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ATTACHED EQUIPMENT TO FOREST MACHINE FOR COMBATING UNWANTED VEGETATION*

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Abstract

To achieve the goals of forestry (growing a stand with specified characteristics), it is necessary to take care of the forest, and first of all at the initial stages of its restoration. It is during this period (up to 10 years after felling) that the forest area is overgrown with unwanted vegetation, which prevents the main species from growing. Currently, the technology for removing unwanted tree and shrub vegetation around trees of target species is still not perfect enough, due to the low degree of its mechanization. The aim of the work is to develop a design for a device mounted on a manipulator of a forest tractor, capable of performing technological operations both for cutting the trunks of undesirable tree-shrub vegetation located near the tree of the main species, and uprooting undesirable tree-shrub vegetation located at a distance from the tree of the main species. To solve the problem, the method of functional-structural-technological analysis was used, based on the study of the operating experience of forest machines and their structures. As a result of the work, several design schemes were proposed for the implementation of a device that meets the set goal and has two working zones - a zone of pulling out or uprooting and a cutting zone. The novelty and industrial applicability of the proposed designs is confirmed by the patents of the Russian Federation issued in relation to them.

Keywords: forest maintenance, main species, reforestation, thinning, unwanted vegetation

1. Introduction

Attaining a high-quality growing stand on felled areas in a minimum time is possible only with the artificial creation of appropriate favorable conditions, which requires forestry work (Pak and Gavrilova, 2020). Forest care can be carried out for different purposes. It can be aimed at: preserving and increasing the sustainability and productivity of the forest; improvement of the

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species composition of plantations; improving the sanitary condition of the forest. When looking after a forest, the main operation is thinning - an operation carried out by destroying or weakening undesirable forest plants in the planting and creating favorable conditions for the growth of the best trees of the main species (Platonov, 2017). Forest plants that are undesirable for planting include tree and shrub vegetation, which slows down the growth of trees of the main species.

There are several ways to remove unwanted trees and shrubs (Sokolov, 2006), among which it is worth highlighting:

- mechanical, realized by cutting the stems of plants or pulling them out by the roots from the soil cover (Lepekhin and Chekanyshkin, 2017);
- chemical, realized by treating plants with chemicals that destroy them (Shabanov et al., 2014);
- biological, realized, for example, by means of peripheral embankment of the site, filling the soil surface with bedding manure (Ivashnev and Gavrilova, 2018) or using insect phytophagous (Tomczak and Tomczak, 2018);
- loosening the soil, covering the area around the seedlings.

Each of these methods has its own advantages and disadvantages and can be applied both individually and in various combinations with each other. Practice shows that when removing unwanted vegetation by cutting, only the top part is removed, leaving hemp with an intact root system, which begin to sprout up root growth and an intensive overgrowing of trees of the main species with unwanted vegetation occurs. In addition, when cutting off unwanted vegetation close to the main tree species, there is a fairly high probability of damage to their stem, which can lead to their death. When uprooting unwanted vegetation near the main tree, there is a high likelihood of damage to the root system of the main tree, around which the removal of unwanted tree and shrub vegetation is carried out. Damage to the root system of the main tree species can lead to its death, which makes the thinning process in this way ineffective in young stands. During thinning, the biological method is practically not applicable due to the complexity of its management and the unpredictability of its consequences, because instead of some types of undesirable tree and shrub vegetation, others may appear, and when insects are used, an uncontrolled large population of them may appear.

The use of the chemical method in forest care is very difficult, and often turns out to be impossible, because The chemical composition used can not only destroy unwanted tree and shrub vegetation, but also trees of the main species, reduce the nutritional value of the soil on which the chemical composition falls, and also worsen the ecological situation for living organisms. In addition, the use of chemicals requires supply and safe storage, which increases the volume and complexity of auxiliary forestry operations.

The choice of this or that method depends on the age of the undergrowth of the main species, the composition of the species of undesirable tree and shrub vegetation, the intensity of its overgrowth, the availability of technical means, and other natural and production conditions. These methods are implemented by various technical devices. Since technical devices are quite expensive and require certain costs for their storage, assembly / disassembly on the base vehicle, maintenance, and taking into account the fact that they are not used constantly, but periodically and within a short period of time, enterprises strive to reduce them as much as possible. range. In view of the above, more and more preference is given to universal technical devices capable of combining several technological operations.

