JOURNAL OF ENGINEERING SCIENCES

Volume 13, Issue 2 (2026)

Dziuba L. F., Rebezniuk I. T., Chmyr O. Y., Barabash B. Z. (2026). Substantiation of the design parameters of a sectional screen for a drum-type wood chipping machine. Journal of Engineering Sciences (Ukraine), Vol. 13(2), pp. A1–A11. https://doi.org/10.21272/jes.2026.13(2).a1



© 2026 The Author(s). This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

p-ISSN 2312-2498
e-ISSN 2414-9381

Substantiation of the Design Parameters of a Sectional Screen for a Drum-Type Wood Chipping Machine

Dziuba L. F.[1][0000-0002-4261-6490], Rebezniuk I. T.[2][0000-0001-5924-7700],
Chmyr O. Y.[1*][0000-0002-6340-9888], Barabash B. Z.[2][0009-0008-7662-0798]

[1] Lviv State University of Life Safety, 35, Kleparivska St., 79000, Lviv, Ukraine;
[2] Ukrainian National Forestry University, 103, Chuprynky St., 79057, Lviv, Ukraine

Article info:

Submitted:	September 10, 2025
Received in revised form:	June 26, 2026
Accepted for publication:	June 29, 2026
Available online:	July 14, 2026

***Corresponding author:**
o_chmyr@yahoo.com

Abstract. The production of wood chips for the pulp-and-paper, wood-based panel, and bioenergy industries requires maintaining a stable granulometric composition (particle-size distribution) of the product. A promising approach to improving chip quality is optimizing screening systems in drum wood chippers. This study aims to develop a mathematical model of the interaction between wood chips and the screen and to substantiate its rational design parameters. The study used methods of solid-body motion mechanics, mathematical modeling, and experimental testing. A mathematical model of the impact interaction between wood chip particles and the screen was developed, accounting for the kinematic parameters of particle motion and the material's physical and mechanical properties. A relationship for determining the number of sections of a stepped screen was derived, and the patterns governing particle movement within the inter-drum space were established. The influence of the number of screen sections and the radial distance between the screen and the drum on the efficiency of wood chip sizing was experimentally investigated. It was found that using a sectional screen improves the separation of substandard particles and the fractional composition of the output product. The following rational parameters were obtained: 11 screen sections and a radial spacing of 15 mm. Under these conditions, the proportion of the substandard fraction is 8–15 %, whereas for a plate-type screen it is 25–32 %. The results may be used in the design and modernization of drum wood chippers.

Keywords: drum wood chipper, sectional screen, elastic impact, particle trajectory, sustainable biomass processing, wood chip grading.

1 Introduction

The European Union is actively developing the renewable energy sector, which uses inexhaustible natural resources such as sunlight, wind, water, biomass, and geothermal energy to generate electricity. Wood has also been highlighted as a renewable energy source.

The demand for forest wood resources to support renewable energy complements the numerous existing objectives for forests [1]. Considering the expected contribution to the renewable energy sector, this study examines and compares national bioenergy policies in five European countries. These countries are Finland, Germany, Norway, Slovenia, and Spain, selected due to their differences in forest-based energy production and utilization. Issues related to renewable energy and the use of energy produced from wood residues are also highly relevant for Ukraine, given the consequences of hostile shelling.

Nearly half the annual wood volume from wood-processing operations in the European Union consists of unused parts of logging residues (e.g., branches, stumps, roots, tops) left in the forests [2]. As is known, wood waste is generated at all stages of logging and wood processing.

To obtain homogeneous chips from different types of wood waste, wood-chipping machines are employed. The primary field of application of such machines is the wood processing industry. However, wood-chipping machines are also used at building enterprises; they are used during maintenance and clearing of garden plots and urban park areas, as well as for removing shrubs along roadsides and power transmission lines. Wood chipping machines efficiently process firewood, branches, shrubs, and other wood waste into wood chips. Industrial chips of a specified size are subsequently used to produce fuel pellets for energy generation.

Industrial wood chips are an important raw material for the pulp-and-paper industry, wood-based panel production, and bioenergy production. The growing use of woody biomass in European countries is driving increased demand for the efficiency of wood harvesting and processing technologies, as well as for the quality of wood chips as a final product [1, 2].

The main equipment used for producing industrial wood chips consists of disc and drum wood chippers. Among them, drum wood chippers have become widely used due to their high productivity, ability to process heterogeneous raw materials, and capability to handle logging and wood-processing residues [3, 4]. Studies show that chippers' performance and chip quality depend on the design of the cutting mechanism, the machine type, material feeding parameters, the configuration of working components, and their operating conditions [4–6].

The quality of industrial wood chips is determined by their particle-size distribution, which directly affects the efficiency of subsequent processing operations. Studies have shown that the granulometric composition of wood chips is significantly affected by the type of chipper, the characteristics of the raw wood, knife wear, and machine operating parameters [6]. Furthermore, the organization of particle movement and sorting within the machine following the cutting process constitutes an important factor influencing chip quality [3].

To achieve the required particle size distribution, drum wood chippers are equipped with screening systems that perform size-based classification of wood chips. The screen design affects the throughput of quality chips, the duration of particle retention within the working (processing) zone, and the probability of substandard fractions being discharged from the chipper. Despite the considerable number of studies on wood chipping processes, primary attention has been focused on improving cutting mechanisms and enhancing the productivity and energy efficiency of wood chippers [3–6]. In contrast, the issue of substantiating the parameters of screening systems remains insufficiently investigated.

The investigation of sectional screens is particularly relevant, as changes in the number of screen sections, their geometric configuration, and the radial distance between the screen and the drum substantially influence the motion trajectories of wood chip particles and the efficiency of their size-based separation.

The absence of scientifically substantiated recommendations for selecting these parameters complicates the design of new drum wood chippers and the modernization of existing ones. In this regard, a relevant scientific and engineering task is the substantiation of the design parameters of a sectional screen for a drum chipper used in the production of industrial wood chips by combining mathematical modeling of particle motion with experimental investigation of the particle classification process.

