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ANALYSIS OF THE OPERATING PRINCIPLES OF METERING DEVICES IN PNEUMATIC SEEDERS

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Abstract

This article analyses the operating principles of metering devices used in pneumatic seeders. The role and application of pneumatic seeders in agricultural engineering and crop production are discussed. Particular attention is paid to the technological importance of precision sowing, the uniform placement of seeds in the soil, the reduction of seed damage, and the improvement of resource efficiency. The article also describes the general structure of pneumatic seeders, their classification features and the main functional components of the sowing apparatus. It is shown that the use of pneumatic seeders makes it possible to improve the quality of sowing, reduce seed and fuel consumption, and increase the level of mechanisation in agricultural production.

Keywords: pneumatic seeder; metering device; vacuum fan system; wheels; energy; GSKB design; sowing machine; EDX 9000.

Introduction

In recent years, the development of agriculture has become one of the priority areas of economic and technological modernisation in the Republic of Uzbekistan. On the initiative of the President of the Republic of Uzbekistan, Shavkat Miromonovich Mirziyoyev, special attention has been paid to the introduction of modern machinery, resource-saving technologies and high-performance agricultural equipment into crop production. In this context, the mechanisation and digitalisation of sowing operations are of particular importance, since sowing is one of the first and most responsible technological stages in crop cultivation [1].

The quality of sowing has a direct effect on seed germination, plant density, uniformity of crop development and final yield. If seeds are placed unevenly in the soil, some plants may receive insufficient nutrition, light or moisture, while others may compete excessively with neighbouring plants. As a result, field emergence becomes uneven, the development of plants is delayed and the productivity of the crop decreases [2]. Therefore, the use of modern pneumatic seeders is becoming increasingly important for agricultural production.

Pneumatic seeders are used for the precise sowing of cotton, maize, sunflower, soybean and other row crops. Their main advantage is the ability to place seeds individually at a predetermined distance and depth. This makes it possible to reduce the consumption of seed material, improve the spatial distribution of plants and create favourable conditions for crop growth. In comparison with traditional mechanical seeders, pneumatic seeders provide higher sowing accuracy because the seed metering process is controlled by air flow and vacuum pressure [3].

The relevance of this topic is also confirmed by the practical experience of Uzbekistan. In 2023, cotton sowing began 18–20 days earlier than in the previous year and was completed within 10–15 days. A total of 2,484 high-performance pneumatic seeders were used on 500 thousand hectares. As a result, 15 thousand tonnes of cotton seed and 5 thousand tonnes of diesel fuel were saved [4]. In order to increase yield, cotton was sown using a double-row scheme on 113 thousand hectares, which was 14 thousand hectares more than in the previous year. In addition, for the organisation of machine harvesting, cotton was sown using a 76 cm row-spacing scheme on 228 thousand hectares, which was 111 thousand hectares more than before [5].

These facts show that pneumatic seeders are not only technical devices but also an important element of modern agricultural production. Their effective use contributes to higher labour productivity, better use of resources, improved sowing quality and increased crop yield.

The aim of this article is to analyse the operating principles of seeding units in pneumatic seeders and to identify the main technological and design factors that determine the efficiency of precision sowing.

Agrotechnical Requirements for the Sowing Process

Sowing is one of the most important technological processes in crop production. The main agrotechnical requirements for sowing include timely performance of the operation within the optimal agrotechnical period, accurate maintenance of the established seeding rate, minimal damage to seeds during their passage through the metering device and precise placement of seeds in the soil.

For row crops, sowing accuracy should be evaluated not only according to the uniformity of sowing depth but also according to the evenness of seed distribution along the row and across the entire field area. The distance between seeds in a row is called the sowing step, while the distance between neighbouring rows is called row spacing. Together, these two parameters determine the feeding area of each plant [6].

The feeding area is an important agronomic indicator because it affects plant growth, crop yield, product quality and the ability of cultivated plants to compete with weeds. If the feeding area is too small, plants compete strongly for light, moisture and mineral nutrients. If the feeding area is too large, the field area is not used efficiently and the potential yield may decrease. Therefore, the optimal selection of sowing step and row spacing is essential for achieving high productivity.

The required feeding area depends primarily on the biological characteristics of the crop. These include the duration of the vegetation period, the development of vegetative mass, the strength of the root system and the ability of the plant to use soil moisture and nutrients. Soil fertility, moisture supply, climatic conditions and cultivation technology also influence the choice of sowing parameters.

Classification of Pneumatic Seeders

Pneumatic seeders can be classified according to several design and technological characteristics. They may be classified by purpose, by the structure of their working bodies, by the type of seed metering system, by traction type, by assembly method, by the traction class of the tractor for which they are designed, by the method of seed delivery to the furrow, by the number of rows, by the type of frame and the number of frame sections, and by the method of sowing.

