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ЕКСПЕРИМЕНТАЛЬНЕ ВСТАТКОВАННЯ ДЛЯ ВИЗНАЧАННЯ РАЦІОНАЛЬНИХ РЕЖИМІВ РІЗАННЯ В БАРАБАННИХ ПОДРІБНЮВАЧАХ ДЕРЕВИНИ

Проаналізовано шляхи удосконалювання принципової схеми барабанних подрібнювачів деревини задля того щоб отримувати якнайбільшого відсотка технологійних трісок потрібних розмірів і якости, насамперед для виробляння паливних гранул. Зазначено, що складниками отримування деревинних трісок певних розмірів у барабанних подрібнювачах слугує низка чинників, які загалом можна об'єднати у два: режим різання та конструкція камери подрібнювання технологійних трісок.

Описано особливості конструкції виробленого експериментального устатковання, на якому буде можна з високим ступенем точности дослідити складники вдосконалювання барабанного подрібнювача деревини.

Ключові слова: *барабанний подрібнювач деревини, режим різання, камера подрібнювання, технологійні тріски, експериментальне устатковання.*

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EXPERIMENTAL EQUIPMENT FOR DETERMINATION OF RATIONAL CUTTING MODES IN DRUM WOOD CHIPPERS

The ways of improving the schematic diagram of drum chippers of wood are analysed in order to obtain the largest possible percentage of technological chips of the right size and quality, primarily for the production of fuel pellets. It is noted that the components of obtaining wood chips of certain sizes in drum chippers are a number of factors that can generally be combined into two: the cutting mode and the design of the chipping chamber of technological chips.

The features of the design of the experimental equipment produced are described, on which it will be possible to study the components of improving the drum chipper of wood with a high degree of accuracy.

Keywords: *drum wood chipper, cutting mode, chipping chamber, technological chips, experimental equipment.*

Interpretation of the Problem.

Since the production of the first choppers for wood processing (the second half of the 19th century), their designs have been constantly improved using established cutting schemes, primarily in accordance with the need to obtain chips of certain sizes.

Due to a number of advantages of drum choppers [1] compared to circular ones, they are designed and produced as both mobile and stationary. Mobile equipment can be used directly in the forest at wood harvesting sites, where both tree trunks and branches, knots and other wood residues are chipped on it. After chipping on such equipment, chips of relatively large sizes up to 200 mm are obtained, which are used as fuel or rechipped to be used for the production of wood fuel pellets.

Stationary drum chippers are installed at enterprises as part of technological lines. Typically, wood is chipped on such chippers into chips with dimensions not larger than 25 mm × 25 mm × 2 mm. The resulting chips are dried, then they are rechipped on hammer mills or chipping machines or disintegrators to obtain fractions of no more than 6 mm. It is from chips of this size that wood fuel pellets are produced.

The components of obtaining wood chips of certain sizes in drum chippers are several factors: the speed of feeding the material, the angle of feeding the wood, the speed of cutting, the number of knives on the drum, the presence of bedknives, the design of the perforated sieve. In general, two components can be distinguished: the cutting mode and the design of the chipping chamber.

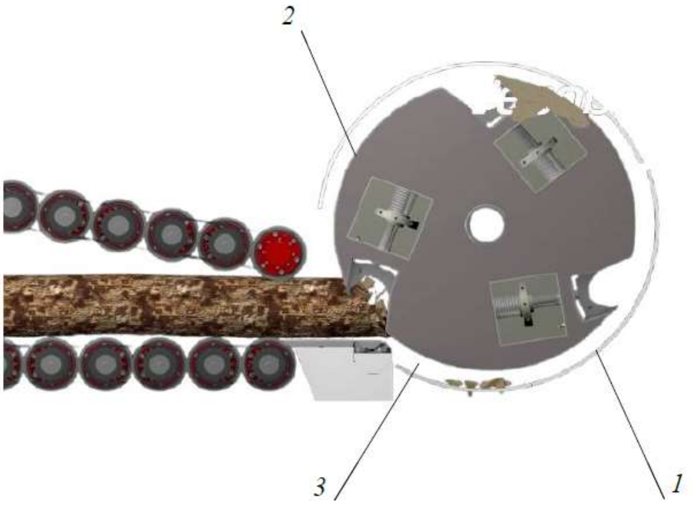
Therefore, it is necessary to first investigate whether it is possible to obtain, by adjusting the wood cutting modes and improving the design and arrangement of the components of the chipping chamber of technological chips, only chips no larger than 6 mm in size as a result of chipping wood in drum chippers.