When planning forest maintenance work, forest managers are forced to develop a technology for carrying out work not from an economic and technological point of view, but based on the technical equipment at their disposal. A preliminary analysis of the effectiveness of the methods of combating undesirable trees and shrubs in forest care indicates the advisability of using the mechanical method. On the one hand, pulling out unwanted vegetation together with the root, as compared to removing it by cutting, makes it possible to reduce the growth rate of the undergrowth, and, therefore, to increase the time intervals between re-thinning in young stands

and thereby reduce their number. On the other hand, pulling it out together with the root leads to damage to the root system of nearby plants.

All of the above determines the relevance of this work, the purpose of which is to develop the design of an effective universal technical device capable of performing two technological operations:

- cutting the trunks of unwanted tree and shrub vegetation near the main tree;
- uprooting of undesirable tree and shrub vegetation located at a distance from the main tree species.

2. Literature review

Laine et al. (2019) noted that a great danger in the formation of clear forest cultures is self-seeding and coppice regeneration of deciduous species, especially birch and aspen. It is noted that the creation of forest crops requires constant care for them. n forestry, a mechanical method of dealing with unwanted vegetation has become widespread. Most of the forest management work in young stands is done with hand tools and equipment. Most often, care in young stands with a small diameter of the trunks of unwanted vegetation is carried out using a motorized brush cutter, where the working body is a disc with cutting teeth located on its outer surface. In the presence of large trees, chainsaws with a long bar are used, for example, a pole-saw with a flexible suspension of the cutting unit based on the Husqvarna 535FBX chain chainsaw. Laine et al. (2019) noted that such a solution increases the productivity of work, reduces the load on the employee's spine.

The desire to shift from manual labor to mechanized and mechanized labor stimulates manufacturers of forestry equipment and forest users to search for new solutions for forest care and the introduction of machines into production to replace manual labor (Kukkonen, 2011).

In the mechanized method of forest care, to cut unwanted vegetation, technological equipment is mainly used, which is hung on the manipulators of light harvesters. According to the type of cutting mechanism, such equipment can be divided into (Hallongren and Rantala, 2013): disk installations; chain sawing machines; guillotine type installations; scissors. It is advisable to supplement this classification with machines with a milling-type working body (mulchers). Hytönen (2013) devoted an analysis to machines and equipment intended for the care of forest crops concluded that it is promising to use, along with continuous-action machines, equipped with a disk working body - brush cutters, machines equipped with a milling-type working body.

The working body of the milling type is a rotating rotor on the cylindrical surface of which grinding working bodies in the form of knives or hammers are installed. The rotor rotates in a plane perpendicular to the soil surface. Such a working body carries out grinding, abrasion of those objects with which it contacts. The use of milling machines makes it possible to combine the removal of trees and shrubs with agrotechnical care, which consists in simultaneous loosening of the soil, removal of weeds, and destruction of felling residues. This technology is effective in preparing the soil surface before planting forest crops. But its use in order to combat trees and shrubs during thinning is inappropriate, because when processing the soil surface near trees of the main species, there is a high probability of damage to their root system, and, consequently, their death. The working body of disk installations is a disc of small thickness with cutting teeth on its outer generating surface. Rotation is carried out in a plane parallel to the soil surface. Such a working body carries out the cutting of the trunks of trees and shrubs. In this case, the cut is carried out with the formation of chips. In the case of using this technique, only the aerial part of the plant is removed, and its root system remains intact in the ground. Risutec T-series, R-series (Uotila, 2019) and Usewood UW40, UW50 units (Strandström, 2016) are the most widely used among installations with a disk working body in world practice.

Installations of the guillotine type carry out cutting of the trunks of trees and shrubs without the formation of shavings by acting on them with a translationally moving knife. Among

guillotine-type installations, the most widespread are the Naarva series E and K hyoltines (Shadrin et al., 2019); Risutec L-series, M-series (Glöde and Bergkvist, 2003).