2 Literature Review

Modern wood shipping machines differ in terms of engine power, cutting tool type, drive configuration, the size of wood intended for processing, and the wood chip fractions obtained. In industrial production, wood chipping machines with a power of up to 900 kW are used [3].

In the study [6], the time and fuel consumption, and the size of the wood chips produced by two industrial chippers were investigated. These machines processed logging residues (tree tops and branches), wood from forest-thinning operations, and pulpwood. The study tested two machines: a drum chipper with a power output of 246 kW and a disc chipper with a power output of 147 kW, which differed in the type of cutting tool employed. The drum chipper is equipped with a screen with 80×80 mm holes. Therefore, the resulting wood chips are sufficiently large.

In the study [5], a wood-chipping machine with a chain mechanism was investigated, adapted for processing smaller timber by reducing drum rotation speed and replacing standard chains with lighter ones.

In the paper [4], the geometric parameters of the produced chips were examined. These parameters are determined by the knife drum design, the number of knives, the feed rate of the raw material, and the drum rotational speed.

The characteristics of lower-power wood chipping machines are examined in [7–9]. Particularly, in [7], the efficiency of the wood chipping machine manufactured by Bandit Industries' 990XP chipper with a power output of 63.25 kW was analyzed. The study was conducted during the processing of wood material obtained from park maintenance activities.

The performance analysis of a stationary shipper powered by a 129 kW diesel engine was conducted in [8]. The machine can chip wood materials up to 450 mm in diameter, with a rotor width of 780 mm.

In the research work [9], the use of the KESLA 645T drum chipper for forest biomass was examined. The drum wood chipper is operated using the power take-off of a VALTRA 203T forestry tractor with an output of 203 horsepower (approximately 149.3–151.4 kW) and is equipped with a crane and a log grapple. The drum had a diameter of 570 mm and was equipped with six blades (three on the right side and three on the left, respectively). The screen was mounted between the drum and the outlet

for the wood. However, the distance between the screen and the drum is not specified in the study.

According to the research work [10], low-power wood chippers are equipped with drive units powered by spark-ignition engines with a power output of less than 19 kW. To identify the cutting mechanism characterized by the lowest energy consumption among commercial machines with a power of up to 10 kW, four wood chipping machines with different cutting mechanisms were analyzed in [10]: a drum, a disc, a two-cylinder, and a machine with two cutting mechanisms – chain and disc, when only one of them can be used. The chipping machines were powered by the same Lifan GX390 drive unit, delivering approximately 10 kW of power. During the wood-chipping process, beams with a square cross-section ranging from 10 mm to 50 mm were used. In the work [10], it is also stated that the drum mechanism performs the wood-chipping process most effectively, as it can process all tested materials – wooden beams of various species and hardness, with cross-sections ranging from 10×10 mm to 50×50 mm.

The influence of wood size on the efficiency of shipping machines and the resulting wood chip fractions has been investigated and described in several studies. In the study [9], the influence of screen hole sizes (40, 50, 65, and 80 mm) on chipping productivity and cost, as well as the distribution of wood chips by size, was analyzed. When the screen hole size ranged from 40 mm to 65 mm, chipping productivity increased by 3.6 times, fuel consumption decreased to 30 %, and chipping costs decreased to 32 %. The content of small chip particles decreased with increasing screen size. The use of a screen with 65 mm holes proved to be the most effective, as it allowed obtaining chips of optimal size at an acceptable chipping speed.

In the study [11], the effects of three different combinations of screen sizes on chipping productivity, fuel consumption, and chip particle size distribution were experimentally evaluated for two types of wood: mixed coniferous residues and whole broad-leaved trees. During the chipping of coniferous wood residues, productivity was higher than during the chipping of whole broad-leaved trees. When small-hole screens are used, the machine's chipping performance is lower and fuel consumption is higher than with larger-hole screens. This study also showed that fine wood chips could be obtained using screens with smaller holes.

The productivity of drum chippers operating on tractors and trucks was investigated in the study [12]. The studies also accounted for the effect of pine pulpwood storage time (drying time) on the technical characteristics of the resulting wood chips. The influence of screen hole sizes on the particle size distribution of wood chips from eight different age groups of stored wood was compared using an 80×80 mm screen for the tractor-mounted chipper and a 100×100 mm screen for the truck-mounted chipper.

The particle size distributions of both chippers were fairly uniform, and the storage time (drying time) of the pulpwood had no significant effect on them. In work [13], the influence of rotor blade geometry on the particle size of wood chips and energy consumption was investigated for the production of beech chips obtained using a knife mill. The effects of wood material size and type on the production cost of wood chips using a disc-type chipping machine were examined in work [14].

In the research work [15], the sizes of wood chips obtained using machines equipped with drum and disc cutting tools were investigated. The size of wood chips was determined using a conventional sieving method and an automated image analysis system based on laser scanning. The average chip length was the same for both machines, but the drum chipper's chips were more uniform in length. The average thickness was similar, but the drum chipper produced slightly thinner wood chips. Using the sieving method, it was found that the drum chipper, compared to the disc chipper, produced a similar proportion of large- and extra-thick wood chips, 51 % more large acceptable chips, 11 % more generally acceptable chips, and 74 % fewer pin-shaped chips and fine particles. The results show that drum chippers deserve further attention as an alternative to traditional industrial-scale disc chippers. According to [15], the advantages of drum wood chippers over disc chippers are a wide range of applications; high quality of wood industrial chips regardless of the quality of the raw material being chipped, lower specific energy consumption per unit volume of wood chips produced, repairability and ergonomics during operation, and the ability to quickly re-adjust and replace cutting blades. In drum-type chippers, the working tool, which consists of a rotating steel drum equipped with chipping knives, can be either a closed solid drum, in which case the chips fall into the counter-blade (anvil) recesses (meaning the chips do not enter the drum cavity), or a hollow drum, in which case the chips enter the interior of the drum. Drum-type machines are usually loaded horizontally from a feed conveyor. Drum-type machines typically have a large feeding inlet, which allows large pieces of wood to be processed into chips. The size of wood chips depends on their intended subsequent use.

