SOWING MACHINES AND SYSTEMS BASED ON THE ELEMENTS OF FLUIDICS / *ВИСІВНІ МАШИНИ ТА СИСТЕМИ НА ОСНОВІ ЕЛЕМЕНТІВ ПНЕВМОНІКИ*

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ABSTRACT

On the basis of the research results it is established that to increase the productivity and quality, as well as to reduce the work intensity of planting machines it is necessary to unite the metering and timing system on one principle – the principle of discrete action. The rational basis for this is using of control and power fluidic devices, and active distribution of pneumatic devices and pneumatic power systems. On this basis, pneumatic seeding systems on the row and one grain sowing were developed, which also allows distributing seeds differentially when this seeding technology is used for precision farming.

РЕЗЮМЕ

На підставі результатів досліджень встановлено, що для підвищення продуктивності і якості, зниження енергоємності роботи посівних машин необхідно об'єднання висівного апарату і системи синхронізації на одному принципі – дискретної дії, а раціональною основою для цього є застосування керуючих і силових струменевих елементів, а також активних пневматичних розподільних пристроїв і пневматичної системи живлення. Виходячи з цього, розроблено пневмоструминні висіваючі системи для рядової і однозернової сівби, що також дозволяють диференційовано розподіляти насіння при сівбі по технології точного землеробства.

INTRODUCTION

The traditional methods of agricultural technique production do not provide the increase of the labour productivity in proportion to expenses already, and also return of capital investments, and, at the same time, reduce efficiency of agricultural production. The state of Science and Technique presently allows finding principally new technical decisions.

At the same time, some systems of mechanization control and automation are working under trying conditions exploitations (at temperatures, different from normal, high accelerations, intensive oscillation and shock loadings, in the conditions of heavy dustiness, etc.). Therefore, search for the new technological and technical decisions, based on modern achievements of Science and Technique and proper socio-economic requirements, is required.

«Pneumonic» is a new direction in agricultural machinery. Pneumonics or pneumatic automation is an area of automation, based on the use of gas streams operation. A stream technique is analogical electronics in regard to both basic principles of construction and practical application. Devices and systems of stream technique do not have mobile details and are utilized in computers, pumps of heart-lungs, control the system rockets, submarine boats, metal-cutting machine-tools, etc. Jet elements are working on in relation to small overfalls of pressure. Jet techniques have a number of advantages before electronic. Its technique is maximum simple, lasting, cheap and reliable (*Kassimov A., 2010*). It is more reliable at high and low temperatures, and also at the high levels of radiation and steadier to the mechanical loadings and vibrations, which is very important in a mobile technique (*Aulin V.V. et.al, 2016*).

Jet techniques are a new direction of automation, but the perspective of its application in industrial and in agricultural engineering is great enough. In this connection there are many interesting questions yet to be solved, namely – possibilities of wider use of Jet elements and devices.

As generally known, the mortgage of high harvest at the low expenses of labour and facilities is timely and high-quality implementation of technological operations on agricultural crops tillage in accordance with agro technical requirements, in particular case sowing. For this purpose, the reliable, productive, high-quality working sets of technique are needed for all of operations in tillage technologies.

The study of the general state and prospects of the development of food stuff production technical providing shows that the extensive approach in relation to traditional facilities and mechanization process is unable to provide rationally the increase of amount and quality of products and works in the future, and also to the capacity requirement, adequate making progress capital investments, circulating cost and power expenses. The scopes of extensive growth are already obvious in the processes of traditional mechanization (*Kashubo N.D., 2007*).

The analysis of existing sowing machines and systems shows that the scientific thought was aimed at the original principles of sowing machines work. It allows improving the quality of the sowing process (*Firsov A.S. and Golubev V.V., 2013*). Lately, the decision on sowing process automation and its control has begun to appear (*Kobchenko S.N. and Medvedev E.Yu., 2015*). However, analysing the algorithmic models of technological processes of existing constructions of seed meters and systems for the different types of sowing and seeds, it is possible to draw a conclusion, namely that the operative algorithm of these constructions requires much more energy to overcome the friction of the materials, though less energy is required to fulfill the elementary operations of sowing.

