Devices for trimming trees in urban areas

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Abstract. In an urban area, the care of large trees is problematic. When they age, branches, peaks should be trimmed. The use of logging machines is hampered by their large size and also significantly pollutes the urban environment, due to significant emissions of harmful substances into the atmosphere. In addition, the felling and delimbing process itself is not safe, and its use in an urban environment poses a threat to human life, the integrity of buildings and infrastructure. In most cases, to solve such problems, special workers (arborists) are used, who either climb onto the tree trunk, or are in the crane basket and cut the tree piece by piece. Such technologies are costly, unsafe and, at times, can cause inconvenience to others. The design and a detailed algorithm for the operation of a device are presented, which allows you to cut branches and trunks of trees and ensure their controlled descent to the ground without a threat to people and infrastructure. In this case, the operator controls the installation remotely. The device consists of movement and delimbing mechanisms, a chain saw for pruning large branches and tree tops, and a system for lowering the cut parts to the ground. The analysis showed that the proposed device is more effective than its counterparts and tree pruning by arborists.

1. Introduction

Currently, the state of the environment in many settlements is unsatisfactory [1]. Therefore, green spaces located in parks, residential areas and along roads are of particular interest. But the more the trees approach the places of human activity, the more often it becomes necessary to care for them. One of the main measures for the correct maintenance of urban green spaces is crown pruning. The greatest attention in these works is paid to emergency trees, by which today it is customary to mean plants that, if dropped, can damage buildings, communications, as well as harm the health of people and animals [2].

There are many machines available for felling and delimbing trees [3-9]. However, their use in urban environments is problematic. At the same time, most of the used machines and equipment for delimbing

pollute the environment due to the presence of an internal combustion engine. Many organizations responsible for these trees are forced to hire special workers (arborists) who either climb the tree trunk or sit in a crane basket and trim the tree piece by piece. Such technologies require significant material and financial costs, and are also unsafe. To reduce the probability of death when pruning trees, it is necessary to remove the human factor when cutting tall-growing branches and the upper part of the trunk. As a result, the purpose of this study is to develop a device design for remote tree pruning within the city without a threat to human life, the integrity of buildings and infrastructure and infrastructure and also ensuring the reduction of the environmental impact on the urban ecosystem.

2. Materials and methods

In this study, an analytical method for working with information was applied, as well as a computer simulation method, with the help of which drawings and 3D model of the device were made.

3. Results

Within the framework of this study, an effective device for remote tree pruning in an urban environment with omnidirectional wheels for moving along a tree trunk [10] was developed, presented in figure 1. It allows you to cut branches, branches, tops in the vertical position of the tree. In this case, the operator controls the installation remotely. Heavy equipment is not used for the operation of the installation, which is an actual advantage in urban conditions, and also ensuring the reduction of emissions of harmful substances into the atmosphere.

