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Study of parameters of the working body of the forest machine for removal of woody shrub vegetation

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Abstract. The process of reforestation consists of a set of activities aimed at restoring destroyed or damaged forests. The process of forest restoration is a long one. For successful reforestation it is necessary to carry out measures ensuring effective establishment and growth of forest crops. These activities are carried out in a mechanized way using forest machines with different working bodies. Forest machines for removal of woody and shrub vegetation allow to carry out reforestation works and silvicultural care in forestry. The forest machine with a flat-rotating working body having a vertical axis of rotation can be used for clearing the territory from woody-shrub vegetation for the preparation of the area before planting forest crops and for the subsequent silvicultural care of forest crops. The article presents the normative legal framework that defines the requirements for reforestation and proposes a methodology for creating a standard-size range of the working body of the forest machine for the removal of woody shrub vegetation. The purpose of the work is to analyze the parameters of the working body of the forest machine for the removal of woody shrub vegetation. The analysis is based on the results of scientific research of the work of the flat-rotating working body and the size range created on its basis. The methodology for determining the dynamic parameters of the size range of the flat rotary working body is presented. Object of research: forest machine for removal of wood-shrub vegetation. Subject of the study: the working body of the forest machine for the removal of woody shrub vegetation during reforestation. To achieve the goal of the study the following methods were used: analysis and synthesis of the working body of the forest machine with a flat-rotating working body; modeling of the working body of the forest machine on the basis of the size range.

1Introduction

To ensure reforestation, it is necessary to carry out a set of measures, which includes removal of woody and shrubby vegetation in the process of preparing the area for reforestation and in the future during silvicultural care of forest crops.

Reforestation works are carried out on clearcuts, burned areas, radinas, wastelands, glades and other lands. Reforestation is a costly and time-consuming process that includes the

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selection of species, planting material, as well as special technological and organizational measures with the formation of young trees of valuable tree species [1, 2].

Artificial reforestation is more effective in comparison with natural reforestation. Artificial reforestation improves the vegetation cover and biomass of forest stands [3,4]. In the absence of silvicultural care, natural evolution of forest plantations occurs in the areas, which usually leads to the replacement of valuable coniferous species with less valuable deciduous species [5].

The need to clear areas of woody and shrubby vegetation arises at clearcuts already in the first years after cutting [6].

Methods of removing woody-shrub vegetation are considered in [7]. For this purpose, new technical means are being developed and investigated [8, 9]. The required power of the working body drive depends on the dynamic parameters of the working body [10].

Taking into account the diversity of forest areas for the reproduction of valuable species, let us consider the process of modeling the working bodies of forest machines designed for clearing forest areas before planting forest crops and for the subsequent silvicultural care of forest crops. The purpose of this study is to analyze the parameters of the working body of a forest machine for silvicultural maintenance.

2 Materials and methods

This paper is an empirical study and is based on analyzing the results of a scientific study.

Object of the study: forest machine for removing woody shrub vegetation during reforestation.

Subject of the study: the working body of the forest machine for removing woody-shrub vegetation during reforestation.

The following methods were used to achieve the research objective:

- analysis and synthesis of the working body of the forest machine with a flat-rotating working body;
- modeling of the working body of the forest machine on the basis of the size range.

For a forest machine with a plane-rotating working body designed for cutting and removal of woody shrub vegetation in a size range is presented, made on the basis of the approved rotor of the forest machine. For this working body the tenth decreasing geometric series is defined, the graph of dependence of dimensional numbers of which is presented in Figure 1.