Existing constructions of sowing machines still have high intensity, which results in using a lot of energy. It entails a high cost, insufficient reliability of machines, relatively large labour intensiveness of tuning, adjusting and maintenance of machines, and also restrains creation and applying in industry of new kinds of machine constructions. The analogical position is technique automation in agriculture.

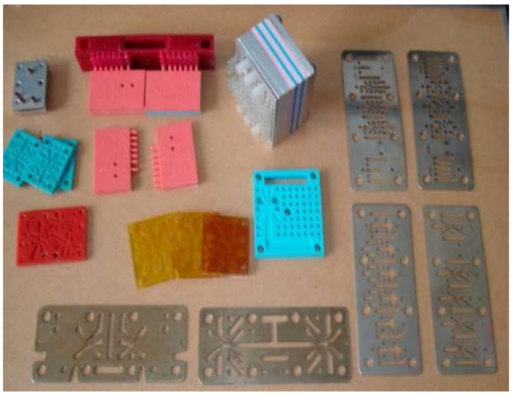
The stake of the automated agricultural machines in the general volume of their output does not exceed 30%, the simplest means of control and management are used, together with hydraulic, mechanical and mixed devices. The application, for example, of microelectronics in the systems of automation of agricultural machinery separate groups is within the limits of 16%.

Further development of agriculture, its concentration, and consequently, the possibility of its intensification was put on an order-paper by new requirements to form the material and technical base of machine constructions.

Therefore, presently there is a question of development and applying in industry new, universal agricultural machines, including sowing, with minimum energy of production and exploitation, high reliability, automation of working process and possibility of its durability on every area of machine moving (*Garbers H., 2015;* Alt V.V. et. al., 2008).

To accomplish the set tasks, new direction is offered for creation of seed meters and devices on the basis of Jet elements. They are appropriate both for the ordinary sowing and for vegetable crops sowing, and also for the one seed sowing of the cultivated crops.

In agriculture, the information of Jet device on the basis of power Jet elements (Fig.1) can be used in seed sowing, the main new sowing systems being created as a result.



a)

b)

Fig. 1 - Power jet elements for sowing devices

a – for controlling, b - executive power elements

Hereupon, the task is to research the possibility to apply power Jet elements in devices for sowing different crops seeds.

Here we used the special tasks associated with the area of aeromechanics, the solution of which has led to the use of fluidic elements for sowing.

These tasks study the impact of economies of scale and modes of air movement in the development of fluidic devices that are designed to work in specialized seed devices.

To optimize the operation of the jet elements the dimensions of the cameras, the duct and the ratio between the values of pressure and flow control channels have to be rational (*Chernovol M.I. et.al., 2015*).

In addition, application of power stream elements restrains a device for a number of reasons - by their insufficient efficiency, by absence of the developed model standards as dimension, rows type etc. Therefore, for the removal of these retentive factors additional researches are required.

MATERIAL AND METHODS

During the research the following materials were used:

– models of seeding machines with elements of fluidics (look at Fig.2, 3, 6) and existing sowing machines N 126.13.000 (from planter SUPN-8);

– devices for flow measurement (G6РЛ meter, rheometer-indicator, T-2-80) and instruments for measuring pressure (NWO-100У3) and rarefaction (ТМР-100У3 and the manometer and U-shaped manometer); - stand “sticky tape” (see Fig. 3b);

– seed material: seeds of wheat, sunflower and sugar beet; - sowing machine to the tractor MTZ-80 (see Fig. 5). In the course of research designed planters used hydrostatic and hydrodynamic methods of determining pressure, flow and air velocity in seeding devices and systems as well as standard test methods of seeding machines and systems for dotted seed sowing in terms of seeding reliability and its conformity to the agronomic indicators. It is envisaged the definition of the following indicators:

– the uniformity of seed distribution and the measurement of the intervals between the seeds on the sticky tape and in the groove on the germination of seeds;

– - seed damage by its visual inspection after sowing;

– the stability and uniformity of sowing by weighing portions of seeds, which are sown at a distance of 100 meters;

– the presence of twins near the seed and omissions of the individual seeds in the process of planting, visual inspection of seed number on the tape and germination after sowing.