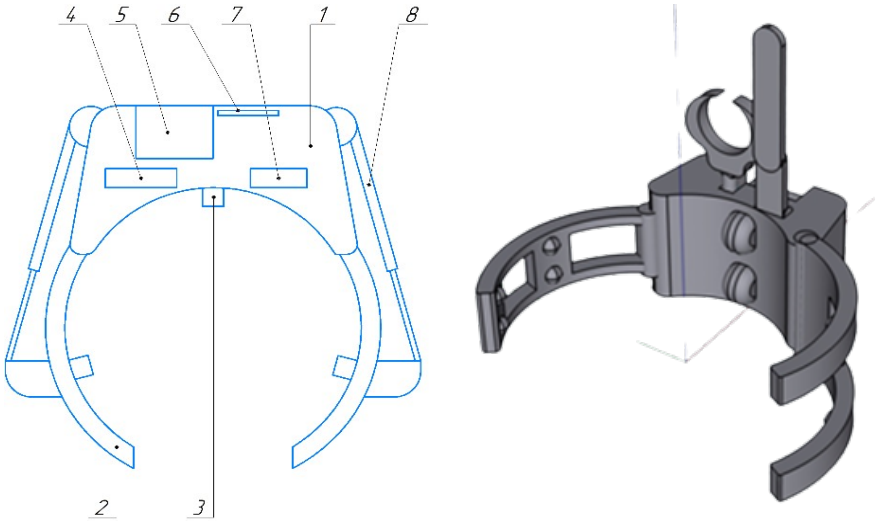

Figure 1. Schematic and 3D model of a device for remote tree pruning within the city: 1 – case; 2 – a mechanism for grasping a tree trunk; 3 – omnidirectional wheels for movement along the tree trunk; 4, 5 – cable assembly system with tensioner and spring mechanism; 6 – control and monitoring board; 7 – electric chain saw.

The operation algorithm of the device for remote tree pruning within the city is as follows [11-12].

The operator starts the device, turns on its control panel and presses the button responsible for the operation of the jaws, the signal is transmitted to the motion control unit, after which the simultaneous synchronous opening of the jaws occurs.

The device is brought to the bottom of the tree trunk, presses the button again, the signal is transmitted to the motion control unit and to the drive, which closes the jaws with the help of a hydraulic cylinder and a synchronizer rod. The device closes the jaws until the omnidirectional wheels

mounted on the device body are firmly pressed against the tree trunk due to the compressive force acting on them.

After fixing the device to the tree, the operator, by pressing the corresponding buttons on the control panel, can transmit to the device the commands "move up along the trunk", "move down along the trunk", "rotation clockwise perpendicular to the axis of the trunk", "rotation counterclockwise perpendicular to the axis of the trunk of tree". By pressing one of the proposed buttons, the operator transmits a similar command to the control system, motion control unit, drive, mechanical travel system and controls the movement of the device along the tree trunk, directing it to the branches that need to be cut.

Sensors located in the immediate vicinity of the electric chain saw detect the nearest branch to which the device approaches, determine the distance to it and transmit the information to the remote control. After receiving and processing the information, buttons appear on the display that are responsible for releasing the building bracket with a cable attached to it into the part of the tree that will be cut, and turning on the electric saw.

If the operator identifies the nearest branch or bough as the one that needs to be cut, he, by pressing the corresponding buttons that appear on the display, sends a command through the motion control unit to the trigger mechanism of the staple or the electric saw drive. Thus, he first carries out the attachment of the construction bracket to this part, and then turns on the electric saw and, rotating the device perpendicular to the axis of the trunk, performs a cut. If the operator believes that the nearest branch or bough does not need to be cut, then he continues to control the movement of the device along the trunk.

After cutting any of the parts, the previously attached cable is thrown over the stationary block and automatically instantly tensioned, allowing the cut part to hang in the air. After tightening the cable, the device transmits information to the remote control, which displays a button on the display, which is responsible for the gradual descent of the part of the tree hanging on the cable

By pressing the button that appears on the display of the remote control, the operator transmits a command to the cable system engine, which, while the button is held down, slowly lengthens the cable, lowering the attached part of the tree to a height at which the operator can detach it. The operator disconnects the cut part from the cable, presses the corresponding button on the control panel, after which the cable system engine returns the cable to its initial position in order to prepare for the descent of the next branch.

Then the operator repeats the listed points until all branches and bough es are cut off. If after that the operator needs to cut off the upper part of the tree trunk, then he has the opportunity to switch the device to the mode of cutting the trunk by pressing a special button on the control panel. This button will send a command to the motion control unit, which will turn on the motors designed to position the saw perpendicular to the trunk axis and turn the shackle trigger towards the tree trunk. In this mode of operation of the device, the cut will be made not due to the rotation of the device, but due to the servo drive, which changes the angle of inclination of the electric saw.

After completing the work, the operator moves the device to the lower part of the trunk, presses the button responsible for the work of the jaws, the jaws open and the operator removes the device from the tree.