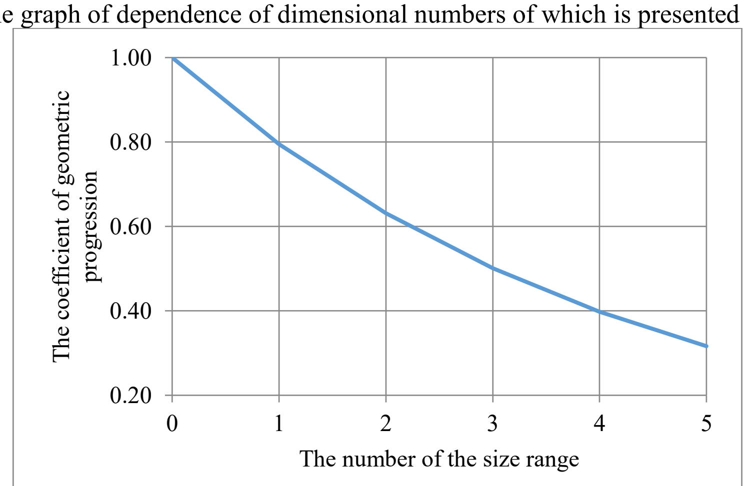


Fig. 1. Decreasing geometric progression (tenth row).

Figure 2 shows the rotor of a forest machine with a flat-rotating working body.

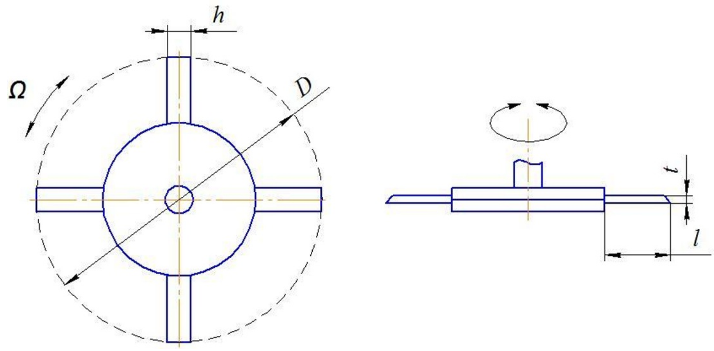


Fig. 2. Rotor of a forest machine with a flat-turning working body.

None of the existing designs of the working body does not fully meet the challenges of silvicultural care [11]. Therefore, research and development of various modifications of working bodies are continuing, taking into account the basic requirements for them [12, 13]. Let us analyze the flat-rotating working body of a forest machine for silvicultural maintenance. The width of the shearing device, which may consist of several flat-rotating working bodies arranged along the width, in the transport position is limited by the value of *2550 mm*. Taking into account the working width of the cutting unit of the forest machine, the following condition can be written down:

$$D \cdot i \leq 2200, mm \tag{1}$$

where D – rotor diameter, *mm*; i – number of rotors, *pcs*.

The value of *2200 mm* is accepted taking into account the structural design of the shearer in the form of a frame structure, which limits the width of the shearer walls. Table 1 summarizes the main characteristics of the size range of forest machine with flat-rotating working body.

Table 1. Size range of forest machine with flat-turning implement.

Name of the parameter	The value of the parameter		
Rotor diameter D, *mm*	550	700	1100
Knife departure l, *mm*	110	140	220
Knife thickness t, *mm*	8	10	16
Knife width h, *mm*	50	65	100

For the subsequent modeling it is necessary to determine the following parameters of the plane rotating working body: kinetic energy L, moment of inertia J and perform the selection of the drive for the rotor.

3 Results and Discussion

The kinetic energy L is determined by the well-known formula:

$$L = \frac{1}{2} J\Omega^2,\ J, \tag{2}$$

where J – the moment of inertia, $kg{\cdot}m^2$; Ω – the angular velocity, *rad/s*.