Chainsaw machines include a saw bar, which serves to move the saw chain with cutting teeth located on it, a driving sprocket associated with a rotation drive. Bracke Forest made the sawing mechanism in the form of a round bar and chain. The saw mechanism is equipped with a protective cover. To improve the efficiency of work, the equipment is equipped with a tree storage device, which consists of lever systems. One pair of levers holds the cut tree trunks, the other pair grabs new ones. After the bundle of stems has accumulated in the device, they are piled on the ground for further transportation and processing into fuel chips. Such equipment is offered by Pentin Paja Oy, Bracke Forest, Risutec etc. To increase the effect of mechanized thinning, it is proposed to additionally equip the sawing devices with a supply of fluids with Chondrostereum purpureum. Research results show that this method reduces the re-growth of unwanted vegetation.

A number of companies offer attachments in the form of scissors. Scissors are two parallel plates moving relative to each other, on the long sides of which there are slots. The cutting of the trunks of tree and shrub vegetation is carried out when they fall into the indicated slots and when one plate moves relative to the other, when the projections on one plate overlap the slot on the other. The length of the working area can vary from 130 to 240 cm. Also, this equipment can be installed on small radio-controlled machines (Ligné et al., 2005). This device is located in the front of the machine and is more intended for clearing areas from trees and shrubs along linear objects (roads, power lines etc.).

The listed types of equipment are based on the principles of mechanical cutting of unwanted vegetation. One of the disadvantages of mechanical cutting is that the area, after the forest has been taken care of, again begins to quickly overgrow with unwanted vegetation and it is necessary to repeat thinning in the young stands. Heikkilä et al. (2005) developed a forest care machine that uproots unwanted vegetation together. The Uprooter P55 attachment is a frame with two parallel grids, which are closed by a hydraulic cylinder. Inside the frame, a central rectangular window with a size of 0.41 by 0.67 m is made. The weight of the equipment is 980 kg, the working area is 5.5 sq. m. The operator aims the device at the seedling, lowers it with open grips, clamps unwanted vegetation and pulls it out. Then in 2011 the company made a lighter version of the Uprooter P25. Equipment weight 590 kg, working area 2.5 sq. m. In this device, the central window is removed, and grooming (pulling out unwanted vegetation) is done around the seedling. There is one more modification P16 (Shegelman, 2012). It is made in the form of a grab at the ends of the grip of which there are rubber inserts to increase the friction force. The operator opens the jaws of the grapple gripper, points on the tree, grabs it and pulls it out by the roots.

As a result of research of Vasilev et al. (2016), it was revealed that the productivity of the Uprooter P55 machine averages 0.14 hectares per hour (7.1 hours/hectare). A feller with a motorized brush cutter performs work with the same productivity. Therefore, the cost of the machine is high. Mokhirev et al. (2018) compare the work of two models of lifting machines (uprooter P25 and P55). The performance of the machines does not differ much. For P55 - 6.0 h/ha, P25 6.3 h/ha. The performance and quality of the machine depends on the density of the stand and the height of the trees harvested. The authors of the articles conclude that the productivity of machines for uprooting is the same as when working with a brush cutter manually, and the cost of the machines is higher. In this case, efficiency is achieved by reducing the number of thinning during the period of forest growing (Seliverstov et al., 2010).

The development of mechanization of thinning in young stands is a promising direction (Tambi and Grigoriev, 2020), but so far, in terms of the cost of work, in terms of quality of performance, and in terms of productivity, it is more efficient to use manual brushcutters. For example, Rukomoynikov (2013) compared the performance of the Husqvarna 252RX brush cutter and the operation of the Vimek 404R machine with a disk attachment. Manual forest care turned out to be more effective: faster, better, cheaper. But at the same time, the authors point out that mechanized forest management has prospects. Machines can work in the dark, in adverse weather

conditions, easier management, development of automation and control. Similar conclusions were reached by (Shirnin et al., 2011) comparing the Farmi Trac 5000 and FMG 0470 machines with a cleaning device and manual maintenance with a brush cutter.

