Electromechanical stand for the process of throwing soil with a cutter-thrower

M A Gnusov¹, M V Drapalyuk, D Yu Druchinin and L D Bukhtoyarov
Ministry of Science and Higher Education of the Russian Federation, Voronezh State University of Forestry and Technologies named after G.F. Morozov, 8 Timiryazeva Street, Voronezh 394087, Russian Federation

¹E-mail: mgnusov@yandex.ru

Abstract. Every year in all countries of the world there are natural disasters, including forest fires. Quality wood is lost. Today the problem is dealt with both by research teams and production companies. The article presents one of the methods for studying the throwing process and adjusting the adequacy of simulation models. The creation of an electromechanical stand for the process of throwing loose elements allows you to monitor the process of separating portions of soil from the main layer, as well as track and digitize movements in molasses with various characteristics of the entire system under study.

1. Introduction
Despite the fact that fires bring diversity to the natural ecosystems of our planet, opening up the possibility of renewal of species biodiversity [1], they are a dangerous natural disaster that requires prompt elimination in the event of its occurrence [2]. The use of soil for churning, filling and stopping the edge of a forest ground fire is carried out manually or using mechanized equipment to extinguish a forest fire with soil [3]. Methods of mechanization and automation of the process of preventing and eliminating forest fires have been actively developing in recent years not only in the territory of the Russian Federation, but also in other countries of the world [4, 5, 6, 7, 8]. Domestic and foreign teams of scientists carry out scientific research aimed at increasing the efficiency of forest fire suppression, including with the help of soil [9, 10, 11]. The complexity of the mechanical system, which requires directing and collecting portions of soil into a general flow to extinguish a fire, requires a step-by-step study and a separate study of each structural element. The formation of a portion of the soil includes raising it to the level of the soil surface (figure 1, a), separation from the blades of the cutter (figure 1, b), the supply of a mechanical impulse (figure 1, c), which is necessary for the passage of the site with the subsequent direction of the soil area to the required quantity at a given distance (figure 1, d). The process proceeds quickly, with the formation of a dust cloud in the area of the blades of the milling body.
Figure 1. Scheme of the phased formation of a portion of soil.

The development of machines for extinguishing forest fires with soil, the working body of which is made in the form of a cutter with blades throwing soil, and the study of their working processes is carried out on specially created laboratory installations or prototypes.

In 2012, it was created by a team of scientists from Voronezh State Forestry University named after G.F. Morozov under the guidance of professors of the Department of Forestry Mechanization and Mechanical Engineering M.V. Drapalyuk and I.M. Bartenev. A combined machine for extinguishing a forest fire with soil and laying mineralized strips has been developed and manufactured [12]. The team was faced with the task, firstly, to increase the efficiency of preventing and extinguishing ground forest fires by throwing soil, and secondly, to develop a combined ground-throwing machine that combines the process of spreading soil and creating mineralized strips, such as the PF-1 cannon and type GT-3, respectively, which reduces the greatest costs for design, industrial production, operation and storage of equipment. Laboratory studies were aimed at studying the creation of an optimal flow by carrying out preliminary preparation of a soil shaft using spherical discs (figure 2) [13].

Figure 2. Soil strip-laying machine.

In 2016, these studies were continued in the work of D.S. Stupnikov under the guidance of Professor M.V. Drapalyuk. The aim of the work was to increase the efficiency and quality of preventive work, as well as to directly extinguish forest fires by justifying the parameters and operating modes of the machine for extinguishing forest fires with soil. The peculiarities of the principle of action of the soil gun are that the soil is delivered to the milling cutter-thrower without additional forced lifting. The
separation of soil from the monolith occurs in portions and is directed into an open window in one of the sides of the movement of the unit [15].

![Figure 3](image)

**Figure 3.** Prototype forest fire ground-throwing machine. 1 - hydraulic motor; 2 - pneumohydroaccumulator; 3 - high pressure hoses.

A device for extinguishing a forest fire proposed in [16]. Made on the basis of a closed car. The unit is supposed to be used in the active phase of extinguishing with the possibility of entering the complex directly into the zone of fire development and throwing sand at the edge of the forest fire.

One of the well-known samples of ground-throwing equipment is a series produced by the Spanish company EXiT
tt [17].