It is important to understand when designing what parameters to include in the design of the working body. To do this, let's consider the cutting work, taking into account the acceptable reduction in angular velocity of rotation equal to *10%* of the nominal. Then, let's write down the cutting work in the following form:

$$A = \frac{1}{2} J\left(\Omega^2 - (0{,}9\Omega)^2\right) \approx 0{,}1J\Omega^2,\ J. \qquad (3)$$

The cutting work A for the flat-rotating working element of a forest machine can be determined by the following formula [14]:

$$A = 0{,}65\tau_w S k_t l k_D,\ J, \qquad (4)$$

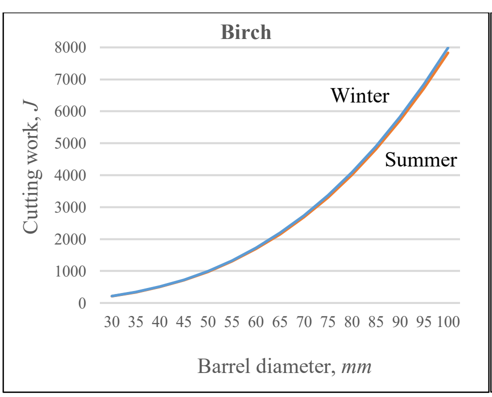
where τ_w – the shear strength, *MPa*; S – the cutting area, mm^2; k_t – temperature coefficient; l – the cut length, m; k_d – the dynamic coefficient.

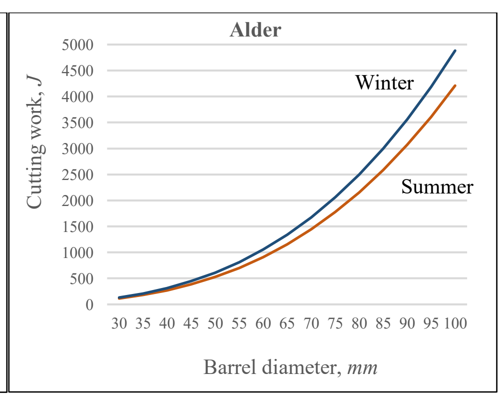
Table 2 presents the data of the shear strength τ_w and the temperature coefficient k_t determined experimentally and presented in [14].

Table 2. A summary table of the experimental data.

Breed	**Strength limit, *MPa***	**Coefficient for temperature**	
		+20ºC	**-14ºC**
Birch tree	9.3	1	1.02
Alder	5.0	1	1.16
Willow	6.5	1	1.23
Pine tree	4.1	1	1.46

Figure 3 shows the calculated data of cutting work for the plane rotary implement determined by formula (4). Depending on the species of tree and shrub vegetation, the dynamics coefficient is assumed to be k_d=*1.65* [14].





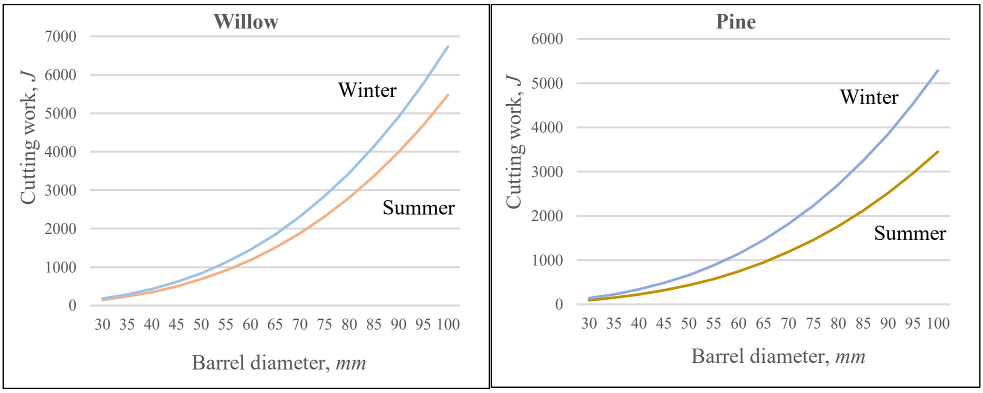


Fig. 3. Calculated data of cutting work for a plane rotary tool.