3. Materials and methods

To achieve this goal, it was necessary to solve the following tasks:

- to study the peculiarities of technological operations with various methods of removing trees and shrubs by mechanical means;
- to study the equipment used for the removal of trees and shrubs by mechanical means and its design features;
- to develop a design of a universal technical device that combines the advantages of methods for removing undesirable trees and shrubs, both by cutting the stems and by pulling them out by the roots.

The technological process of thinning in young stands was chosen as the object of the study, namely, the clarification operation. The subject of the research was the equipment for the clarification operation in young stands. The method of functional-structural-technological analysis and synthesis of technical solutions was used as a research method. The method of functional-structural-technological analysis is based on a comprehensive study of the object and subject of research, in terms of their functionality, the structure that forms their basis, and manufacturability. At the same time, the object of research is considered as a complex system consisting of many subsystems, each of which is divided into a number of even simpler subsystems.

The method of synthesis of technical solutions involves the development of new technical solutions based on the results of functional-structural-technological analysis. According to this method, the relationship of its individual structural elements and their influence on the functionality of the object is established. This takes into account the manufacturability of individual structural elements in each subsystem, its influence both on the manufacturability of each subsystem and on the general manufacturability of the system as a whole. This method is a development of the method of functional and technological analysis, developed by the honorary worker of forestry of Russia prof. Shegelman I.R. the essence of which is described by Malyukov et al. (2014).

When searching for information that serves as the initial data for the functional and structural and technological analysis of the object and the subject of research, patent information search was used, which consisted of studying the patent fund of the World Intellectual Property Organization (WIPO), as well as available sources of scientific and technical information, including and electronic libraries and scientometric databases: Elibrary, Cyberlrninka, Sciencedirect, Scopus etc.

4. Results and discussion

The analysis of technical devices showed that there are several design schemes for installing the working body on the vehicle: frontal location, side location, location on the manipulator. Front and side positions are inconvenient because they ensure the operation of the device in a narrow technological corridor and require many shunting movements to move the device to the desired area. Therefore, the preference was given to the location of the executive body at the end of the manipulator arm instead of the grab gripper. Such an arrangement on the manipulator will provide the maximum possible service area of the device from one parking lot of the base vehicle, from all sides of it. In addition, the manipulators of forest machines are equipped with a hydraulic system, a grab suspension system and control equipment that can be used to connect the device's executive bodies and control their operation. In this case, it was taken into account that the manipulator is characterized by such a value as the load moment, which

determines the maximum load that can be applied to the boom at its maximum reach. This parameter limits the maximum permissible overall dimensions of the device, which are taken into account indirectly through its mass, and the effort to pull out trees and shrubs.

There are various designs of technical devices that differ in the presence or absence of their own power unit. The presence of its own power unit leads to the autonomy of the device and its independent operation from the engine of the base vehicle, but this increases the bulkiness of the device and significantly complicates its design and operation, requiring the use of additional consumable fuels and lubricants. In connection with the above, as well as taking into account the fact that the vehicle during thinning must have good maneuverability and high ground clearance, because This type of work has to be carried out in difficult natural and industrial conditions, it was decided to use a forest tractor equipped with a manipulator, for example, a harvester or forwarder, as the basic vehicle, and the device should be made in the form of attachments.

When developing the structure, it was decided that the working space should be divided into two zones: the zone of pulling out or uprooting - the zone of impact on tree and shrub vegetation by its uprooting; cutting zone - a zone of influence on trees and shrubs by cutting its trunks. The difficulty lay in the fact that in each zone a different effect on trees and shrubs should be carried out, and, therefore, in each of them specific working organs should be installed, differing not only in geometric shape, but in the movements performed.

In the pull-out zone, the working body must ensure a reliable grip of trees and shrubs by its aboveground part, for example, stems, and impart a vertical force sufficient to pull the plant out of the soil by the root. In this case, the design of the grip and the compressive force of the grip should be such as to provide a sufficient area of contact between the structural elements of the grip and the stems of the plants, in which the stems of the plants would not be squeezed (not excessively thinned) and would not break when a vertical load is applied during their pulling out. Otherwise, the root system will remain in the ground, and as a result, damage to the aboveground part will begin to develop vigorously root growth. In the cutting zone, the working body must ensure the cutting of the trunks of the tree and shrub vegetation growing in the immediate vicinity of the main tree species. In this case, the installation operator must be able to visually check the cutting area in order to prevent accidental damage to the main tree species.

