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Study of the Unloading and Selection Process of Energy Willow Cuttings for the Creation a Planting Machine

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Abstract. **The article highlights the problems of ensuring continuous unloading of energy willow cuttings from slotted bunkers. During the free discharge of rod-like bodies, such phenomena as crypt formations, distortions, pinching occur, which stop the discharge under the action of gravity. Finding such parameters, under which the system will work evenly and without stops, will make it possible to automate many processes related to working with such material, in particular, when developing a piecemeal selection mechanism for a planting machine. The study revealed and analyzed the possible forms of vaults that are formed during unloading from creating obstacles to movement. As a hopper model, for unloading cuttings, a slotted hopper in the form of two walls located at angles to the horizontal plane is considered. These walls form an unloading slot with adjustable width of the unloading window and an adjustable tilt angle. During the study, vaults were recorded, which are formed at different parameters of the bunker during free unloading. As research has shown, in order to ensure uninterrupted unloading of cuttings, there is such a width of the unloading window of the hopper, which will ensure uniform pouring of cuttings without crypt formations and stops associated with this process. The analysis of continuous discharge of rod-like material established that for cuttings of energy willow, the width of the window, which ensures continuous discharge, is 8-12 cm.**

Keywords: vault formation, unloading, cuttings, energy willow, bunker, vault, automation of planting.

INTRODUCTION

Many machines used in production technological lines use in their principle of operation such processes as loading, unloading, selection, transportation of various materials, which most often consist of the same type of particles. The high-performance and high-quality operation of such machines largely depends on the speed of unloading the product, the equipment used, and the parameters and modes of operation of the unloading devices [1-2]. The problem becomes even more complicated when it is necessary to ensure uniform and continuous discharge of material in which one size (length) significantly exceeds the other two sizes. An example of such a rod-like material is plant cuttings. The need to study this issue is dictated by the growing popularity of fuels from bioenergy crops, the volume of which requires fast and productive machines to create so-called energy plantations. One of the most common such crops is energy willow (e.g. Salix viminalis), which is planted vegetatively with cuttings 20-25 cm long and 8-20 mm in diameter [3-6]. Planting of energy willow plantations is carried out by machines in which the

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planting material is fed manually, which significantly limits the possibilities of increasing the efficiency of the units. When creating an automatic planter of such material, the task of fast and accurate feeding of cuttings arose, which led to the search for ways to justify the movement of cuttings during unloading from the storage tank [7-12]. Existing methods of automating the planting of such material are mainly reduced to the use of cassette mechanisms, however, this method requires careful preliminary preparation of the planting material and requires time spent on charging the cassettes. This study is designed to reveal the possibilities of uninterrupted gravity unloading of rod-like materials from a slotted hopper, which can be the initial stage of the development of a cassette-free planter of energy willow, which will make it possible to significantly increase the productivity of planting units, the quality of their work, as well as reduce the number of workers on the establishment of energy plantations.

It is known from the practice of functioning of bunkers that the main obstacle to the unloading of lumpy materials is the phenomenon of crypt formation, which, interrupting the natural spilling of materials, negatively affects their consumption characteristics. There is no comprehensive theoretical solution to this problem in the scientific literature. In the field of research on the dynamics of spillage of loose media from containers, fight against crypt formation, and in the field of development of crypt-destructive equipment, we note the significant contribution of the following scientists: Alfiorov K., Bilousov A., Bogomyakhi V., Goryushinskyi B., Horyushinskyi I., Gyachev L., Jenike E., Zheltkova S., Zenkov R., Kvapil R., Keglyn B., Kunakov B., Sokolovsky V., Tretyakov H., Yatsun S. and others. In their works, the main characteristics and physical and mechanical properties of bulk materials, which in one way or another affect the process of crypt formation, are considered, the general directions of research in the field of uninterrupted functioning of bunker devices and the improvement of crypt moving equipment for bulk cargoes with a wide range of physical and mechanical properties are reflected [14- 24]. Numerous studies of the process of crypt formation made it possible to establish only some dependencies that explain the essence of this process. The degree of influence of a huge number of different interdependent factors on crypt formation is difficult to assess practically and predict theoretically: it is the geometry of the hopper and outlet opening, and the physical and mechanical properties of materials, and the conditions of loading, storage and release. Precisely due to the difficulty of ensuring uniform continuous movement, which is hindered by the process of crypt formation, until now there is no universal feeding device that would work effectively with any loose material, and the variety of material that requires unloading contributes to further searches for justifications for movement one or another material.

It is also difficult to overestimate the scientific and practical importance of research into the mechanism of movement of loose materials under the influence of their own weight, since the physical and mechanical properties of these materials and the patterns of their discharge have a decisive influence on the design of bunkers, as well as discharge devices and devices that stimulate discharge.