As stated in [16], there are quite strict requirements for the size of wood chips intended for the production of fuel pellets.

These requirements relate to the specified particle size, impurity content, and physico-mechanical properties. According to ISO 17225-2:2021 [17], it should originate from natural wood or chemically untreated wood residues and must ensure the production of pellets of the established quality classes "A1", "A2", "B", "I1", "I2", and "I3". Typically, fuel pellets are produced from industrial wood chips with a fraction not exceeding 6 mm.

The production of industrial wood chips on an experimental machine, the design of which is described in [18], is shown in Figure 1.

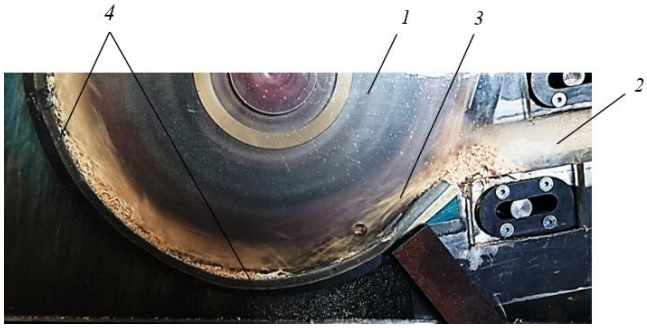


Figure 1 – Production of industrial wood chips on experimental equipment: 1 – rotating drum; 2 – wood for chipping; 3 – industrial chips; 4 – screen

The longitudinal dimensions of the chips, which move at high speed along a straight trajectory tangent to the drum of the chipping machine, should be equal to 6 mm. The chip movement speed is determined by the drum's radius and its angular speed. If the chips are the size of the holes in an arched screen located close to the drum, and if they pass through the holes, they fall onto the tray. If the chip particles are larger than the holes in the screen, or if they do not fit into the holes, they strike the screen. After impact, these particles continue to move in the space between the drum and the screen. Operational observations have shown that up to 50 % of the cut chips can move to the upper counter blade (bed knife) on the upper part of a solid-arched screen without separate sections.

In the works under consideration, the productivity of wood-chipping machines is primarily assessed based on power consumption. However, the performance of machines for the production of industrial wood chips should also be assessed by the percentage of chips of the required size within the total amount produced. To increase the productivity of machines that produce industrial wood chips for fuel pellet production, it is advisable to improve the chip sifter screen design.

The purpose of the study is to substantiate the shape and design parameters of the screen of the wood chipping machine and the distance for its placement relative to the drum based on modeling the impact interaction of wood chip particles with the screen, as well as confirmation of experimental studies regarding the productive efficiency for wood chips of the required size. To achieve this goal, the following tasks need to be solved:

1) to develop a mathematical model of the interaction between industrial chips and a screen based on the theory of elastic body impact, and to establish the movement trajectories of chips of varying moisture content in the space between the drum and the screen to substantiate the placement of chip movement restrictors on the screen in the form of screen sections connected in a stepped manner;

2) to investigate the effectiveness of using a screen of improved design in an experimental machine for wood chipping.

3 Research Methodology

3.1 Mathematical model of the interaction between chips and a screen

To develop a mathematical model of the interaction between industrial wood chips and the screen, the following assumptions are made: the impact of a wood chip particle on the screen surface is considered oblique; the restitution coefficient value after impact depends on the moisture content of the wood used for chip production; and there is no impact friction between the wood chip and the screen.

The simulation of wood chip movement will be performed using a computational diagram (Figure 2).

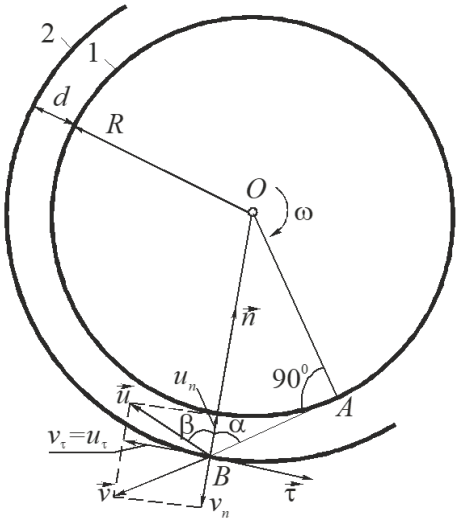


Figure 2 – Computational diagram of the interaction between a wood chip particle

In Figure 2, the following designations are used: 1 – drum; 2 – screen; R– drum radius; d – radial distance between the drum surface and the surface of the rounded screen; point O – the center of the drum rotation; point A – the place where the chip particle separates from the wood, where the particle begins to move along a trajectory tangent to the drum surface; point B – the point of impact of the chip particle on the screen surface; ω – angular speed of the drum; v – the speed of the chip particle before impact; u – the speed of the chip particle after impact; α – the angle of incidence of the chip particle on the screen surface before impact; β – the angle of reflection of the chip particle from the screen surface after impact; n, τ – the normal and tangent to the surface of the screen at the point of impact, respectively.

The impact of a chip particle on the screen surface is oblique because its speed v forms an angle α with the screen surface normal at the point of impact, if the chip particle does not fall into the screen hole. The speed u of the chip after impact forms an angle β with the normal to the screen surface (Figure 2).

Ignoring the impact of friction between the chip particle and the screen surface, i.e., assuming the surface to be smooth, the momentum law along the axis normal to the surface can be written:

$$\vec{S} = m\vec{u} - m\vec{v}, \quad (1)$$

or in projections onto the normal and tangent to the surface of the screen, it can be obtained:

$$\begin{cases} S = S_n = mu_n - mv_n; \\ S_{1n} = mv_n; \\ S_{2n} = mu_n; \\ S_\tau = 0 = mu_\tau - mv_\tau; \\ u_\tau = v_\tau. \end{cases} \quad (2)$$

The coefficient of restitution for an oblique impact is equal to the ratio of the normal component of the chip particle speed after the impact to the particle speed before the impact.

$$k = \frac{S_{2n}}{S_{1n}} = -\frac{u_n}{v_n}. \quad (3)$$

For solids, the coefficient of restitution is within the range $0 \le k \le 1$.