Analysis of Recent Research and Publications.

Today, the common scheme of a drum wood chipper is (Fig. 1.1) [2] the one in which a steel perforated sieve of plate arc shape *1* located at a certain equal distance from the cylindrical surface of the knife drum *2* of the chipper is used to screen out the homogeneous fraction of technological chips. The inner working surface of the sieve *1* and the cylindrical surface of the knife drum *2* limited on both sides the chipping chamber of technological chips *3*.

The disadvantage of this design is the low productivity of obtaining chips of given sizes, since a certain percentage of chips of large sizes that need to be rechipped are retained in the chipping chamber after cutting wood.

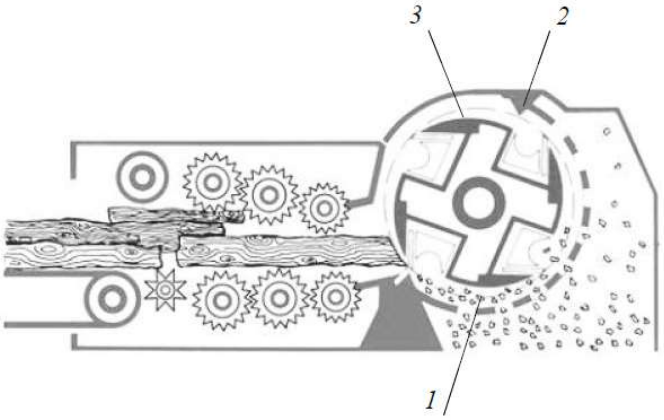
To rechip technological chips faster, chippers are designed and produced according to the scheme (Fig. 1.2), in which the chipping chamber *1* in its upper part is limited by the bedknife *2* [3]. With this design of the chipper, the technological chips fly out of the chipping chamber less, hit the edges and surfaces of the bedknife *2* less, are partially rechipped and sifted through the sieve under the action of air flows and centrifugal force.



1—sieve; *2*—cylindrical surface of the knife drum;
3—chipping chamber of technological chips.

Fig. 1.1. **Common design scheme of a drum wood chipper [2]**

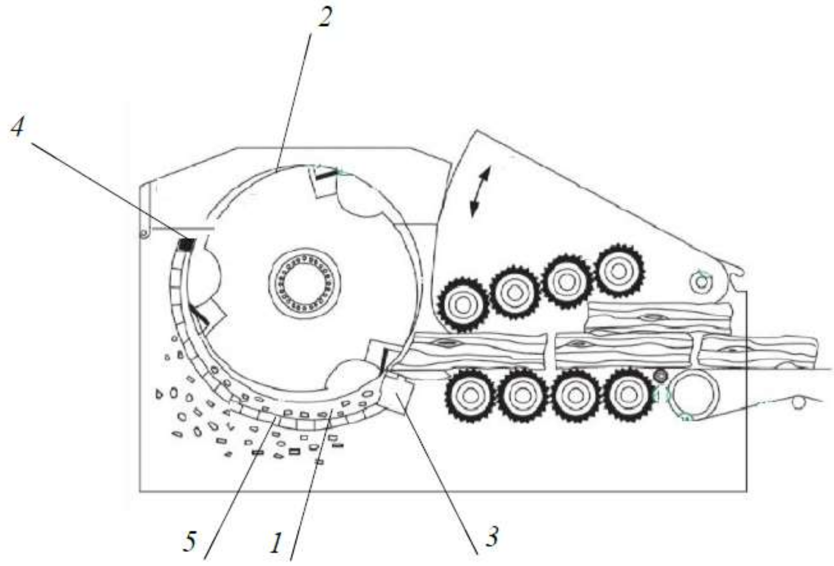
The rear surface of the cutting knife of the drum *3* is made according to the Archimedes spiral. The percentage of technological chips of large sizes that need to be rechipped in such a structure of the chipping chamber, compared to the previous version of the chamber design (see Fig. 1.1) is somewhat smaller, but is still high.