Scientists single out two main directions for ensuring uninterrupted discharge of bulk cargo from containers:

1. prevention of the occurrence of vaults, which can be achieved by the correct selection of capacity parameters;

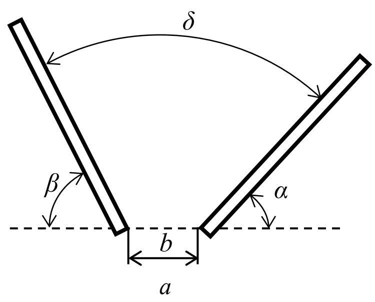
2. destruction of the formed vaults with the use of various vaulting devices.

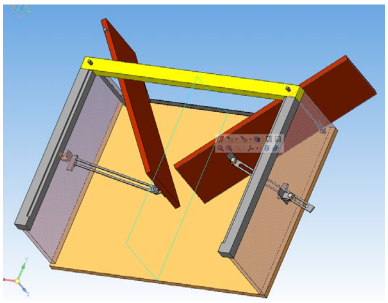
Both directions are relevant, but we will consider the first more progressive, since it is better to prevent crypt formation than to fight it [6]. Modeling the movement of particles of loose material during unloading, as well as the choice of means for destroying the vaults formed in the container, depends on the physical and mechanical properties of the material and the parameters of the container itself. In this work, we are interested in the behavior of rod-like heterogeneous materials (which are, in particular, cuttings of energy willow or poplar) in the process of unloading from the hopper under the action of gravitational forces, so the purpose of the article is to search and highlight the patterns of movement of rod-like bodies in the process of their discharge from the hoppers. To achieve this goal, the following tasks should be solved:

- justify the bunker model for unloading energy willow cuttings;
- to create an experimental model of the bunker that would meet the conditions for unloading rod-like materials;
- analyze the process of vault formation for rod-like materials and identify the characteristic features of vault formation for willow cuttings;
- to reveal the possibility of continuous shedding of energy willow cuttings and the nature of this process;
- create recommendations for feeder hoppers for energy willow ponds and identify directions for further study of this process.

MATERIALS AND METHODS

It is convenient to unload rod-like materials from bunkers with sloping walls and a slotted unloading window (Fig. 1).





b

Fig. 1. Experimental installation: *a* - a model of a bunker for unloading energy willow cuttings. α and *β* are the angles to the horizontal plane of the two walls, δ is the angle of inclination of the discharge funnel formed by the two walls; b. - the width of the unloading window; *b* - a view of the laboratory installation.

The nature of filling the bunker with such materials will be carried out in layers one above the other, therefore, in a first approximation, studying the movement in this system can be limited to the study of processes in the plane perpendicular to the bodies and walls of the bunker, neglecting the possibility of their movement in the transverse direction. Therefore, when making a working laboratory installation, let's limit the space of the bunker with two parallel walls at a distance slightly greater than the length of the material used for unloading.

The laboratory installation allows you to adjust the angles of the two walls α and β in wide ranges, as well as to change the width of the discharge window, which is necessary for research without delay.

RESULTS AND DISCUSSION

In the process of conducting experiments to study the characteristics of the discharge of rod-like material through the slotted discharge window, cuttings of energy willow were loaded in a uniform layer into the bunker with the discharge window closed. When setting small window width parameters, vaults will inevitably be formed. By fixing the position of the cuttings when the movement is stopped, it is possible to identify the factors that affect the process of crypt formation of this material. And by expanding the discharge window, you can achieve conditions under which discharge will take place continuously. By using high-speed photography, it is possible to identify the regularities of such eruptions for use in the further study of this process. In the work of I.V. Horyushynskyi, I.I. Kononova, V.V. Denisov gave the following definition of the vault formation process: vault formation is the formation of vaults in containers during the release of bulk cargo [25]. Plant cuttings have a rod-like shape, therefore, excluding other factors, crypt formation here can be considered as a process in one plane, where the discharged material forms an arched structure. At the same time, the cuttings in the vault (each of them) are kept from falling by normal reactions and corresponding frictional forces of the neighboring cuttings. And the cuttings that occupy extreme positions (tangential to the walls) are held by normal reactions and frictional forces not only of the neighboring cuttings, but also by the forces of their interaction with the material of the bunker walls (Fig. 2).

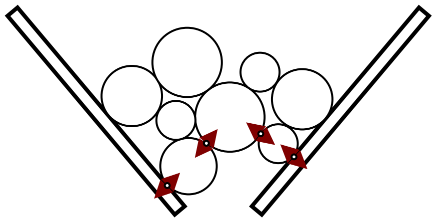


Fig. 2. Scheme of crypt formation when cuttings are shed.

In order to find possible solutions to the problem of continuous shedding of energy willow cuttings, it is important to analyze the possible forms of the formed vaults. As it was said above, when using rod-like materials in an environment limited by their length, the crypt formation can be considered only in one plane. Taking this into account, we will try to compare the formation of vaults under controlled conditions and directly for an array of cuttings.