According to their purpose, seeders may be universal or specialised. Universal seeders are designed for sowing a wide range of crops, while specialised seeders are intended for one crop or for a narrow group of crops with similar biological and technological requirements [7]. Specialised seeders include beet seeders, vegetable seeders, melon seeders, cotton seeders and forestry seeders.

The design of pneumatic seeders depends on the type of crop, row spacing, seed size, sowing rate and field conditions. For row crops, pneumatic seeders are often equipped with several sowing sections. In many cases, such machines include at least 12 sowing units. Each sowing section performs a separate technological function and ensures the accurate delivery of seeds to the furrow.

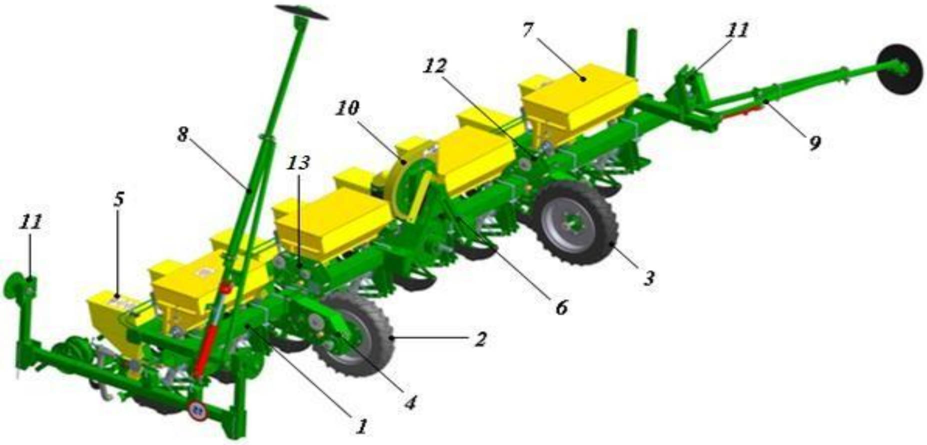

Figure 1. General view of a pneumatic seeder.
1 — frame; 2, 3 — wheels; 4, 12, 13 — holding mechanisms; 5 — working section; 6 — mounted device; 7 — additional fertiliser system; 8, 9 — markers; 10 — vacuum fan system; 11 — transport devices.

The frame serves as the main supporting structure of the seeder. The wheels provide movement and help maintain the stability of the machine during field operation. The working sections perform the main sowing process, while the additional fertiliser system allows fertilisers to be applied simultaneously with sowing. Markers are used to ensure the correct alignment of subsequent passes [8]. The vacuum fan system is one of the most important elements of a pneumatic seeder because it creates the air pressure or vacuum required for seed metering and delivery.

Operating Principles of Pneumatic Seeding Units

The seeding unit is the main working body of a pneumatic seeder. Its function is to separate individual seeds from the seed mass, dose them according to the established seeding rate and deliver them to the furrow at the required spacing. In pneumatic seeders, this process is carried out with the help of air flow, vacuum pressure or positive pressure, depending on the design of the machine.

In vacuum-type pneumatic seeders, seeds are held on the holes of a rotating metering disc by vacuum. As the disc rotates, individual seeds are captured and transported to the discharge zone. At this point, the vacuum is interrupted, and the seed falls into the seed tube and then into the furrow. The accuracy of this process depends on the stability of vacuum pressure, the diameter and shape of the holes in the metering disc, the size and shape of seeds, the rotational speed of the disc and the adjustment of the seed singulator.

If the vacuum pressure is too low, seeds may not be held reliably on the disc, which leads to skips in the row. If the vacuum pressure is too high, more than one seed may be captured by one hole, causing doubles. Therefore, correct adjustment of the vacuum system is necessary for high-quality single-seed sowing.

Another important element is the seed singulator. Its purpose is to remove extra seeds from the metering disc and leave only one seed on each hole. The effective operation of the singulator is essential for maintaining the required seed spacing. Poor adjustment of the singulator may increase the number of missed seeds or double seeds, which negatively affects plant density and yield formation.

The seed tube also affects sowing accuracy. After leaving the metering disc, the seed moves through the seed tube into the furrow. During this movement, seed bouncing, air resistance and vibration of the machine may disturb the uniform spacing of seeds. Therefore, the design of the seed tube should provide smooth movement and stable delivery of seeds to the soil.

Figure 2. Seeding devices.
a) modern multi-row pneumatic seeding device; b) four-row seeder; c) seed metering device.

The seeding devices shown in Figure 2 demonstrate that pneumatic seeders may differ in the number of rows, structural arrangement and type of metering mechanism. However, their general technological purpose is the same: to ensure accurate dosing, reliable delivery and uniform placement of seeds.