1—chipping chamber; *2*—upper bedknife; *3*—working surface of the drum.

Fig. 1.2. **Design scheme of a drum wood chipper, the chipping chamber of which is limited from the outside by the upper bedknife [3]**

The next step in improving the design of the chipping chamber of the drum wood chipper is the location of the sieve relative to the working surface of the drum [4]. In this design of the chipper (Fig. 1.3), the chipping chamber of technological chips *1* is formed by: the rear surfaces of the cutting knife of the drum *2* made according to the Archimedes spiral; the lower bedknife (in the cutting area) *3*; the upper bedknife *4*; the steel perforated sieve *5*, having a plate arc shape, envelops the working surface of the knife drum *2* and is installed at different distances from the cylindrical surface of rotation of the cutting edges of the knives: the largest one is near the lower bedknife *3*, the smallest one is near the upper bedknife *4*. This arrangement of the sieve determines the formation of the edges of the holes as if in the form of microstairs, which rechip the technological chips in the chipping chamber as micro-bedknives. In this sieve arrangement, the number of technological chips of large sizes decreases, but their chipping is also insufficient.



1—chipping chamber of technological chips; *2*—working surface of the drum; *3*—lower bedknife; *4*—upper bedknife; *5*—sieve.

Fig. 1.3. **Design scheme of a drum wood chipper with a special sieve arrangement [4]**

Based on the analysis of the structures of the chipping chamber, it follows that it is necessary to create in it, in addition to the upper bedknife, several components that will act as mini-bedknives and will accelerate the rechipping of chips to the desired fraction. Such a task can be solved by improving the design of the sieve.

Setting the Task.

The solution of the task set is achieved by forming the sieve of the drum wood chipper as a stepped plate structure, the steps of which work as additional mini-bedknives that reschip the resulting chips. [5, 6].

Sieve *1* of a drum wood chipper (Fig. 1.4) is made of steel, has an arc shape, and is located at a certain distance from the cylindrical surface of movement of the cutting edges of the knives 2 of the drum *3*, limiting from the outside together with bedknives *4, 5* the chipping chamber of technological chips *6*. The sieve *1* is formed from rectangular lattice plate sections *7* interconnected by adjacent superposition of the longitudinal edge *8* of one section *7* on the longitudinal edge of the other section *7*, creating an integral structure. Due to this connection of the sections *7*, the inner working surface of the sieve *1* has a step-like shape, on which the steps *9* are located opposite the direction of movement of the chips.