The performance of this device is calculated using the formula:

$$N = \frac{(T_{sh} - T_1)k}{T_2 + \upsilon l + (T_3 + T_4 + T_5)n}, \quad (1)$$

Where N is number of trees processed per shift, pcs; T_{sh} – shift time, s; T_1 – preparatory-final time, s; k – coefficient of working time utilization; T_2 – time of fixing the device on the tree, s; υ – speed of movement of the device on a tree, m/s; l – tree height, m; T_3 – time of cutting a branch and bough, s; T_4 – time of attachment of a branch and bough to the the lowering mechanism, s; T_5 – time of descent of a branch and bough to the ground and ascent of the cable back, s.

The execution time of operations is influenced by many factors, both natural and the conditions of the surrounding urban environment.

As part of the research, the performance of the device was calculated under various favorable and unfavorable conditions, depending on the number of branches cut on the tree. The results are shown in the graph in figure 2.

The result of the review showed that there are such analogs: Pruning robot [13] (figure 3), PFP tree trimmer [14] (figure 4).

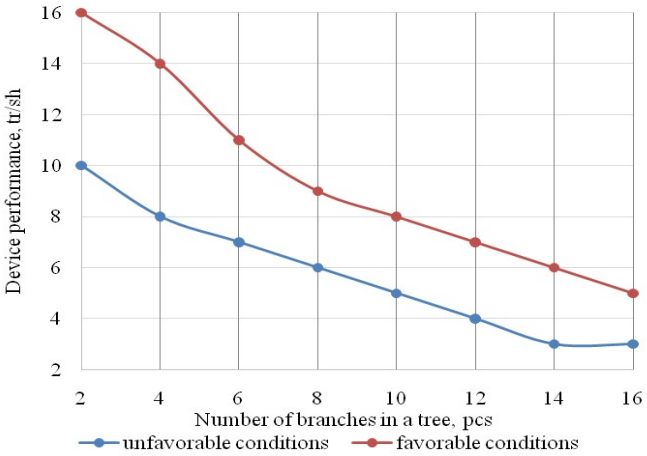

Figure 2. Dependence of the shift productivity of the device on the average number of branches on the processed tree under favorable and unfavorable conditions.

Figure 3. Tree trimmer Pruning robot.

Figure 4. Tree trimmer PFP.

In contrast to the proposed device, pieces of wood cut off by the presented analogs freely fall down, therefore they can damage infrastructure, buildings and structures located nearby or cause harm to people. All analogs have limitations in trunk diameter or tree height. Due to its design and formula, the proposed device covers a wide range of different parameters of trees. So a given device for remote pruning of trees within the city can be competitive in the market for similar devices and cope with the existing problem.

4. Discussion

As a result of the research, it can be concluded that pruning trees in settlements without a threat to human life, the integrity of buildings and infrastructure is an urgent problem, the optimal solution to which has not yet been found. Most of the existing devices and methods of pruning are not intended for settlements, where cutting off parts of a tree and lowering them to the ground must be done as carefully as possible, because any careless movement can cause damage to structures or people.

The proposed device will be able to solve the existing problem, since it has all the necessary characteristics for this and combines one of the promising technologies for delimbing. Also, this

design allows you to reduce the volume of emissions into the atmosphere due to the use of an actuator drive from a low-power internal combustion engine or an electric motor powered from the mains.

5. Conclusion

As a result of the research, the technologies and design features of the equipment for delimbing were studied. On the basis of a critical analysis, the main shortcomings of the existing equipment were identified and their own design was proposed, developed on the basis of 3D modeling. The proposed device for delimbing has a remote control system, the executive elements of which are equipped with an electric drive and provide the ability to select, fix, prune and lowering branches to the ground that must be removed, and also allows you to reduce the volume of emissions into the atmosphere. At the same time, on the basis of the carried out theoretical studies, the shift productivity was determined, which varies in a wide range (3–16 tr/sh) and depends on the number of branches and operating conditions.

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