When $k = 0$, a completely inelastic impact occurs; when $k = 1$, a perfectly elastic impact takes place, in which the angle of incidence equals the angle of reflection. The coefficient of restitution depends on the material properties and the shapes of the colliding bodies, but not on their speeds. The minus sign indicates that the normal component of the speed reverses direction during the impact. If the coefficient of restitution is known for these two materials, then, knowing the angle of incidence α and the speed v of the wood chip particle before impact, the following expressions are obtained for the post-impact speed u, the momentum S, and the angle of reflection β:

$$u_n = kv_n;\ u_\tau = v_\tau;\ S = m(1+k)v_n;$$

$$tg(\beta) = \frac{1}{k} tg(\alpha). \quad (4)$$

The angle of reflection β at which particles of wood chips are reflected from the surface of the screen, the tangent of which is described by the dependence (4), depends on the angle of incidence α and the coefficient of restitution k. This coefficient is expressed as the ratio of the speeds of the chip particles: the speed v before impact is known and equals the product of the drum's angular speed ω of rotation and its radius R:

$$v = \omega \cdot R,$$

then, after an elastic impact, the chip particle's movement speed u is unknown.

It is assumed that the coefficient of restitution depends on the moisture content of the wood. For wood with lower moisture content (drier wood), the coefficient of restitution will be higher than for wood with higher moisture content. Under this assumption, chips from drier wood, after colliding with the steel screen, will move faster through the space between the screen and the drum than chips from wood with higher moisture content. In this case, the effect of the air flow, which arises as a result of the drum's rotational motion, on the speed of the chips after impact can be neglected. Considering the numerical values of the coefficient of restitution during the elastic impact of wood chip particles against a steel surface and the recommendations [19], for subsequent calculations, the coefficient of restitution ranged from 0.40 for chips from wet wood to 0.54 for chips from dry wood. That is, chips of wet wood will move at a slower speed after impact than chips of dry wood. However, it is impossible to determine the angles of incidence and reflection from the speeds alone, so the geometry of chip movement between drum 1 and screen 2 can be considered (Figure 3).

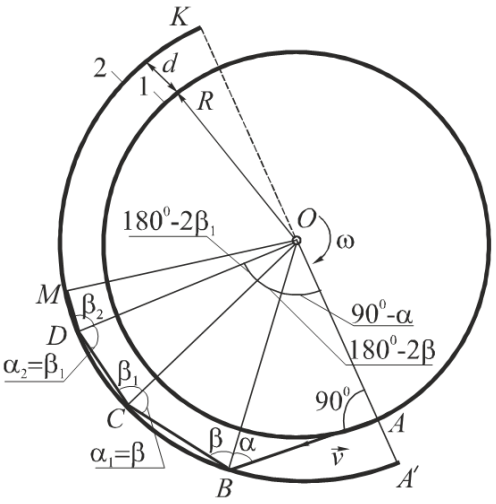


Figure 3 – Movement trajectory of a wood chip particle between drum 1 and screen 2 of a wood chipping machine

In Figure 3, the triangle OAB is right-angled. From this triangle, the path traveled by a particle of wood chips from being cut from the wood to impacting the screen surface is equal to the length of the cathetus AB:

$$AB = \sqrt{(R+d)^2 - R^2} = \sqrt{2Rd + d^2}. \quad (5)$$

The tangent of the angle of incidence of the chip particle and the angle of incidence are equal to

$$tg(\alpha) = \frac{OA}{AB} = \frac{R}{\sqrt{2Rd+d^2}};$$

$$\alpha = atan\left(\frac{R}{\sqrt{2Rd+d^2}}\right). \quad (6)$$

The angle of reflection, taking into account (4) and (6), depends on the coefficient of restitution k, the radius R of the drum, and the distance d between the drum and the screen. Therefore,

$$\beta = arctg\left(\frac{1}{k}\frac{R}{\sqrt{2Rd+d^2}}\right). \quad (7)$$

Thus, when a particle of wood chips does not fall into a hole in the screen but hits its surface at point B and

rebounds from the screen surface at angle β, it continues its linear motion in the space between the screen and the drum to point C. It was assumed that particle motion occurs only due to rebounding from the screen surface.

After the first impact of the chip particles on the screen surface, the length of the trajectory BC (Figure 3) at point B from the isosceles triangle OCB is as follows:

$$BC = (R + d)\sqrt{2 + 2\cos(2\beta)}. \quad (8)$$

It is assumed that at point C, an elastic impact occurred with the screen surface at an angle α_1, which, from triangle OCB, is equal to the angle of reflection β at point B:

$$\alpha_1 = \beta = arctg\left(\frac{1}{k}\frac{R}{\sqrt{2Rd+d^2}}\right).$$

If a wood chip particle at point C again acquires some initial speed, it will continue moving along a straight-line trajectory CD until it collides with the screen surface at point D. The angle of reflection at point C is equal to:

$$\beta_1 = arctg\left(\frac{1}{k}tg(\alpha_1)\right) = arctg\left(\frac{1}{k^2}\frac{R}{\sqrt{2Rd+d^2}}\right).$$

The length of segment CD derived from triangle OCD:

$$CD = (R + d)\sqrt{2 + 2\cos(2\beta_1)}.$$

The angle of incidence of the particle at point D is equal to α_2. After an elastic impact at point D, the wood chip particle will continue its motion along the straight-line trajectory DM, inclined at an angle β_2 to the normal OD.