For preliminary calculations, the rotor moment of inertia can be determined by converting formula (3):

$$J = \frac{10A}{\Omega^2}, \ kg{\cdot}m^2, \qquad (5)$$

where A – cutting work, J; Ω – the angular velocity, *rad/s*.

Assuming a random distribution of trunks over the area, the distance between two trunks is determined by the following formula [14]:

$$r_d = \frac{1}{2\sqrt{n_s}} - d, \ m, \qquad (6)$$

where n_s – number of trunks per $1\ m^2$, pcs/m^2; d – diameter of trunks, m.

The time required to restore the turnover is calculated by the formula:

$$t_v = J\frac{(\Omega - 0{,}9\Omega)}{M} = 0{,}1J\frac{\Omega}{M}, \ m, \qquad (7)$$

where J – the moment of inertia, $kg{\cdot}m^2$; Ω – the angular velocity, *rad/s*; M – the drive torque, *Nm*.

Then, the operating speed of the forest machine can be determined from the ratio:

$$U \le \frac{r_d}{t_v}, \ m/s. \qquad (8)$$

Productivity when placing the working bodies on the front linkage across the width of the forest machine is determined by the formula:

$$P = 3.6 \cdot 10^{-4} \cdot U \cdot D \cdot i, \ ha/hour, \qquad (9)$$

where U – accepted working speed of forest machine, *m/s*; D – rotor diameter, *mm*; i – number of rotors, *pcs*.

Axial-piston hydraulic motors of 310.2.28, 310.2.56 and 310.2.112 models with working volume of *28*, *56* and *112* cm^3/rev respectively are accepted for rotor drive. Calculated parameters of the rotor for the forest machine with a flat-rotating working body are summarized in Table 3.

Table 3. Design parameters of the rotor of a forestry machine with a plane-rotating working body.

Name of the parameter	The value of the parameter		
Rotor diameter, *mm*	550	700	1100
Rotor drive: axial piston hydraulic motor	310.2.28	310.2.56	310.2.112
Hydraulic motor torque, *Nm*	94	188	375
Power consumption, *kW*	28	47	75
Maximum diameter of cut vegetation, *mm*	60	80	100
Cutting work*, *(summer/winter) J*	1691/1725	4009/4089	7830/7986
Rotor angular speed, *rad/s*	199	167	110
Rotor moment of inertia, $kg{\cdot}m^2$	0.44	1.46	6.61
Rotor kinetic energy, *J*	8600	20400	39900
Distance between two nearest trunks**, *m*	0.153	0.144	0.124
Time required for rotation recovery, *s*	0.15	0.22	0.29
Travel speed, *m/s (km/h)*	1.00 (3.6)	0.66 (2.4)	0.43 (1.5)
Number of working bodies by working width, *pcs.*	4	3	2
Forest machine productivity, *ha/hour*	0.80	0.50	0.34

*The maximum value from Table 4, which we use in calculations;
**Calculated based on the results of experimental studies [14] at $n_s = 5\ pcs/m^2$.

In the course of the study, the main dynamic parameters of the flat-rotating working body for removal of woody shrub vegetation were determined, presented in Table 3. The obtained dynamic parameters can be successfully used by design organizations and machine-building enterprises to create and improve the design of shearing device of forest machine for removing woody shrub vegetation.

4 Conclusion

The article proposes a methodology for creating a size range of the working body, in which the flat rotary working body tested in working conditions was taken as a basis. On the basis of the size range it is possible to create a design range of different workpieces of the same design [14]. The criterion for limiting the size range was the working width of the shearer in transport position when mounting the shearer on the front linkage of the basic forest machine tractor. The arrangement of the flat rotary working tools considered in this article is possible not only on the front linkage, but also on the outrigger console or on the forest machine arm.

The choice of the drive for the rotor was based on commercially available products of domestic production. The application of the size range of the rotor expands the technological possibilities in the creation, manufacture and further operation of the forest machine.

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