance our mini-tractor MTR-1 differs significantly from the Swedish mini-skidders Iron Horse IH 2055/2090 Pro (figure 2).

Checking of the MTR-1 was carried out for several years on forest thinning areas. In the artificial and natural forest stands during thinning driving tests and various technologies of wood skidding under the canopy of the forest were carried out. The technical specifications of the mini-tractor are determined experimentally and are shown in table 1. One of the studies was chronometric observations to determine the time spent on cut, bucking, loading, transporting and unloading for one transport package. All operations were carried out by one person. The diameter of cut trees was from 16 to 30 cm, the number of trees in the transport package – from 1 to 4 ones. Its volume was on average 0.61 m³, the skidding distance – 30-40 m. These studies are presented in table 2.
Based on the results obtained it can be calculate that the total volume of harvested wood in one hour using a mini tractor will be 1.0 m$^3$ and its performance in works related only to load, transport and stack harvested logs – 1.7 m$^3$. Based on the sequence of operations and safety the worker needs 10 minute break after each hour of work. Given this circumstance the volume of harvested wood in one hour is reduced to 0.85 m$^3$ and the second indicator – to 1.4 m$^3$. As a result the net work time, excluding lunch break, is 5 hours. Thus theoretically one worker during this time can produce 4.3 m$^3$ of wood. It is established that to carry out the whole complex of work from cutting of trees, log skidding to harvesting of cut branches one worker really may produce 3.5 m$^3$ of wood. The ratio between theoretically calculated wood volume and really harvested is 0.8.

| Table 2. Time spent to form and transport one transport package. |
|---------------------------------------------------------------|
| **Duration of operations, min**                              |
| % of the spent                                               |
| Choosing and cutting of trees                                |
| Cutting Bucking of trees and cutting branches                |
| Harvesting cut branches                                      |
| Loading                                                      |
| Skidding and returning back                                  |
| Unloading                                                    |
| Total                                                        |
| 2±0.7                                                       |
| 6±1.3                                                       |
| 7±1.3                                                       |
| 12±1.2                                                      |
| 5±0.7                                                       |
| 4±0.6                                                       |
| 36±5.5                                                      |
| 5.5                                                          |
| 16.7                                                        |
| 19.4                                                        |
| 33.3                                                        |
| 13.9                                                        |
| 11.2                                                        |
| 100                                                         |

**Figure 1.** Mini-tractor MTR-1.  
**Figure 2.** Iron Horse IH 2055/2090 Pro.

**Table 1.** Technical specifications of mini-tractor MTR-1.

| Technical specifications |
|--------------------------|
| Length, m                |
| Width, m                 |
| Load capacity, kg        |
| Mass, kg                 |
| Engine, type             |
| Power, kw/h.p.           |
| Additional equipment     |
| Specific pressure on the soil, kg/cm$^2$ |
| Load, m$^3$              |
|                          |
| 1.6                      |
| 1.1                      |
| 500                      |
| about 300                |
| carb, four-stroke        |
| 5.1/7.0                  |
| winch, rope 20 m, trailer|
| 0.15                     |
| 0.5-0.8                  |
Table 2 shows that a third part of total time is used on loading the mini-tractor. Such a large expense of time is associated with moving of worker (often repeated) from the trailer to the mini-tractor and back. It was necessary to find a way to reduce the time and facilitate this action. To solve this problem remote control of equipment is the most attractive. It is known that such systems have significant advantages over manual ones [7]. They are constantly becoming more complicated and improved [8].

Such a system was developed, manufactured and together with a 12-volt battery installed under the operator’s seat. Figure 3 shows the block scheme of the winch control mechanism. The torque on the winch drum is transferred from the engine variator to the pulley (5) using a belt transmission. The work of the winch remote control (9) takes place as follows. The mini-tractor’s speed switch lever is placed in a neutral position. In this position of winch lever (7) there is a free unwinding of the rope from the winch drum (6) in the direction of the tree without branches (tree length) and its checkering. On the signal from the joystick to the receiver (1) motor-reducer (11) is activated, which through the rake (10) with a shock absorber (8) puts the winch lever (7) in “on position”. The moment of the winch turning on through the sensor (12) is alerted by sound signal (3) and light signal (4). The light signal continues to work with the winch “on”. The speed rotation of the winch drum (6) is adjusted by the joystick lever. In the case of an emergency the joystick has an emergency engine stop button. After log loading or long log on the mini-tractor on command with the joystick winch lever (7) put in the position “off”. The process is repeated until the transport package is formed. If the electronics are broken it is possible to work manually.