Advantages of Pneumatic Seeders

The main advantage of pneumatic seeders is their high precision. They can place seeds at a predetermined distance and depth, which improves the uniformity of plant stands. This is especially important for crops that require a specific feeding area and uniform development during the growing season.

Another advantage is the reduction of seed consumption. Since seeds are placed individually and accurately, there is less need for excessive seeding rates. This is particularly important when expensive, high-quality or treated seeds are used. Reducing seed consumption decreases production costs and increases the economic efficiency of sowing.

Pneumatic seeders also reduce seed damage. In mechanical metering systems, seeds may be damaged by friction, compression or impact. In pneumatic systems, the seed metering process is gentler because the seed is moved mainly by air flow and vacuum pressure. This helps preserve seed viability and improves field emergence.

Energy efficiency is also an important advantage. Correctly adjusted pneumatic seeders reduce unnecessary passes over the field, decrease fuel consumption and improve the overall productivity of sowing operations. In Uzbekistan, the use of high-performance pneumatic seeders has already shown practical benefits by reducing seed and diesel fuel consumption.

In addition, pneumatic seeders can be combined with fertiliser application systems, electronic monitoring devices, GPS navigation and automatic control units. These possibilities make them suitable for precision farming and digital agriculture.

Use of Pneumatic Seeders in Uzbekistan

The agricultural sector of Uzbekistan is increasingly introducing modern mechanised technologies. Pneumatic seeders play an important role in this process because they improve the quality and speed of sowing operations. Their use is especially important in cotton production, where sowing accuracy directly affects plant density, the organisation of machine harvesting and final yield.

The introduction of pneumatic seeders has made it possible to increase the level of mechanisation in sowing operations. It has also contributed to earlier sowing within optimal agrotechnical periods. Earlier completion of sowing is important because it allows crops to use favourable soil moisture and temperature conditions more effectively. This may improve germination, early plant development and yield stability.

The use of pneumatic seeders also supports resource-saving agriculture. Savings in seed and fuel reduce production costs and decrease the environmental impact of agricultural operations. This is consistent with the modern requirements of sustainable and environmentally safe crop production.

The analysis shows that the use of pneumatic seeders can increase crop yield by 8–12 percent and reduce fuel and seed consumption by 10–15 percent. These indicators confirm the technological and economic importance of pneumatic seeders in modern agriculture.

Prospects for Improvement

Despite their advantages, pneumatic seeders still require further improvement. The efficiency of these machines depends largely on the design of the metering device, the stability of the vacuum system, the quality of seed singulation and the uniformity of seed delivery to the furrow.

One of the main directions for improvement is the optimisation of aerodynamic parameters. The air flow in the metering system must be stable and sufficient for reliable seed capture, transport and release. Any instability in air pressure may lead to skips, doubles or uneven seed spacing. Therefore, future research should focus on determining optimal air pressure values for different seed types and operating conditions.

Another important direction is the introduction of intelligent sensor systems. Sensors can monitor seed flow, detect skips and doubles, measure working speed and control the performance of each sowing section. Such systems allow the operator to identify problems during operation and make adjustments in real time.

The development of electronic modules for automatic air pressure control is also promising. These modules can analyse operating conditions and regulate vacuum pressure automatically. This would reduce the dependence on manual adjustment and improve sowing accuracy under changing field conditions.

The integration of GPS and IoT technologies is another important step towards digital agriculture. GPS systems can improve field navigation, reduce overlaps and gaps, and support accurate row placement. IoT technologies can connect seeders with digital platforms, allowing data collection, remote monitoring and performance analysis. As a result, sowing operations can become more precise, efficient and controllable.

Conclusion

The analysis shows that pneumatic seeders are modern and efficient agricultural machines that provide high-quality sowing of row crops. Their main technological advantage is the ability to place seeds individually at the required distance and depth. This improves the uniformity of crop stands, reduces seed consumption and creates favourable conditions for plant development.

The efficiency of pneumatic seeders depends mainly on the correct operation of the seeding unit, the stability of the vacuum fan system, the quality of seed singulation and the accurate delivery of seeds to the furrow. If these elements are properly designed and adjusted, pneumatic seeders can significantly improve sowing quality and increase the productivity of agricultural operations.

In Uzbekistan, the use of pneumatic seeders has expanded in recent years and has contributed to the mechanisation of sowing processes, earlier completion of cotton sowing, reduction of seed and fuel consumption and improvement of crop production efficiency. This confirms the practical importance of pneumatic seeders for national agriculture.

Further development of pneumatic seeders should focus on the optimisation of aerodynamic parameters, the introduction of intelligent sensor systems, automatic control of air pressure and the integration of GPS and IoT technologies. These

technological solutions will increase the productivity and reliability of pneumatic seeders, improve seed placement accuracy and support the creation of resource-saving and environmentally safe agricultural production systems.

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