The length of this segment is determined from triangle ODM (Figure 3):

$$DM = (R + d)\sqrt{2 + 2\cos(2\beta_2)}, \quad (9)$$

where the following parameter is used:

$$\beta_2 = arctg\left(\frac{1}{k}tg(\alpha_2)\right) = arctg\left(\frac{1}{k^3}\frac{R}{\sqrt{2Rd+d^2}}\right).$$

At the point of contact D with the screen, the wood chip particle does not acquire the additional kinetic energy that it would obtain upon contact with the drum. Therefore, after the chip particle strikes the screen at point M, Further movement may occur under the influence of the airflow generated around the rotating drum. In the space between the drum and the screen, particles collide, interact, and repeatedly contact both surfaces. However, the kinetic energy associated with such interactions is neglected and assumed insignificant. Such restrictors may take the form of protrusions on the screen sections.

The lengths of the sections of the movement trajectory of the chip particle, described by expressions (5), (8), and (9), depend on the radius R of the drum, the distance d between the drum and the screen, and the angles of reflection β, β_1, and β_2.

To construct a sectional screen that restricts the movement of wood chip particles in the space between the drum and the screen by means of section protrusions, the lengths of these sections were calculated for different values of d and R depending on the coefficient of restitution. The calculation results are presented in subsection 4.1.

3.2 Studies on the effectiveness of using a sectional screen in an experimental wood chipping machine

The efficiency of the sectional screen was experimentally investigated using a drum wood chipper (Figure 4).

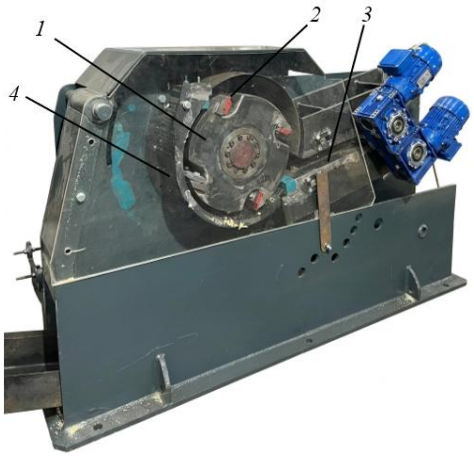


Figure 4 – General view of the experimental drum wood chipper: 1 – knife drum; 2 – cutting knife; 3 – feed mechanism; 4 – stepped screen (adapted from [18])

The diameter of the machine drum (Figure 4, designation 1), on which four knives (Figure 4, designation 2) are mounted, is 400 mm. The knife sharpening angle was 32°, and the cutting angle was 50°. The drum rotated at an angular speed of 52.33 rad/s, which corresponds to a rotation frequency of 500 rpm. The speed of linear motion of wood chip particles (Figure 1, designation 3) under these parameters is 10.5 m/s. During the study, spruce wood in the form of bars with a cross-section of 50×50 mm (Figure 1, designation 2), with three moisture content levels W (20, 30, and 40 %), was chipped. The moisture content of the wood was determined using a moisture meter. The wood feed rate was 4 m/min, and the feed per tooth (chip load) was 2 mm. The chain feed mechanism (Figure 4, designation 3) ensured the feeding of wood without slippage. The movement of industrial wood chip particles was constrained by a screen (Figure 4, designation 4).

Three types of screens were tested (Figure 5), differing in the number of sections. The junctions between the sections served as barriers to the movement of wood chip particles that did not pass through the 10×10 mm screen holes. The first screen consisted of 11 sections (Figure 5, designation 1), the second screen consisted of 7 sections (Figure 5, designation 2), and the third screen consisted of 3 sections (Figure 5, designation 3).

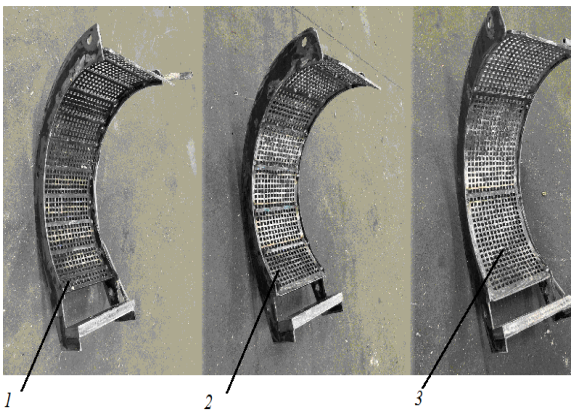


Figure 5 – Sectional screens of the experimental drum wood-chipping machine: 1 – with 11 sections; 2 – with 7 sections; 3 – with 3 sections

The screens are formed from rectangular lattice plate sections joined to each other by overlapping the longitudinal edge of one section onto the longitudinal edge of the adjacent section, thereby forming an integral structure. The internal working surface of the structure has a stepped configuration, with the steps oriented in the opposite direction to chip movement (Figure 6).

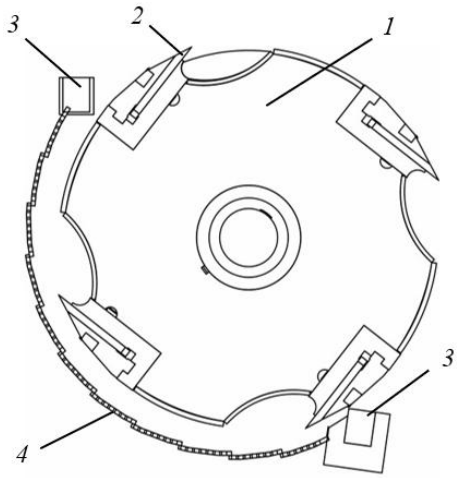


Figure 6 – Diagram showing the arrangement of a stepped sectional screen in a drum wood chipper: 1 – knife drum; 2 – cutting knife; 3 – bed knife (counter blade); 4 – stepped screen (adapted from [18])

To assess the effect of the distance between the drum and the screen on the amount of industrial chips sifted out, each screen was alternately placed at distances of 15, 20 from the drum. The results of experimental studies are presented in subsection 4.2.

To investigate the influence of the number of stepped screen sections, the radial distance between the screen and the drum, and the wood moisture content on the percentage of the substandard fraction in the total mass of wood chips, a methodology of mathematical design of experiments was employed [20].

