Research and development of the method of soil formation and delivery in the form of a concentrated flow to the edge of moving ground forest fire

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Research and development of the method of soil formation and delivery in the form of a concentrated flow to the edge of moving ground forest fire

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Abstract. This paper provides an overview and analysis of existing tools and machinery for fighting ground forest fires. The paper examines theoretical issues of applying soil-thrower machine to extinguish forest fires. In the paper, the information database on the usage of existing technology in modern conditions is studied in order to evaluate the effectiveness of the usage of new technology. The design of the presented machine makes it a universal one, replacing two technological units and thereby reducing the material consumption of technological process of extinguishing fire with soil and laying firebreaks; it increases the amount of ground to extinguish the fire, increasing efficiency in the fight against fire, as well as the traveling speed of the unit and its performance.

1. Introduction

Forests are important part of the ecosystem and they play a significant role to preserve and maintain the environment. The main hazard is forest fires because its consequences are terrible in nature. Therefore, there is a need to detect and extinguish fire before it spreads to destroy the resources [1]. Forest fire spreading is a complex process affected by multi-factors. Understanding the relationships between these multi-factors and forest fire spreading trend is vital to predicting the fire spreading promptly and accurately to make the strategy in forest fire extinguishing [2-11].

A forest fire is an uncontrolled wildfire spreading in a wooded area. The causes of forest fires are commonly classified as natural or anthropogenic. Usually lightning is the most common natural cause of big forest fires on Earth. Today, the proportion of fires that are natural (caused by lightning) is 7%-8% of the total, i.e. most forest fires are caused by human activities. Therefore, there is an urgent need for the work of fire services and the regulation of the observation of fire safety requirements.

Sometimes fires are artificially induced. Such fires are generally referred to as controlled. The objective of controlled fires is: the destruction of fire-hazardous combustible materials, the disposal of wood wastes, the preparation of plots for the planting of seedlings, the control of pests and forest diseases etc., as well as the intentional triggering of forest fires for the purpose of further felling (e.g. in the Russian Far East areas bordering with China).

Recently the summer in Russia has been unusually hot and dry. The heat is causing large forest fires, which did not happen previously. Lives are lost, many houses and much infrastructure are destroyed, and hundreds of thousands of hectares of forest are burned. In view of these events, requirements for forest protection have increased. At present, there is a dramatic increase in resources for fire management and material resources for forest fire-fighting agencies. This results in the
continuous search for new means of forest fire fighting, as well as the perfection of existing methods and technical means. It is a well-known fact that it is easier to detect and extinguish a fire at its early stages than to fight an already-raging force [12].

The research objective is increasing the performance efficiency of the soil-thrower/fire-break maker by means of removing the upper inflammable coating consisting of vegetable debris.

2. Experimental Part

Water is the most widespread way of fighting forest fires. It is used for extinguishing upper, ground and soil forest fires, whereby, depending on the type of fire, fire spreading conditions, the availability of water and the type of the used machines. The application of this fire-fighting method can be used for localization, as well as complete extinguishing of forest fires.

Water is taken from lakes, rivers, springs and other water bodies close to the fire or supplied in fire-fighting tank vehicles and in tanks of special forest fire-fighting units.

Water pump units of fire-fighting tank vehicles, plunging pumps operating from tractor engines, fire power pumps (portable, trailed, small-sized) and forest fire extinguishers [12] are used to extinguish forest fires.

Fire extinguishing is also performed with the help of airplanes and helicopters. Extinguishing fires with the help of aviation is very expensive and not always efficient. If there is a large fire area perimeter and complicated fire edge, single discharges even of large quantities of water on limited areas do not produce significant effects. It is difficult to discharge water exactly along the fire edge. It is also difficult to define the particular location of the ground fire edge due to smoke shift and total smoke coverage. Additionally, another disadvantage of fire-fighting aviation is the need for very time-consuming refueling. Use of fire-fighting aviation considerably complicates the work of other fire brigades because of the injury risk when discharging large quantities of water. Use of fire-fighting aviation to a great extent is justified in case of intensive upper fire reaching important infrastructure. It is expedient to extinguish ground fire using cheaper and more effective methods.

One of the most well-known and widely used methods for extinguishing ground forest fires is making a mineralized fire break at some distance from the fire and throwing soil for suppressing the fire. Making mineralized fire breaks is preventive and precautionary measure. Fire breaks are made on the borders of wooded lands adjacent to railroads, agricultural lands, highways, livestock farms, settlements and other objects.

It is not beneficial and sometimes impossible to fight forest fires with water and with fire-extinguishing compositions because of the origin area of the fire, use of soil for forest fire extinguishing has a great potential, as there is always large quantity of soil in close proximity to a fire.

The simplest tools used for preventing and extinguishing ground fires are reversible forest ploughs. It is also possible to use forest share ploughs PL-1; PLP-135; PKL-70; PKLN-500 and others (manufacturer - LesPromResurs Plant, Russia). Disk ploughs PLD-1.2; PDV-1.5; PD-0.7, diskers BDNT-2.2; BDST-2.5; ditchers and other tools have also worked well (manufacturer - PA LESAGROMASH LLC, Russia). Cultivator KLB-1.7 is usually used for restoration (manufacturer - Leskhoznab LLC, Russia).

Application of well-known machines such as fire-break maker PF-1 and soil-thrower GT-3 (manufacturer - Federal budget institution St. Petersburg Research Institute of Forestry) is hindered by the fact that they are developed for operation on light soils, do not create a soil layer when extinguishing the fire edge that rules out repeated inflammation or fire continuation and have weak anti-inflammatory protection. In these machines soil is ejected at a right angle to the fire edge. Moreover, they are very specialized machines, which increase their maintenance and operation costs, and they are not sufficiently effective in conditions of changing mesorelief in the machine’s path. Among foreign soil-thrower machines tractor soil-thrower machine - ditcher developed by the company Dynamics Corporation of America should be noted (USA).