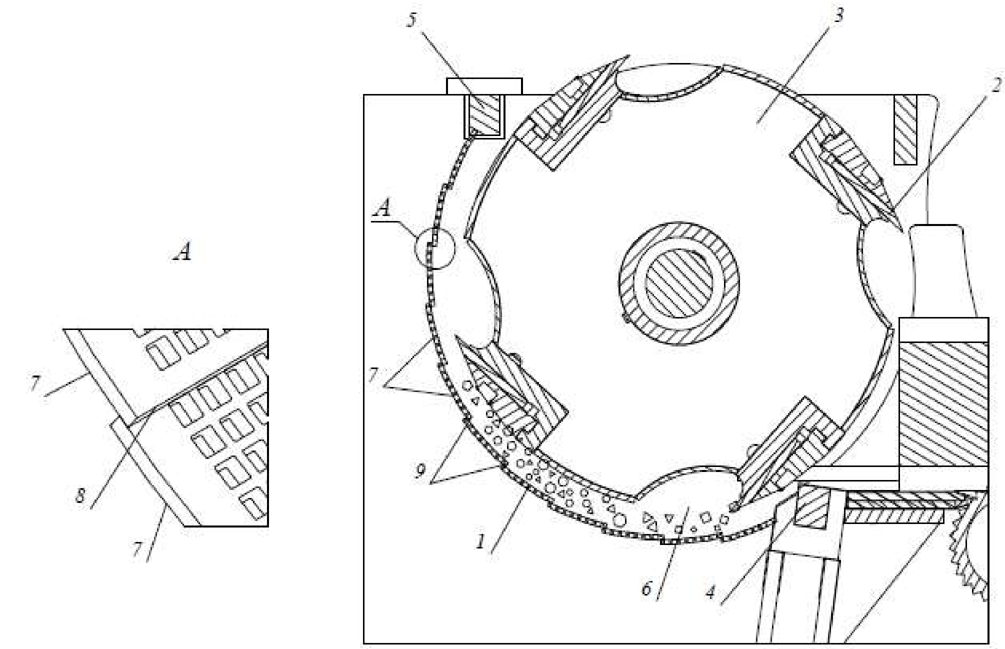
After the initial cutting of wood with a cutting knife 2, the resulting chips enter the chipping chamber *6*, from where most of the chips pass through the holes of the plate sections *6* of the sieve *1*. The steps *9* formed on the inner surface of the sieve *1*, working as additional mini-bedknives, rechip the resulting chips of large sizes to fractions of less than 6 mm, necessary for the production of fuel pellets.

The proposed design of the sieve makes it possible to obtain better results of wood chipping compared to known methods due to the stepping design of the sieve, the steps of which work as mini-bedknives that rechip the resulting chips to the above dimensions. To investigate how the use of a stepped plate sieve and wood cutting modes will affect the performance of chipping wood into technological chips of the desired fractions, it is necessary to develop special experimental equipment.

The purpose of the work is to develop a working model of a drum chipper of wood on the basis of the analysis of the process of cutting wood on drum chippers of wood, the study of their design, the principle of operation and the main parameters affecting the size and quality of the resulting chips, on which it will be possible to study with a high degree of accuracy, while rejecting all side factors as much as possible, the components of improving the equipment.

Solving the Task.

Experimental equipment is a working model of a drum chipper of wood, which has all the features of a commercial drum machine, and in structural terms, in order to thoroughly investigate the process of chipping wood into technological chips, it has a number of features (Fig. 1.5).



1—sieve; *2*—cutting knife; *3*—knife drum; *4*—lower bedknife; *5*—upper bedknife; *6*—chipping chamber; *7*—plate section; *8*—longitudinal edge of the plate section; *9*—steps.

Fig. 1.4. **The structure of a drum wood chipper with a stepped plate sieve [4]**

The box-shaped *frame 1* is welded from steel plates 12 mm thick with jumpers inside and a welded base flange with junction plates compatible with the third side rack, which form a rigid frame that can withstand not only heavy mechanical loads, but also significantly absorb vibration and noise during operation. To observe the movement of chips in and around the chipping chamber *2*, the side of the frame is made of transparent plexiglass. A hinged cover *3* is installed above the knife drum.

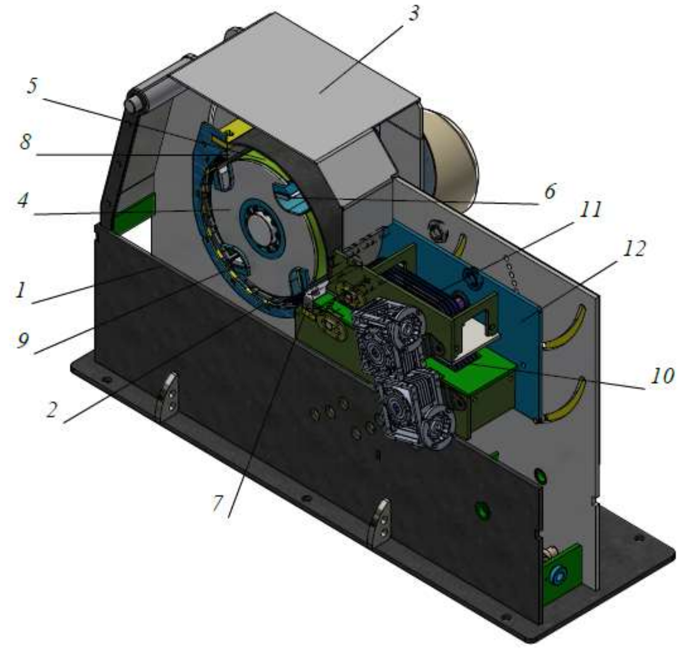
The cutting mechanism is a four-knife welded drum *4* with a diameter of Ø = 400 mm, which is cantilever mounted on the working shaft. The rear surfaces *5* of the cutting knives *6* of the drum *4* are made according to the Archimedes spiral.