In the course of the work, three layout schemes (Fig. 1) were proposed, differing in the location of the working zones: the zone of pulling out or uprooting and the cutting zone. The first scheme (Fig. 1a, 1b): the zones of uprooting and cutting are located next to each other. Such a scheme is structurally simple to implement, the operator is provided with a good view of both the lifting zone and the cutting zone, but at the same time the overall dimensions of the structure in the horizontal plane increase. The second scheme (Fig. 1c): the grubbing zone is the main zone, and the cutting zone is created as needed by rotating the bounding box with the cutting body from horizontal to vertical position. This scheme has a compact design in the horizontal plane with a folded cutting zone. Also, when the cutting working area is folded, the cutting bodies are as far away from the soil surface as possible, which minimizes the likelihood of their contact with large obstacles on the soil surface, for example, boulders, and, consequently, the likelihood of their mechanical damage. But this scheme is more complicated in terms of its constructive implementation, which leads to a slight increase in the metal consumption of the structure and, as a consequence, to a decrease in the useful load moment of the manipulator. It should be noted that with such a layout scheme, the cycle time increases when performing the operation of cutting off trees and shrubs, associated with the time spent on bringing the cutting tool from the transport position to the working position.

The third scheme, Fig. (1d): the zones of uprooting and cutting are located one above the other. With this arrangement, small overall dimensions of the device in the horizontal plane are provided, but the overall dimensions in height increase. In such a scheme, due to the increased distance from the soil surface to the level of the gripping jaws located in the uprooting zone, it is impossible to capture low-growing vegetation. In addition, as the grip level shifts from the root

collar to the apex, the stem becomes thinner, which means that the load it can withstand decreases and the likelihood of the stem breaking and leaving its roots in the soil increases.