There are also heavier forest fire-fighting machines based on caterpillar forestry tractors like LHT-100 and TLP-4M (manufacturer - Onega Tractor Plant, Russia). Such machines are very expensive
and specialized ones, therefore, only special forest-fire centers have them. The control areas of centers cover substantial territories, therefore such technology is transported in trailers by public roads to the location of faraway trailers, making arrival and readiness time is significant.

Highly mobile variants of forest fire-fighting machines are developed on the basis of amphibious vehicles, light and main tanks, military tractors and armored vehicles. As a rule, such machines have high productivity and are used for fighting large-scale forest fires. The cost of such machinery is extremely high.

Currently developed forest fire-fighting vehicles based on GAZ-3307 model have been developed (manufacturer - Auto-Profi LLC, Russia). Towing performance abilities of such vehicles are strongly limited and they are unable to move through low forest cover. Their transmission cases are not protected against possible impacts with stubs and deadwood, while the fire team is not protected against trees falling in the forest fire. Besides, the stock of these extinguishing agents is limited and the soil tillage fire-fighting method is ignored.

Even less suitable for extinguishing forest fires are maneuverable, light forest patrol and forest fire-fighting complexes based on SOBOL and UAZ vehicles (manufacturer - Gorky Automobile Plant, Russia). Such vehicles are able to perform patrolling, auxiliary functions (e.g. communication, delivery of light equipment or crew, etc.) and to extinguish fire with water. The stock of these extinguishing agents is limited; the application of the soil tillage fire-fighting method is impossible due to the low towing performance abilities of basic chassis.

The objective is achieved by inserting a device in the form of a reversible auger into the soil-thrower/fire-break-making structure and installing it in front of the disks. The auger moves the soil cover from the center to the left and right, forming an open, mineralized fire break. Within this fire break the cultivator tooth and disks form two shafts in the form of continuous microhills of loose soil. Cutter-throwers provide throwing soil separately in different directions, as well as in the direction of the fire. Cutter-throwers are placed a certain distance from each other in the longitudinal direction. They turn on a vertical axis and are installed with the help of a remote hydraulic cylinder at an angle from the unit movement direction. The auger is driven through the mechanical transmission from the tractor power-take off shaft. Cutter-throwers are driven through hydraulic motors.

General view of the fire soil-thrower and fire-breaking maker is shown in Figure1.

The fire soil-thrower and fire-breaking maker is comprised of frame 1, attachment mechanism 2, auger 3, cultivator 4, spherical disks 5, cutter-throwers - front 6 and back 7, gearbox housing 8 with axes of cutter-throwers placed in it, connected with hydraulic motors 10, remote hydraulic cylinder 11 for turning the soil throwers in the horizontal plane around the vertical axis 19 together with guiding jackets 12. The auger is driven 3 from the tractor power-take off shaft through the driveshaft 16, chain drive 18 and gearbox housing 17. Shank 13 of the cultivator tooth 4 is pivotally connected to the frame 1. The cultivator tooth has a knife 15, with the help of which the cultivator tooth can swing behind and up when encountering an obstacle. Under the influence of draw spring 14 after overcoming the obstacle the cultivator tooth returns to its initial working position [13].

The fire soil-thrower and fire-breaking maker works in the following way: when the hydraulic system and the tractor power-take off shaft are switched on, cutter-throwers 6, 7 are accordingly activated through individual hydraulic motors 10 and auger 3 through driveshaft 16, chain drive 18 and gearbox housing 17. Guiding jackets 12 are installed with the help of guiding plate 9 at angles corresponding to the technical process and soil ejecting distance.

At forward movement of the unit, the rotating auger moves the soil cover to both sides. The cultivator tooth and spherical disks deepen into an open mineralized layer. They loosen the soil and form two microhills in the form of continuous shafts. Next, the cutter-throwers clutch and throw the soil to both sides to form a mineralized fire break with increased width, or throw the soil to one side (to the left or to the right, depending on the unit position with regards to the fire edge).

Cutter-throwers with hydraulic drive, guiding jackets and pivot mechanisms are installed so that the soil would be ejected at an angle from the fire edge for more efficient ground forest fire-extinguishing. The basic soil mass remains in the fire edge zone, providing complete fire extinguishing.
3. Conclusion
Thus, the construction of the proposed machine increases the forward speed of the unit and its productivity. It increases fire-fighting efficiency, covering a significantly longer fire edge with soil in comparison with known soil-throwers. It throws the soil directly in the fire zone, avoiding areas affected by fire. The soil ejecting distance is regulated by the angle of installing guiding jackets, as well as by rotor speed of hydraulic motors. Hydraulic motors provide cutter-thrower reversal control.

The application of a completely new technological process including the formation of a shaft from loose soil and its directionally-regulated removal, that are performed by combined operating parts solves the problem of creating a universal machine operating efficiently both as a mineralized fire break maker as well as a ground forest fire extinguisher in any soil-type conditions.

The application of spherical disks installed on cranked axles provides the formation of a soil shaft for directing sufficient quantity of soil to the fire zone by cutter-throwers and go-anywhere mobility in different types of soil conditions. The swing joint of guiding jackets and their remove control with the help of remote hydraulic cylinders driven by the tractor hydraulic system allows the regulation of the soil ejecting distance and volume in a broad range, reducing these factors on the other side of the fire
edge and increasing them in the direction of the fire.

The possibility of integrating a new forest-fighting vehicle with a widely used wheel or caterpillar tractors of classes 2 and 3 solves the problem of its broad application in forestry.

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