The shaft on radial ball bearings rotates in a flanged H-shaped housing fixed to two cheeks of the frame, which is driven by an electric motor N = 15 kW, n = 1,460 rpm through a V-belt transmitter. The main cutting process takes place at the ‘wood-knife-bedknife’ interaction site.

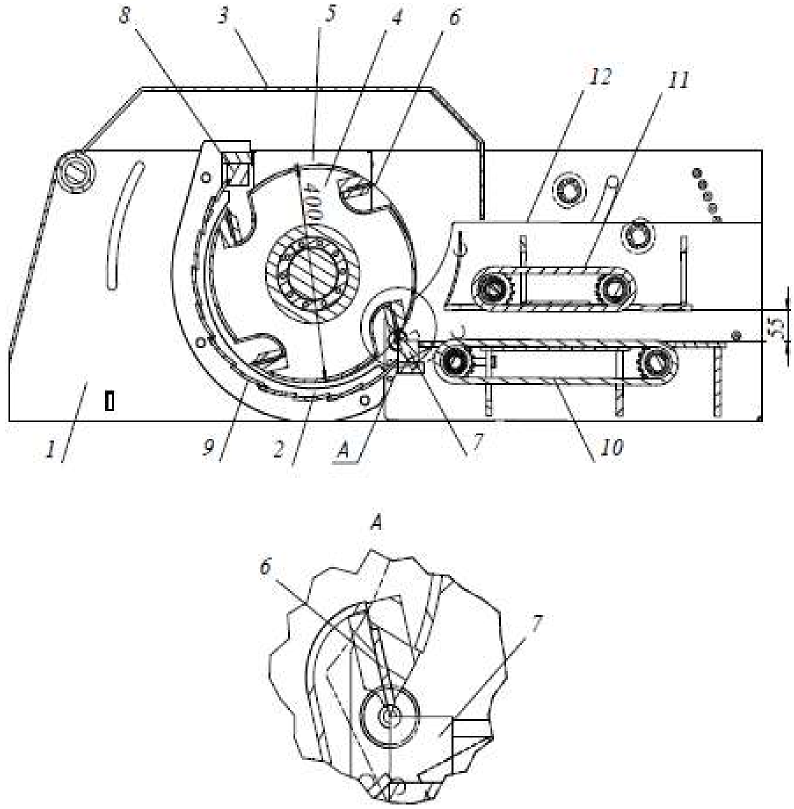
Thanks to the frequency converter, all processes can be investigated at different cutting speeds within 50 m/s.

The chipping chamber is a limited space where technological chips get into after being cut from wood. In the design of the experimental chipper produced (see Fig. 1.5), the chipping chamber of technological chips is formed by: the rear surface of the knife of the drum *5*; the lower bedknife *7*; the upper bedknife *8*; the stepped plate sieve *9*, which has an arc shape made of plate steel sections, envelops the working surface of the knife drum *5* and is installed at the same distances from the cylindrical surface of rotation of the cutting edges of the knives throughout the length of enveloping the surface of the drum. The fundamental difference of the new scheme of the cutting process is that the sieve, located between the lower and upper bedknives, not only acts as the sifter of chipped raw materials, but also actively participates in the chipping process due to the cutting edges of each section. It turns out that the stepped sectional sieve simultaneously performs the function of a number of mini-bedknives. To experimentally investigate the effect of the number of plate sections on the performance of wood chipping, a plate sieve and three plate sieves with the same cell of 8 mm × 8 mm and with different number of sections were developed and produced: 3, 7 (Fig. 1.6), 11. The sieves are designed so that they can be installed at different distances from the cylindrical surface of rotation of the cutting edges of the knives along the entire length of enveloping the drum surface.