The investigated variables were: X_1 – number of screen sections n; X_2 – radial distance between the screen and the drum d; X_3 – wood moisture content W. All these factors were quantitative, controlled, and adjustable. The response variable was the percentage of substandard fraction in the total mass of wood chips. This indicator was determined as follows:

$$P = \frac{m_1}{m_2} \cdot 100\ \%,$$

where m_1 – the mass of the substandard fraction of chips (with particle sizes exceeding 6 mm), kg; m_2 – the total mass of chips, kg.

The main results of the experimental study were used to evaluate the outcomes of the mathematical modeling. They are presented in subsection 4.2.

4 Results

4.1 Determining the number of screen sections

The results of calculating the angles of incidence and reflection, as well as the lengths of the trajectory segments of the movement of an industrial wood chip particle with a moisture content W at values of the coefficient of restitution k, are presented in Tables 1, 2 for different drum radii R.

As the distance between the drum and the screen increases, the angle of incidence α decreases. For the same angle of incidence α, the length of the segment AB depends only on the distance d and not on the moisture content of the wood. The length of the segment BC depends on the angle of reflection β, which increases with increasing wood moisture content W, that is, with a decrease in the coefficient of restitution k.

According to Figure 3, it is advisable to design the first section of the screen with a length such that its edge is located in the vicinity of point B, where the majority of the cut chips are deposited. The approximate length of the first screen section is equal to the length of segment AB and depends on the drum radius R and the distance d. Taking into account the subsequent motion of a chip particle, the lengths of the following screen sections depend on the lengths of the chip trajectory segments and the central angles corresponding to these segments. However, based on experimental observations, it can be stated that after rebounding from the screen, the chip particle reaches point C at a speed such that any subsequent rebound from the screen is impeded by friction between the screen and the chip. If, at point C, the chip does not enter the screen holes, its further motion is possible only under the action of the airflow generated around the rotating drum.

Taking into account the chaotic motion of wood chips on the CK section between the screen and the drum, it is advisable to design this section of the screen with a uniform stepped arrangement of segments whose length corresponds to the length of section BC (Figure 3).

Table 1 – The lengths of the trajectory segments of the chip particle movement between the drum with a radius R = 200 mm and the arched screen

Distance d, mm	Angle of incidence, α^0	Angle of reflection, β^0	Length of segment AB, mm	Length of segment BC, mm	Length of segment CD, mm	Length of segment DM, mm
Coefficient of restitution k = 0.40						
15	68.5	81.0	78.9	67.0	27.1	10.9
20	65.4	79.6	91.7	79.3	32.2	12.9
25	62.7	78.4	103.1	90.9	37.0	14.8
Coefficient of restitution k = 0.47						
15	68.5	79.5	78.9	78.4	37.3	17.6
20	65.4	77.8	91.7	92.6	44.3	20.9
25	62.7	76.4	103.1	105.9	50.9	24.0
Coefficient of restitution k = 0.54						
15	68.5	78.0	78.9	89.6	49.1	26.7
20	65.4	76.1	91.7	105.7	58.3	31.7
25	62.7	74.4	103.1	120.7	66.9	36.4

Table 2 – The lengths of the trajectory segments of the chip particle movement between the drum with a radius R =300 mm and the arched screen

Distance d, mm	Angle of incidence, α^0	Angle of reflection, β^0	Length of segment AB, mm	Length of segment BC, mm	Length of segment CD, mm	Length of segment DM, mm
Coefficient of restitution k = 0.40						
15	72.2	82.7	96.0	80.0	32.2	12.9
20	69.6	81.6	111.4	94.0	37.9	15.2
25	67.4	80.5	125.0	106.9	43.2	17.3
Coefficient of restitution k = 0.47						
15	72.2	81.4	96.0	93.7	44.4	20.9
20	69.6	80.1	111.4	110.0	52.3	24.6
25	67.4	78.9	125.0	124.9	59.6	28.1
Coefficient of restitution k = 0.54						
15	72.2	80.2	96.0	107.3	58.6	31.7
20	69.6	78.7	111.4	125.8	68.9	37.3
25	67.4	77.3	125.0	142.7	78.4	42.6

Hence, the number of screen segments on the BK section is determined as the ratio of the arc length BK to the length of the section BC. The arc length BK is as follows:

$$\overset{\frown}{BK} = \frac{(R+d)\cdot(90^0+\alpha)\cdot\pi}{180^0}. \quad (10)$$

The total number of screen sections is equal to the sum of the number of sections of length BC and one section of length AB:

$$n = \frac{(90^0+\alpha)\cdot\pi}{180^0\sqrt{2+2\cos(2\beta)}} + 1, \quad (11)$$

where the angles α and β are determined using formulas (6) and (7).

The values of the lengths of the segments AB and BC, the arc lengths BK, and the number of screen sections n, depending on distances d and coefficients of restitution k for drums with radii: R = 200 mm (Table 3) and R = 300 mm (Table 4).

Table 3 – The number of screen sections for a drum with a radius R =200 mm

Distance d, mm	Length of segment AB, mm	Arc length BK, mm	Length of segment BC, mm	The number of screen sections, n
Coefficient of restitution k = 0.40				
15	78.9	596.5	67.0	10
20	91.7	599.5	79.3	9
25	103.1	603.8	90.9	8
Coefficient of restitution k = 0.47				
15	78.9	596.5	78.4	9
20	91.7	599.5	92.6	8
25	103.1	603.8	106.0	7
Coefficient of restitution k = 0.54				
15	78.9	596.5	89.6	8
20	91.7	599.5	105.7	7
25	103.1	603.8	120.7	6

Table 4 – The number of screen sections for a drum with a radius R =300 mm

Distance d, mm	Length of segment AB, mm	Arc length BK, mm	Length of segment BC, mm	The number of screen sections, n
Coefficient of restitution k = 0.40				
15	96.0	893.6	80.0	12
20	111.4	894.0	94.0	11
25	125.0	896.0	106.9	9
Coefficient of restitution k = 0.47				
15	96.0	893.6	93.7	11
20	111.4	894.0	110.0	9
25	125.0	896.0	124.9	8
Coefficient of restitution k = 0.54				
15	96.0	893.6	107.3	9
20	111.4	894.0	125.8	8
25	125.0	896.0	142.7	7

4.2 Results of the experimental studies

The effectiveness of sectional screens was evaluated using the sieving method, based on the percentage of industrial wood chips with a size exceeding 6 mm (h > 6 mm). To separate crushed industrial wood chips into several fractions, a screening equipment was designed and manufactured, in which the chips are sieved using two screens (Figure 7).