![Figure 4](image)

**Figure 4.** Soil-throwing equipment from the EXiT
tt company.

The name in Spanish «extinción incendios tierra-tierra» sounds like a ground fire extinguishing unit. The company has developed and created several samples of units capable of extinguishing a forest fire using soil. Soil-throwing machines work mainly on light soils.
2. Materials and methods

The development and creation of a full-fledged unit has both positive and negative sides, which impose their own time and economic constraints. Resource conservation is one of the main challenges facing society. The development of simulation models reduces the number of experiments required. The development of models in CAD programs allows you to optimize the shape of the unit being created, reduce the energy consumption of the structure, and increase the manufacturing accuracy. The results obtained using software products necessarily require confirmation in the course of experimental studies [18, 19].

Modern opportunities offer various solutions to the identified problems of reducing the energy consumption of processes, cost-effective processes, versatility of the created and developed units and stands. Additive technologies allow you to print models to optimize shape and design, complex elements and assemblies. They also allow you to create milling and milling-throwing working bodies. We have developed and created in the program for engineering calculations a stand for studying the process of throwing and flight of soil particles (figure 5).

![Figure 5. Model of a stand for throwing soil particles with a cutter. 1 - box; 2 - stepper motor; 3 - carriage; 4 - cutter-thrower; 5 - guides.](image)

The cutter is driven by a stepper motor controlled by an Arduino. The wiring diagram is shown in figure 6. The NEMA 14 stepper motor has a 1.7 x 1.7 baseplate and has more torque than comparable smaller stepper motors. This motor has 6 lead wires and operates on a voltage of 12 V. It can also operate on a lower voltage, but its torque will decrease accordingly. With each step, the axis of the NEMA14 motor rotates 1.8 degrees.
The number of steps per revolution (Steps per Revolution) for each specific stepper motor is calculated using the angle by which the stepper motor is rotated in one step (step angle). The A4988 stepper motor driver module controls the operation of the stepper motor by supplying different phases of power to it at the desired time. The A4988 motor driver can control the stepper motor in 5 different modes: full step, half step, quarter step, 1/8 step and 1/16 step. The stand scheme is launched using the program. For the program to work, you need to download a library for controlling a stepper motor using arduino-libraries / Stepper and add it to the Arduino IDE. After assembling the hardware of the project and uploading the program code to the Arduino board, you will be able to control the direction of rotation of the NEMA 14 stepper motor using a potentiometer.

Parameters of the electromechanical stand are calculated through the coordinates of the approximation from the simulation of the movement of the soil and the setting of the main parameters of the developed and investigated space according to the Pythagorean theorem:

\[ r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}. \]

The stand is made using additive technologies, which made it possible to lighten the main units, reduce the time for manufacturing, and also simplify the operations of collecting elements due to the fact that the fitting was carried out in the SolidWorks software.
For laboratory studies of the milling-throwing working body, an electromechanical stand was developed for adjusting the model of throwing soil particles in a given direction, which allows you to get an idea of the system and conduct laboratory studies with various parameters of the working body, rotation frequency, environment and operating conditions of the mill-thrower. On the basis of a series of experiments, in which the parameters of the installation of the geometric shape of the cutter-thrower and the physical and mechanical properties of bulk elements are changed, the nature of the effect of the parameter is established and recommendations are given for choosing the optimal values of the parameter of the working element and the conditions of use.

The design of the electromechanical stand for a complete presentation of the system must correspond to the high accuracy of detailing the main parameters and the properties being laid in order to correctly reproduce the movement of the soil, with a high temporal resolution, to reproduce the interaction of the working planes of the cutter-thrower with the soil (or its imitation in the form of other particles of bulk material) in the process of throwing it and moving it in the air.

The proposed research methodology is focused on using the capabilities of modern technical means and computers. Within the framework of the approximation, the soil is represented as a set of a large number (about $10^3$–$10^5$) of individual elements. The sizes of the elements can be either the same to simplify the study, or different to exclude the adverse effects of the periodicity of the close packing of the elements. Soil elements mechanically interact both with each other and with the working surfaces of the investigated cutter-thrower.

3. Conclusions
The data obtained in the course of a series of experiments are processed by methods of statistical processing of research results or digitized using machine vision. And they can be used to set up simulation models based on the received data about the system. A prerequisite is the analysis of already known data, which are laid down in the form of the parameters of the thrower cutter-thrower.