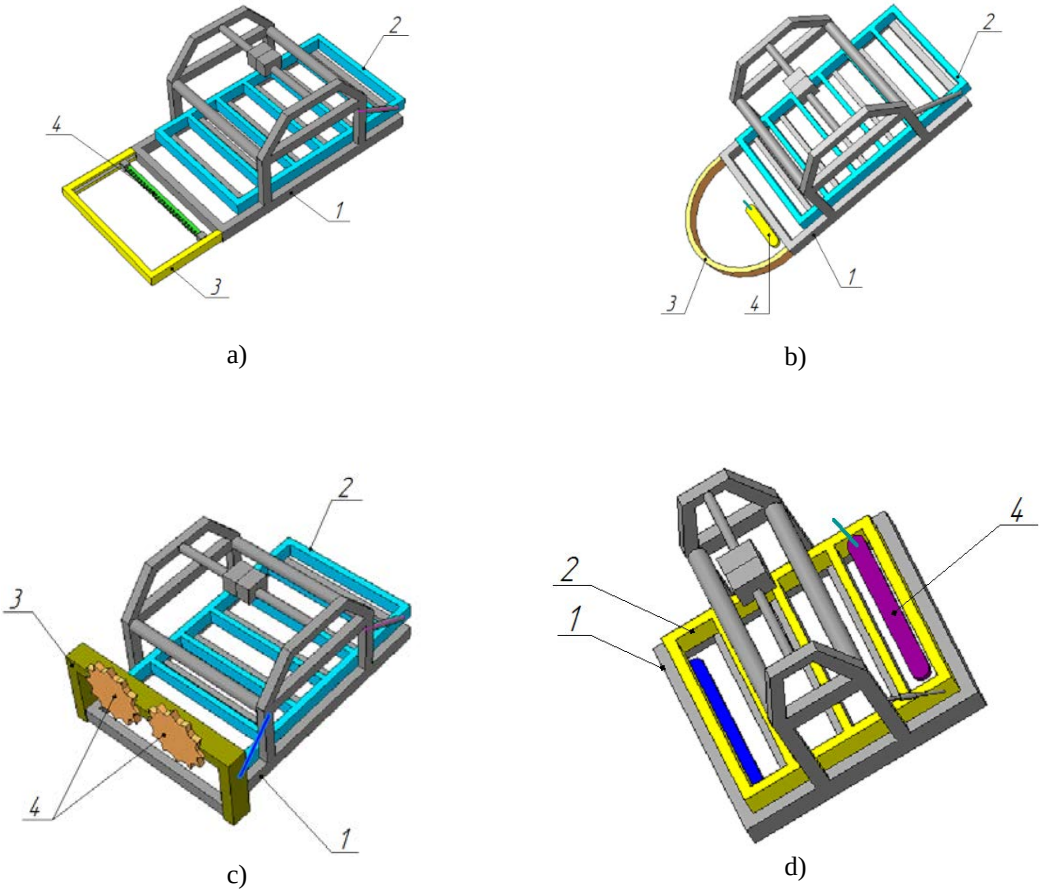

Fig. 1. Mounted working body.

The mounted working body (Figure 1) for combating unwanted vegetation includes a frame 1 with transverse rods, a grid 2 movable relative to the frame, also equipped with transverse rods, a limiting frame 3 and a cutting executive body 4.

A hinged working body mounted on a manipulator of a forest tractor is brought to the zone of removal of trees and shrubs and lowered onto it, moving in a vertical plane. In this case, the trunks of tree and shrub vegetation are inside the frame, then by displacement of the movable grate they are clamped between the transverse rods of the frame and the movable grate. Further, the mounted working body is lifted together with the tree and shrub vegetation clamped in it and thereby pull it out of the soil together with the root. If it is necessary to cut tree and shrub vegetation, the working body is lowered near the tree of the main species and the cutting executive body is used to cut the trunks of trees and shrubs that are inside the limiting frame. By the position of the limiting frame, the operator controlling the work of the working body controls the cutting area and makes sure that no damage to the main tree occurs.

As a cutting working body, various designs can be used, for example, in the form of a motorcycle shears (Fig. 1a), disk type (Fig. 1c), in the form of a chain saw (Fig. 1b). Also, the

enclosing structural elements of the cutting zone can have a different geometric design, which affects the convenience of work.

The novelty and industrial applicability of the found technical solutions is confirmed by patents of the Russian Federation:

- patent of the RF 199670, priority dated 05.12.2020. “Hinged working body for forest care” (Shegelman et al., 2020a);
- patent of the RF 200052, priority from 04.28.2020. “Hinged working body of a forest machine” (Lukashevich et al., 2020a);
- patent of the RF 198849, priority from 04.14.2020. “Working body for the fight against unwanted tree and shrub vegetation in the care of the forest” (Vasilev et al., 2020);
- patent of the RF 198850, priority from 04.14.2020. “Working body of a forest tractor for forest care” (Lukashevich et al., 2020b);
- patent of the RF 198851, priority dated 04.14.2020. “Working body for the removal of trees and shrubs” (Vasilev et al., 2020);
- patent of the RF 198955, priority dated 04.14.2020. “Working body of the machine for forest care” (Shegelman et al., 2020b).

5. Conclusions

The analysis performed by the authors showed a significant lag of the domestic forestry industry from technologies and equipment for forestry operations from the world's leading manufacturers of forestry equipment. A promising direction of work in the field of creating competitive forest machines is the creation of modular forest machines, which is the subject of a number of works (Malyukov et al., 2014), as well as research in the field of creating modular systems of cutting machines (Malyukov et al., 2014).

In the course of the work, on the basis of the results of the conducted information search, the following were studied: the features of technological operations with various methods of removing trees and shrubs by mechanical means; equipment, both domestic and foreign, used in the removal of trees and shrubs by mechanical means and its design features.

With the use of functional-structural-technological analysis, several design versions of a universal technical device have been developed, which combine the advantages of methods for removing undesirable tree and shrub vegetation, both by cutting its trunks and by pulling it out by the root.

At present, the specialists of Petrozavodsk State University are working on modeling the structures described in the work in order to establish their most optimal parameters, designs, operating modes, taking into account various natural and production conditions.

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