Figure 7 – General view of the screening equipment for sieving industrial wood chips

The design of the screening equipment enables the separation of industrial wood chips into three fractions: less than 2 mm, from 2 mm to 6 mm, and greater than 6 mm.

The data from the experimental study are presented in Table 5.

According to the experimental results, the lowest percentage of large industrial wood chips (more than 6 mm) is observed when the distance between the drum and the screen is the smallest, 15 mm. When the specified distance is reduced from 25 mm to 15 mm, the volume of chips of the required size decreases most sharply when the wood moisture content W = 40 %, ranging from 33.2 % (for 25 mm) to 8.2 % (for 15 mm).

Table 5 – Results of experimental studies on the effectiveness of using screens with n sections placed at distances d from the drum with a radius of R = 200 mm

d, mm	n	W, %	h > 6, %
15	3	20	11.5
		30	13.0
		40	12.6
	7	20	10.4
		30	10.2
		40	9.7
	11	20	11.5
		30	9.2
		40	8.2
20	3	20	23.2
		30	23.8
		40	23.1
	7	20	20.1
		30	18.4
		40	17.8
	11	20	17.3
		30	16.9
		40	16.7
25	3	20	29.0
		30	29.5
		40	29.0
	7	20	30.3
		30	30.8
		40	30.4
	11	20	31.0
		30	31.8
		40	33.2

In general, when the distance between the drum and the screen is reduced as described above, the throughput of chips larger than 6 mm decreases by approximately 75 % (4 times).

Another parameter influencing the reduction in the volume of chips larger than 6 mm is the number of screen sections. At a distance of 15 mm between the drum and the screen and with a wood moisture content of 40 %, the percentage values decrease from 12.6 % for a screen with three sections to 8.2 % for a screen with 11 sections.

In general, as the number of screen sections increases from 3 to 11, the volume of chips larger than 6 mm decreases by approximately 35 %.

When the moisture content increases from $W = 20\%$ to $W = 40\ \%$, and the distance between the drum and the screen is 15 mm, the throughput of chips larger than 6 mm decreases by no more than 30 % (for the number of sections $n = 11$).

However, when the distance from the drum to the screen is 25 mm, changes in wood moisture content do not significantly affect the chip volumes under study, except when using screens with 11 sections. With such a screen, as the moisture content of the wood increases from $W = 20\ \%$ to $W = 40\ \%$, the throughput of chips larger than 6 mm generally increases, mostly by no more than 10 %.

5 Discussion

The results of the conducted studies confirm the expediency of applying mathematical modeling to substantiate the design parameters of a sectional screen in a drum machine for the production of industrial wood chips. In contrast to most existing studies dealing with the improvement of drum wood chippers, where primary attention is given to the parameters of the cutting mechanism, knife geometry, cutting speed, and energy consumption of the process [6], this study investigates the chip sizing (calibration) process directly within the machine's working zone through the analysis of particle–screen system interactions.

In many previous studies, the quality assessment of industrial wood chips was primarily conducted through experimental methods, which required substantial material costs and did not allow predicting the influence of design modifications on machine performance at the design stage. The proposed approach differs by employing a mathematical model of the motion of industrial chip particles, developed based on the theory of impact of moving bodies, which enabled the determination of particle trajectories with different moisture content and substantiation of the screen's positioning relative to the drum before experimental investigations.

The advantage of the applied methodology lies in the combination of theoretical and experimental investigations. The mathematical model enabled the identification of chip particle movement patterns within the inter-drum space and the determination of the zones with the highest probability of contact with the screen. In contrast to approaches based solely on statistical analysis of experimental results, the proposed method provides a physical explanation of the interaction processes between the chips and the screen. It can be used to predict the performance of machines of various standard sizes [18, 20].

Another advantage of the study is the investigation of a sectional screen design. In most existing designs, continuous cylindrical plate screens are used, and their efficiency is primarily evaluated based on the total screening area. In the present study, the influence of the number of sections on chip calibration efficiency was established, enabling the determination of a rational number of sections and substantiating the design solution for their application.

The proposed methodology also has certain limitations. The developed mathematical model considers the motion of individual wood-chip particles and their impact on interactions with the screen. In contrast, in the real process, a complex multiparticle interaction is observed, accompanied by particle collisions, changes in particle orientation, and non-uniform loading of the machine's working space. As a result, the actual motion parameters of the wood chips may deviate from the calculated values to some extent.

In addition, the model accounts for the influence of wood moisture content on particle motion; however, the individual effects of wood species, chip geometry, the anisotropy of wood's mechanical properties, and machine component wear have not been investigated separately. These factors may affect the accuracy of predicting calibration efficiency and require further study.

Thus, the results of the study demonstrate that the proposed approach enables a scientifically grounded determination of the sectional screen's design parameters and its positioning relative to the drum, while the combination of mathematical modeling and experimental validation constitutes a key strength of the study. At the same time, further refinement of the model through the incorporation of multiparticle interactions, the properties of different wood species, and modern numerical modeling techniques will improve the accuracy of predicting the performance of screening systems in drum machines for the production of industrial chips [18, 20].

6 Conclusions

Based on the developed mathematical model of the impact interaction between wood chips and a steel screen, it was found that for a drum chipper with a drum radius of 200 mm, it is most appropriate to use screens with 8–12 sections for producing wood chips smaller than 6 mm. Increasing the drum radius to 300 mm allows increasing the number of screen sections from 10 to 16, depending on the distance from the drum and the wood's moisture content.