Acknowledgments
The reported study was funded by RFBR, project number 19-38-60041\20.

References
[1] Pausas J G and Keeley J E 2009 A Burning Story: The Role of Fire in the History of Life BioScience 59(7) 593-601 doi:10.1525/bio.2009.59.7.10
[2] Bartenev I M, Malyukov S V, Gnusov M A and Stupnikov D S 2018 Study of efficiency of soil-thrower and fire-break maker on the basis of mathematic simulation int. Journal of Mechanical Engineering & Technology 9(4) 1008-18
[3] Drapalyuk M V, Popikov P I, Stupnikov D S , Sharov A V and Sherstyukov N A 2019 Increasing
the efficiency of the working process of a forest fire ground-sweeping machine with an energy-saving hydraulic drive of the throwing rotor Forestry journal 1(33) 147-52

[4] Orlovsky S N 2004 Justification of the technology of application and layout of the tractor forest fire ground gun Proceedings of higher educational institutions Forest Journal 3(339)

[5] Drapalyuk M V et al. 2019 Forest fires: methods and means for their suppression IOP Conference Series: Earth and Environmental Science 226 012061 http://dx.doi.org/10.1088/1755-1315/226/1/012061

[6] Afzal H and Zafar N A 2016 Robot-based forest fire detection and extinguishing model 2nd International Conference on Robotics and Artificial Intelligence (ICRAI) http://dx.doi.org/10.1109/icrai.2016.7791238

[7] Sivaram P, Kumar M and Rajasekaran S 2012 Line based Geometrical Path Planning Algorithm for Extinguishing Forest Fires International Journal of Computer Applications 52(8) 22-6 dx.doi.org/10.5120/8222-1650

[8] Kuznetsov G V, Piskunov M V and Strizhak P A 2017 How to improve efficiency of using water when extinguishing fires through the explosive breakup of drops in a flame: Laboratory and field tests International Journal of Thermal Sciences 121 398-409 dx.doi.org/10.1016/j.ijthermalsci.2017.08.004

[9] Gedjo V M, Dubovyi V K and Leonovich A A 2019 New ways and means of localization and extinguishing surface forest fires IOP Conference Series: Earth and Environmental Science 316 012005 dx.doi.org/10.1088/1755-1315/316/1/012005

[10] Narita D, Gavrilyeva T and Isaev A 2021 Impacts and management of forest fires in the Republic of Sakha, Russia: A local perspective for a global problem Polar Science 27 100573 dx.doi.org/10.1016/j.polar.2020.100573

[11] Rodríguez-Veiga J, Ginzo-Villamayor M and Casas-Méndez B 2018 An Integer Linear Programming Model to Select and Temporally Allocate Resources for Fighting Forest Fires Forests 9(10) 583 dx.doi.org/10.3390/f9100583

[12] Drapalyuk M V, Bartenev I M, Goncharov P E, Bukhtoyarov L D, Popikov P I, Gnusov M A, Druchinin D Yu and Markov O B 2013 Patent RF128887

[13] Bartenev I M et al. 2012 Combined forest fire-fighting ground gun and recommendations for its use Polymathematic network electronic scientific journal of the Kuban State Agrarian University 84

[14] Drapalyuk M V, Goncharov P E, Stupnikov D S and Sharov A V 2016 Forest Fire Ground Thrower Patent RF2616021

[15] Drapalyuk M et al. 2019 Improving the efficiency of the working process of forest fire soil throwing machine with hydraulic rotor Forestry Engineering Journal 9(1) 151-6 Available at: http://dx.doi.org/10.12737/article_5c9201707790a1.57571839

[16] A fire truck that suppresses fires without water [Electronic resource]. URL: https://wildfireroday.com/2011/03/27/a-fire-truck-that-suppresses-fires-without-water/ (date of the application: 11.04.2020)

[17] Dirt throwing machine for suppressing wildfire [Electronic resource]. URL: https://wildfiretoday.com/2011/07/04/dirt-throwing-machine/ (date of the application: 11.04.2020)

[18] Lysych M N 2020 Study of driving dynamics of modular forestry tillage machine-tractor units in CAE SolidWorks Motion IOP Conference Series: Earth and Environmental Science 595(1) 012024

[19] Lysych M N 2020 Study driving dynamics of the machine-tractor unit on a virtual stand with obstacles Journal of Physics: Conference Series 1515(4) 042079