For the first case, let's take cylindrical bodies of different diameters. In our case, coins of different denominations are quite suitable. Some variants of vaults formed during the movement of such bodies are shown in Fig. 3.

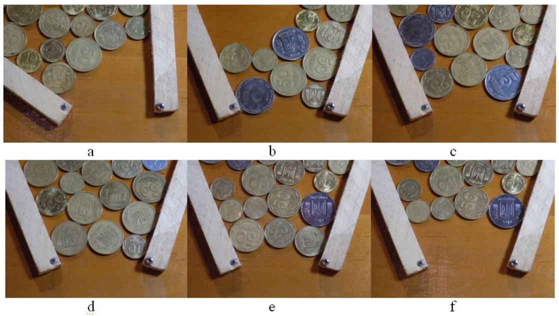
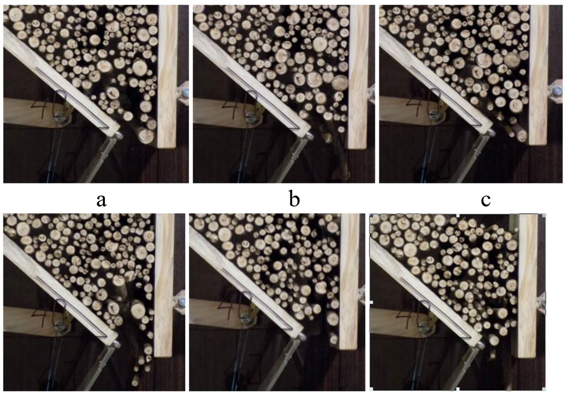


Fig. 3. Examples of vaults formed when cylindrical bodies are unloaded on a plane.

Analyzing fig. 3, it can be concluded that the formation of vaults in the system of one plane can be completely described by the laws of interaction between particles according to the positions they occupy. Moreover, the forms of the vaults themselves, although they are random, are generally formed according to one and the same laws and can be predicted in general terms. Taking into account the dimensional characteristics of plant cuttings, it is not difficult to predict that the length of the cuttings can also affect the process of crypt formation. In fig. 6 shows some variants of fixed vaults when cuttings are unloaded through the unloading hole at angles α=90° and β=40°, and Fig. 7 shows the same at angles α=60° and β=40°.

Thus, we can see that the shape of the vaults is significantly different from the previous vaults in one plane. The difference is at least that the extreme cuttings in the plane of the side wall do not always come into contact with the wall of the bunker, and some cuttings in this plane do not contact the neighboring cuttings at all, intertwining with them somewhere in the depth of the layer. Often, the hanging of the cuttings provokes a non-uniform pinching of them along the length, when one of the ends is released before the other and thus trying to take a vertical position, which can be seen in fig. 4 - b, d, e.

Note that in many cases, the reason for such differences is the length of the cuttings being skewed relative to each other. Also, the reason was sometimes defects in the shape of the material - curvature, notches, taper, etc. When many of these reasons coincide in one layer, you can even observe the picture as in Fig. 5, which makes the process of uniform unloading problematic, and the controlled output of material in the desired orientation is practically impossible.



a b c

d e f

Fig. 4. Examples of vaults formed when cuttings of energy willow are unloaded.

Such problems arise with small values of the width of the unloading window, when static vaults prevail over dynamic ones. When the width of the window is increased, the unloading process is more uniform, and in this case it is possible to observe and analyze the regularities of the discharge of the material. It has been established that for energy willow cuttings, the width of the window, which ensures continuous shedding, is 8-12 cm.

a b

Fig. 5. Problems of unloading energy willow cuttings in the area of the unloading window.

Conclusions

In order to solve the issues of freeing the process of planting energy willow from manual labor during the supply of planting material from storage containers to the planting site, there is a need to create an automated supply system. The selection and transportation of cuttings in such a system can be organized using gravity unloading from the bunker. The hopper model for unloading rod-like materials consists of two walls located at an angle to the horizon, at the bottom of which an unloading window with an adjustable width is formed. The analysis of the unloading process and the shape of the vaults shows that in the case of such a rod-like material as cuttings of energy willow, in addition to the general reasons for the formation of vaults and the regularities of their shape formation, there are also other influencing factors. A feature of plant cuttings is their shape, which complicates crypt formation and causes such additional conditions and factors. such as distortions of the cuttings in the layer, irregular shape of the cuttings, unevenness of their pinching along the length, etc. When creating conditions under which there is no occurrence of static vaults, it was possible to analyze the patterns of unloading cuttings from the bunker. As a result of the study, it was established that to ensure the uninterrupted unloading of cuttings, it is possible to choose such a width of the unloading window of the bunker, which will ensure uniform pouring of cuttings without crypt formations and stops associated with this process. The use of the obtained data in further research will make it possible to more fully take into account all the factors that arise in the process of unloading and crypt formation, which is important in the study and improvement of this process.

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