The test of the remote control of the winch was carried out at the thinning site on the territory of the Ural training - experimental forestry as part of the task to create a training-experienced object. The test showed that duration of the wood loading operation on the trailer was reliable reduced by 1.7 times compared to the option without using it. The total time to perform entire technology cycle from cutting trees to loading them on the trailer, skidding and unloading is decreased by 19.4%. As a result it is really that when one person performs the entire cycle of logging by one worker the mini-tractor performance can be 4.1 m³/day.
Another positive aspect of using remote control is the high preservation of the undergrowth and stands from damage in the process of log skidding before loading on the trailer (figures 4 and 5).

![Figure 4. Stand before thinning.](image1)

![Figure 5. Stand after thinning.](image2)

Using a joystick at any moment it was possible to stop the winch and adjust a log skidding. In this case, when two workers are working and transport package is being formed, synchronization operations in time on one side of the cutting and the other with wood skidding takes place. They are 15 and 16 minutes respectively. The separate performance of these operations by two workers ensures a real production 7.5 m³/day. In general the productivity of the harvested wood falls by 0.3 m³ and is 3.8 m³ per person daily but the area covered by thinning increases. In the process of thinning, attention was paid to mini-tractor moving along the technological corridor. The process took a long time and was very inconvenient as it was necessary to go backwards or turn around on skridrout entering into stand. With the high density of stand and the 5 meter length of the tractor train (mini-tractor and trailer) it was impossible without entering into stand and damaging of trees and undergrowth.

On the existing trailer which is a pole trailer (figure 6) log loading along of the loading shield (5) by winch is carried out only on one side. The wheelset (3) doesn’t provide a center of gravity in the middle of the trailer. A fairly large load was on the beam (4). It, gradually led to its deformation. After that adjusting of the trailer length became impossible.

![Figure 6. Trailer mini-tractor MTR-1: 1 – frame; 2 – conic; 3 – wheelset; 4 – beam; 5 – loading shield.](image3)

This design of the pole trailer was convenient when there was on the mini-tractor device on which was relied one end of the log. Two points of support on the mini-tractor and trailer ensured an even
distribution of the load on the tractor train. Changing the design of the mini-tractor required a change in the design of the trailer (figure 7). It is supposed to place wheels (3) in the center of the frame (1). A round shaft on bearings of sliding or rolling (7) and a folding loading shield (5) in front and back of the frame are installed. This will allow to load the logs on both sides to ensure more smoother log loading on the trailer and to reduce the load on the winch. The beam (4) freely slides below under the frame (1) through tube or its segments of the square section (6). The logs are loaded by a tractor winch on a trailer and placed in its center between the conics (2). With this design of the trailer the log loading will take place as follows. The mini-tractor with its front part passes along of the technological corridor to loading point. The beam (4) is uncoupled from the mini-tractor and it moves to the opposite part of the trailer. The beam (4) through the tube for beam (6) is moved towards the mini-tractor at the required length which is determined by the length of the log. After that the loading shield (5) goes down and the log on the shield and shaft on the bearings is loaded onto the trailer. A mini-tractor by its front part skid the wood to loading point. Such the skidding technology is excluded the choice of placement and turning of the tractor train inside stands.

This ensures the safety of trees and undergrowth and significantly saves time for this operation. The design of the frame and the height of the trailer which is determined by the height of the wheels was left the same taking into account that work with trailer showed its good stability on a slope. This is one of the main characteristics of the trailer for safe wood skidding [9]. An alternative to the proposed trailer can be a manipulator mounted on a tractor trailer. Of course, the time for loading and unloading of logs is reduced but its aggregation with a mini-tractor leads to an increase of the mass of the tractor train [10]. As a result this entails does other problems which are manifested in specific conditions. In any case, the choice of the design and equipment must be justified and contribute to the solution of the assigned tasks.

4. Conclusion

The creation of the mini-tractor MTP-1, the installation of equipment for remote control of the winch and the testing of the unit in real conditions confirmed our expectations to improve operating conditions and increase productivity of wood skidding. Along with this the modified design of the trailer will help preserve of the natural environment during cuttings. However, the operation of log
unloading is carried out entirely with hands. In our opinion there are no or almost no technical capabilities for further modernization of the MTP-1. In addition, this model is outdated. Modernization of MTP-1 is a stage to design and creation more modern means of small-scale mechanization of cuttings. It is planned to create a mini-tractor with the ability to move and carry out loading and unloading operations completely remotely.

Due to the variety of forest conditions and accordingly different cutting conditions, available tractive mechanisms, the proposed design ideas can be successfully applied with the equipment used for wood skidding, including foreign ones. Thus, the principle of remote control of the winch to implement alternating motion can be used. As a rule, these are levers witch transfer the mechanism from one mode of operation to another. The proposed design of the trailer is effective in the dense forest and when there is undergrowth. That is in the conditions where skidding is carried out along technological corridors and the tractor penetration into forest is banned.

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