RESULTS

Jet sowing system consists of sowing jet apparatus and the device for sowing synchronization with seeders’ speed. A stream technique can work both in the power mode and in the mode of control.

Development of the given direction gives positive results presently. The standards of seed meters are created without mobile details on the basis of power elements and devices of stream pneumatic automation for ordinary crops sowing (Fig.2, a, b, Fig.3), (*Scheglov A.V., 2010; Scheglov A.V., 2011*).

It is also set (*Burkov Y. et.al.*, *2009*; *Kassimov A., 2010*) on the basis results of conducted analysis of the systems**,** that for the high-quality sowing of ordinary and cultivated crops the association of seed meter and system of synchronization is needed on one principle – discrete action, and rational basis for them is the pneumatic feed system. On this basis, the Jet sowing system is also developed including a seed meter with the drive of sowing drum (Fig.3).

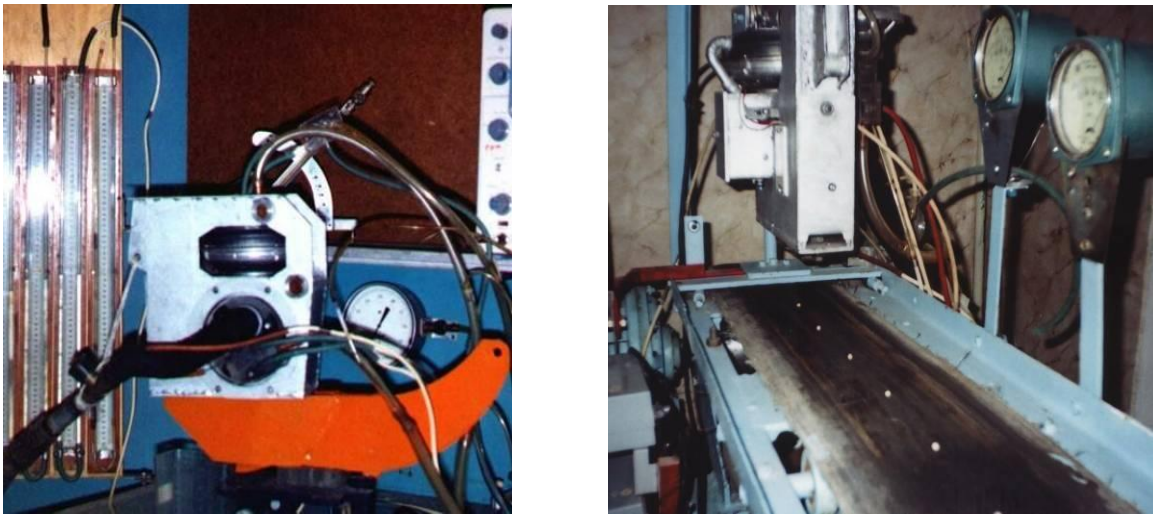
In comparative tests of the new device ATV-7.02 and serial device N126.13.000 it was found that in the new apparatus the uniformity of seeding was better and the injury of seed was missing. Laboratory and field tests on the sowing system showed the high quality of seeds distribution and a perfect agreement with the seeders’ agrotechnical requirements.

Comparison of apparatuses’ operative quality shows that evenness of seed distribution ($\Delta\sigma$) is 2.7cm (for sunflower seeds) and 4cm (for sugar beet seeds, Fig.4).

Exactness of intervals at the developed and serial apparatus was: for the beet seed - 100 and 83%, for the sunflower seed - 100 and 85.4%. In addition, during the researches on the developed apparatus, unlike serial, there was not injuring of sowing material, as air stream fully purged suckers from seeds.

a) b)

Fig. 2 - Seed meters based on pneumatic automation elements for ordinary crops sowing:
a - without moving details, for application in the systems of the centralized sowing (look at Fig.6),
b - for a layout chart there is an "apparatus – plowshare"



a) b)

Fig. 3 - Seed meters based on pneumatic automation elements for one seed sowing:
a - an apparatus is testing the sowing stability,
b - a device is testing the uniformity of seeding on the sticky tape

Laboratory stand and production testing show high quality of seed distribution (the variation coefficient is 18.2-25.4% and exactness of intervals between plants growth is 86.7-85%), which conform to the agrotechnical requirements for precision seeding machines (*Belodedov V. et.al, 2013)*.