Experimental studies have shown that the smallest percentage of industrial chips exceeding the required 6 mm is obtained when the screen is placed 15 mm from the drum. Positioning the screen with 11 sections at the indicated distance produces the best results in terms of the percentage of the required chips at a wood moisture content of 40 %.

Therefore, for practical application, it is advisable to use screens of this type in drum chippers.

References

1. Lindstad, B.H., Pistorius, T., Ferranti, F., Dominguez, G., Gorriz-Mifsud, E., Kurttila, M., Leban, V., Navarro, P., Peters, D.M., Pezdevsek Malovrh, S., Prokofieva, I., Schuck, A., Solberg, B., Viiri, H., Zadnik Stirn, L., Krc, J. (2015). Forest-based bioenergy policies in five European countries: An explorative study of interactions with national and EU policies. *Biomass and Bioenergy*, Vol. 80, pp. 102–113. https://doi.org/10.1016/j.biombioe.2015.04.033
2. Perić, M., Antonijević, D., Komatina, M., Bugarski, B., Rakin, M. (2020). Life cycle assessment of wood chips supply chain in Serbia. *Renewable Energy*, Vol. 155, pp. 1302–1311. https://doi.org/10.1016/j.renene.2020.04.026
3. Georges, R., Auchet, S., Méausoone, P.J. (2016). Experimental study about the effects of disc chipper settings on the distribution of wood chip size. *Biomass and Bioenergy*, Vol. 35(2), pp. 843–852. https://doi.org/10.1016/j.biombioe.2010.11.009
4. Nati, C., Eliasson, L., Spinelli, R. (2014). Effect of chipper type, biomass type and blade wear on productivity, fuel consumption and product quality. *Croatian Journal of Forest Engineering*, Vol. 35(1), pp. 1–7.
5. Spinelli, R., Mitchell, R., Brown, M., Magagnotti, N., McEwan, A. (2020). Manipulating chain type and flail drum speed for better fibre recovery in chain-flail delimber-debarker-chipper operations. *Croatian Journal of Forest Engineering*, Vol. 41(1), pp. 137–147. https://doi.org/10.5552/crojfe.2020.632
6. Spinelli, R., Cavallo, E., Eliasson, L., Facello, A. (2013). Comparing the efficiency of drum and disc chippers. *Silva Fennica*, Vol. 47(2), 930. https://doi.org/10.14214/sf.930
7. Kormanek, M. (2020). Analysis of wood chipping capacity of the Bandit 990XP chipper-case study. *Journal of Forest Science*, Vol. 66(2), pp. 63–69. https://doi.org/10.17221/146/2019-jfs
8. Suardi, A., Latterini, F., Alfano, V., Palmieri, N., Bergonzoli, S., Pari, L. (2020). Analysis of the work productivity and costs of a stationary chipper applied to the harvesting of olive tree pruning for bio-energy production. *Energies*, Vol. 13(6), 1359. https://doi.org/10.3390/en13061359
9. Choi, Y.-S., Cho, M.-J., Paik, S.-H., Mun, H.-S., Kim, D.-H., Han, S.-K., Oh, J.-H. (2019). Factors affecting the chipping operation based on the screen size of the drum chipper. *Forests*, Vol. 10 (11), 1029. https://doi.org/10.3390/f10111029
10. Warguła, Ł., Kukla, M., Wieczorek, B., Krawiec, P. (2022). Energy consumption of the wood size reduction processes with employment of a low-power machines with various cutting mechanisms. *Renewable Energy*, Vol. 181, pp. 630–639. https://doi.org/10.1016/j.renene.2021.09.039
11. Han, S.K., Han, H.S., Bisson, J.A. (2015). Effects of grate size on grinding productivity, fuel consumption, and particle size distribution. Forest Products Journal, Vol. 65(5–6), pp. 209–216.
12. Laitila, J., Routa, J. (2015). Performance of a small and a medium sized professional chippers and the impact of storage time on Scots pine (Pinus sylvestris) stem wood chips characteristics. *Silva Fennica*, Vol. 49(5), 1382. https://doi.org/10.14214/sf.1382
13. Arce, C., Krátký, L. (2023). Effect of the rotor blade geometry on particle size and energy demand for knife-milled beech chips: Experimental identification and mathematical modelling. *Biosystems Engineering*, Vol. 236, pp. 120–130. https://doi.org/10.1016/j.biosystemseng.2023.10.014
14. Moskalik, T., Gendek, A. (2019). Production of chips from logging residues and their quality for energy: A review of European literature. *Forests*, Vol. 10(3), 262. https://doi.org/10.3390/f10030262
15. Timmerfors, J.G., Sjölund, T., Jönsson, L.J. (2019). New drum-chipping technology for a more uniform size distribution of wood chips. Holzforschung, Vol. 74(2), pp. 116–122. https://doi.org/10.1515/hf-2018-0279
16. Rebeznyuk, I.T., Barabash, B.Z. (2023). Development of the design of drum wood-cutting machines. *Bulletin of Kharkiv National Automobile and Highway University*, Vol. 101, pp. 7–11.
17. International Organization for Standardization (2021). ISO 17225-2:2021. Solid biofuels – Fuel specifications and classes – Part 2: Graded wood pellets. Geneva, Switzerland. https://www.iso.org/standard/76088.html
18. Barabash, B.Z., Rebezniuk, I.T. (2025). Experimental equipment for determination of rational cutting modes in drum wood chippers. *Naukovi Notatky*, Vol. 82, pp. 125–134.
19. Aliyev, E.B., Bilous, I.M. (2025). Simulation of the process of grain destruction by impact cutting. *Central Ukrainian Scientific Bulletin. Technical Sciences*, Vol. 12(43(1)), pp. 133–146. https://doi.org/10.32515/2664-262X.2025.12(43).1.133-146
20. Barabash, B.Z., Rebezniuk, I.T. (2026). Investigation of the influence of the screen system parameters of drum wood chippers on the fractional composition of industrial wood chips. *Naukovi Notatky*, Vol. 85, pp. 83–89.