The feed mechanism has structural differences from the mechanisms of typical drum chippers. In developing such a mechanism, the main attention was paid to preventing the impact of all negative side factors on the cutting process, such as: uneven filling of the feeder neck; intermittent nature of the feed due to large dynamic loads in the cutting area, and, as a result, slippage of the feed rollers and conveyor belt.



a

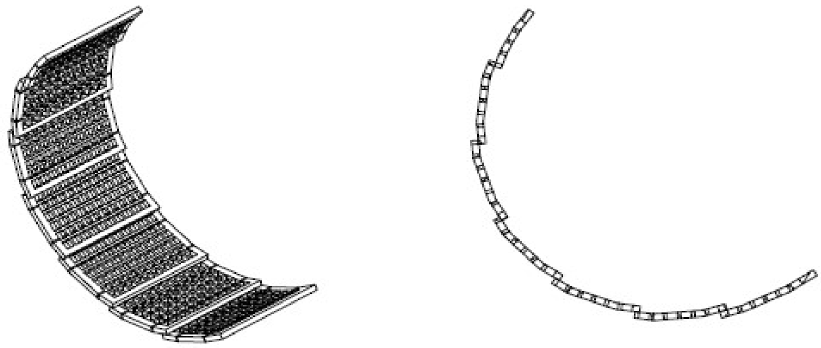


b

1—frame; *2*—chipping chamber; *3*—hinged cover; *4*—knife drum; *5*—rear surface of the drum knife; *6*—cutting knife; *7*—lower bedknife; *8*—upper bedknife; *9*—sieve; *10*—lower feed chain; *11*—upper feed chain; *12*—feed table.

Fig. 1.5. **Experimental drum chipper: *a*—general view; *b*—schematic diagram**

Based on this, in the feeding mechanism (see Fig. 1.5), the lower *10* and upper *11* special six-row chains with a pitch of 12.7 mm with sharp hooks on the outer side, directed at a certain angle to the direction of movement, are used. These chains are mounted in the work table *12*, the location of which can be changed from ground (horizontal) to inclined at an angle of 30°, that is, the feed angle of wood can be changed.



a *b*

Fig. 1.6. **Stepped plate sieve: *a*—general view; *b*—side view**

The thickness of the blank is regulated: 50 ± 1 mm. The distance between the lower *10* and the upper *11* feed chains is unchanged. Therefore, by feeding the calibrated raw material, the upper and lower feed chains drive their hooks into the wood in mutually opposite directions, securely fixing it, thereby preventing any axial displacement. This design of the mechanism makes it possible to objectively investigate cutting processes in a wide range of feed speeds (up to 4 m/min). The lower and upper feed chains are moved by two worm motor reducers i =100 and electric motors N= 250 W; n = 885 rpm.

Automatic machines are installed on the *control panel*, including the input machine, frequency converters, relays of cutting and feeding mechanisms. On the panel, there is a control button, frequency regulators of cutting and feeding motors, a digital data display. To control the operating mode of the drum, a frequency converter is used, which operates in the vector mode of controlling the motor rotation speed and makes it possible to accurately adjust the drum rotation speed in the range from 0 to 2,500 rpm.

Conclusions

The experimental drum chipper produced makes it possible to study the following with a high degree of accuracy:

1 To compare the efficiency of the sieves of the plate form and the stepped structure, namely:

a) To analyse fraction by fraction in mass equivalent wood chips with the largest size of 6.0 mm.

b) To determine the energy consumption per unit mass of products (per-unit cutting work).

2 To determine the effect of cutting speed on per-unit cutting work and quality of products of the desired fraction.

3 To investigate the influence of the number of sections of the stepped sieve on the technological parameters.

4 To investigate the effect of the distance between the knife drum and the sieve on the productivity of the technological process.

5 To set the rational feed angle of wood in the drum chipper.

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