The sowing systems also allow carrying out the differentiated seed sowing and distributing on an area in the technologies of exact agriculture.

In agriculture, sowing devices based on Jet elements can be also used for sowing of seed and distribution of mineral fertilizers; the creation of new universal planters appears as a result.

Seed meters and sensor-based systems based on stream pneumatic automation elements can work in the laboured external environments (at high accelerations, intensive oscillation and shock loadings).

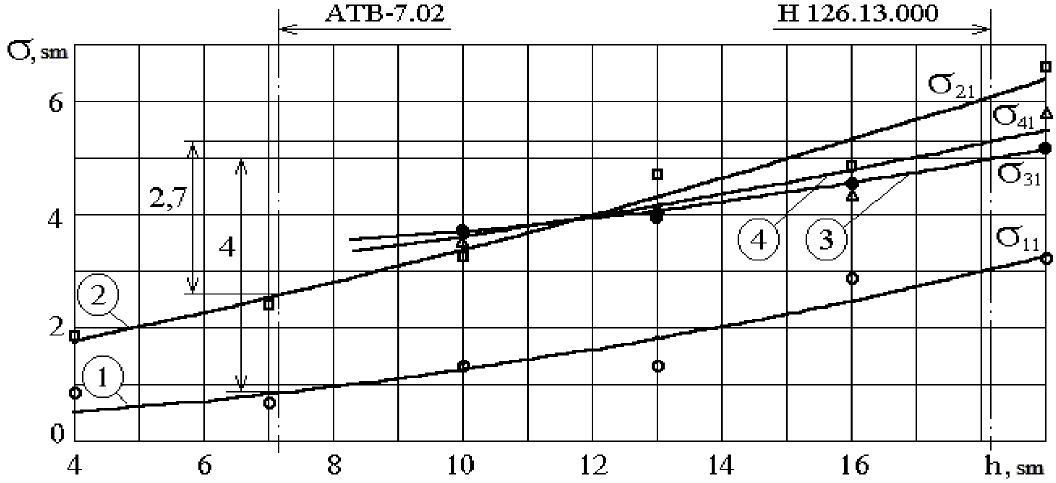


Fig. 4 - Dependence of rejection σ on intervals from the upcasting height "*h*" of seeds

1 and 2 - sugar beet and sunflower for the developed apparatus,
3 and 4 - sugar beet and sunflower for a serial apparatus

There are some other advantages of the sowing systems based on stream pneumatic automation elements, namely: high reliability and longevity; rather low cost of stuff details; simplicity of making technology (casting, unsealing on a 3D-printer); firmness to aggressive influences of environment; small resource-demanding, diminutiveness and fast-acting; a minimum of mobile mechanical and ground details; absence of individual regulations during setting of sowing norms; absence of driving mechanisms and gear boxes; absence of lubrication points; simplicity of tuning on the required sowing norm; simplicity of alteration on different sowing norms and charts; there is a high quality of sowing in all ranges of movement norms and rates; the sowing system requires a relatively small amount of energy; possibility of working process complete automation and control.

To further detail let us consider indexes related to process energy, namely to the power necessary for performing the working process. The comparative power analysis of seed meters and systems operation shows that on driving to the action and working process of Jet seed meters far less power expenses are required (Table 1). Comparison was made for the sowing machine of the ordinary sowing with the width of capture $B = 3m$ and number of plowshares $n_p = 24$.

Table 1

The energy costs of sowing systems operation

Type of seeding system	Power N_S summed up, (Watt)	Available power N_A, (Watt)	Fuel equivalent		System efficiency *η*
			(l/h)	(l/year)*	
Spool-type	440	2200	0.22	33.0	0.20
Pneumatic centralized	4272	12491	1.25	187.5	0.34
Sukhin sowing system	125	329	0.03	4.5	0.38
With elements of fluidics	144	421	0.04	6.3	0.34
Tilled seeder	1300	4632	0.46	69	0.28

*** - when loading the planting machine 150 hours per year**

It is known that for the proper culture, not including harvesters, it is necessary to have at least four separate machines, which have considerable steel intensity and cost, although they work during a limited period of the year. For example, the annual load of different planters reaches 50-160 hours, cultivators – 270-350 hours, etc. It is thus set that there is 116.1MJ of the materialized energy per one kilogram of agricultural machine mass, which corresponds to a heating value of approximately four litres of fuel.

It's obvious that a great deal of material energy which is paid for, doesn't do any work. The search of ways and possibilities is therefore required if not avoidance, minimization of such non-productive expenses of labour and facilities.

Also, one of the possible directions in researches is the creation of universal machines, due to the stream sowing systems which are considered better.

A machine (Fig.5) can have a frame of cultivator with add-on sections, pneumatic station the drive of which can be hydraulic or mechanical from a tractor, general control of the seed sowing or fertilizer distribution system and removable working knots, set on it; containers with sowing devices and devices covering seed with earth; plowshares, cultivation paws and rolling up wheels set on the add-on sections of the cultivator.

Thus, effectiveness of circulating costs, consisting in the decline of high power consumption of sowing process, takes place here. Also, as a result of replacing two machines by one, universal, the possibility to reduce expenses of the materialized energy or fixed assets is obtained.

Fig. 5 - Universal machine "seeder – cultivator"

It is necessary to point out that this is only one of the variants to apply Jet seed meters and systems. There are other possibilities of development in this direction:

- application in «precision» agriculture is easy enough adaptation to changing the line of sowing norms,
- possibility to create not only universal machines of type «seeder - cultivator» but also universal module which facilities the mechanization of corn and cultivated crops tillage.

Also, one of perspective directions is the development of the pneumatic centralized sowing systems (PCSS). Their application allows promoting labour productivity on sowing and reducing sowing machines resource-demanding. But in terms of sowing quality, in particular the unevenness of sowing between plowshares, they do not always conform to the agro technical requirements.

One of reasons for such a position is that the dividing devices of known PCSS do not provide the required evenness of the sown material. At sowing machine inclinations and vibrations, under field conditions, there is the displacement of seed stream from the divisor axis of symmetry, so there is an increased unevenness as a result, while plant productivity largely depends on seed evenness on the sowing area. It is known that for this reason up to 20% of potential harvest is lost. The increased unevenness is due to an equal degree to the mechanical sowing machines with spool-type seed meters, which do not provide the high-quality sowing and distributing of seed, especially during work on slopes because of sowing material moving, which results in uneven distribution of plowshares.

From the review and analysis of literary sources it results that the most applied distributors - both vertical and horizontal type - are passive, which means that the negative effect of gravity, aerodynamic and the inertia forces on the seeds are not compensated. From here, their high technological "sensitiveness" results in external and internal influences, namely inclinations, vibrations, air pressure in the system, seed distribution, concentration of mixture etc. Besides, the distributors of horizontal type have a drawback which appears because of the effect of the so called "Galton board", which means that the main part of the seeds is in the center of the distributor. It is therefore necessary to create and improve distributive devices, providing a high evenness of seeds on plowshares and possessing a sufficient technological "rudeness", mostly eliminating negative influence of external and internal factors.

It is set that this requirement can be achieved by applying the seed active distribution on sowing boots. The constructions, where the active mechanical distributing, untwisting of seed stream is used on sending, under the influence of centrifugal forces, are already known. But in them there are failings - presence of mobile details and regulations, considerable resource-demanding, difficulty in making.

Therefore, for Jet of seed meters for ordinary sowing a divider pneumo-jet device is provided for the process of seed distribution in which takes place the rotation of materials – there is an air current with permanent speed into a cylinder under act of air-blast (Fig.6).

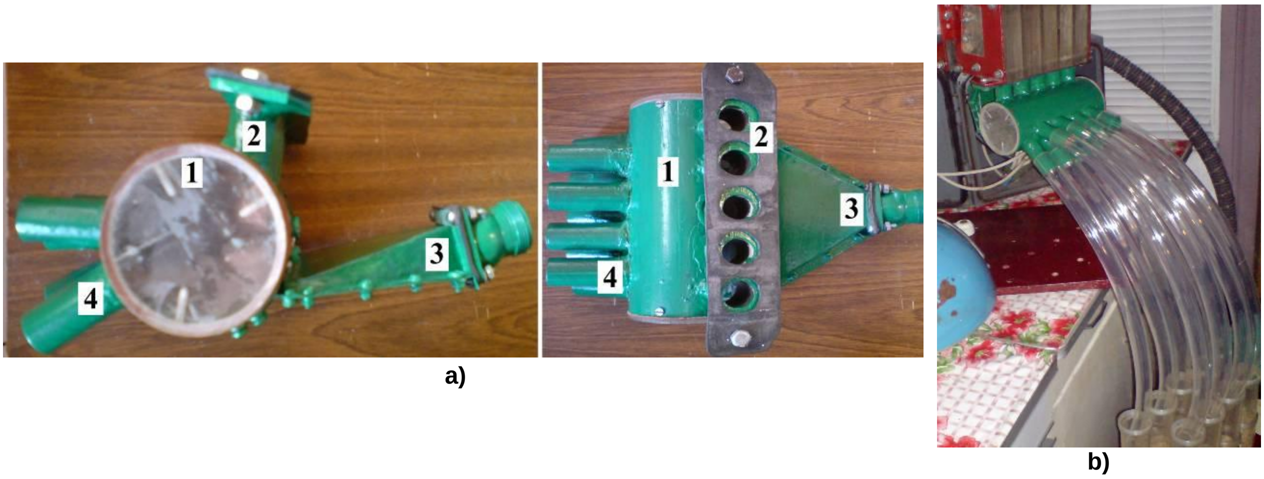


Fig. 6 - Jet sowing apparatus with the Jet distributor for centralized sowing systems:
a - distributor assembled; b - mounted on sowing apparatus

Seeds from a seed distributor are going to the cylindrical body *1* of the dispenser through the input unit nozzles *2*. Air under pressure is fed tangentially into the cylindrical enclosure through the diffuser *3* and interacts with the seed, rotating them within the cylindrical body *1*. As a result of exposure to centrifugal force which presses the seeds against the case, they fall into the outlet nozzle *4*, where the air flow transports them to the coulters and the bottom of the furrow. The radius of the cylindrical housing *1* is selected so that the centrifugal force acting to the seed was greater than the force of gravity, which affects the seed and negatively affects the uniformity of distribution, particularly on the slopes of the fields. Thus, due to compensation of the force of gravity by centrifugal force, the uniformity of distribution of seeds increases.

On the lateral surfaces of cylinder, along its axis, ducting of seed input, chart of feed pressure and output ducting are located. Such distributor chart makes it active, compact and without locomotive parts. Thus, the particles of material under the action of centrifugal force reach the cylinder wall (vertical chamber) and move on it to the output. For distributor normal work, centrifugal forces must be stronger than gravity, displacing seed at inclinations, which reduces the degree of redistribution of sowing material because of inclinations and vibrations.

CONCLUSIONS

The new seeding system machines and their components can be built on entirely new principles, the basics of which are laid in fundamental research in hydraulics, pneumatics and aerodynamics.

Efficiency of seed technological sowing process rises with the use of seed meters based on executive and managing elements of stream pneumatic automation and also stream distributive devices.

Laboratory bench and production test showed high quality seed distribution (coefficient of variation is 18.2 to 25.4% and accuracy of the intervals between plant emergence – 86.7-85%) for the developed devices. For existing devices, these values are 25-30% and 80-82% respectively. The improved designed machine is due to a forced reset of the seeds on the bottom of the furrow and consequently the lack of seed rolling from the preset position.

The planting was sustainable. The uneven formation of the original flow on the devices and between the devices was less than 2% for developed, and 3% for existing machines. This is corresponding to the agro technical requirements for sowing machines.

Evenness of sowing or distribution of seed and plants is thus improved on an area in the same time with sowing machines decrease in energy - and resource-demanding (Table 1).

The use of the new sowing systems based on elements and devices of Jet technique opens the possibility to create universal multi-purpose machines (Fig.5).

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