Automated Line For Ultrasonic Spraying of Anticoagulant Into the Blood Collection Tubes

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***Abstract* – Results of the work on creation of an automated line of ultrasonic spraying of anticoagulant on inner surface of blood collection tubes are presented in the article. Designed line provides automatic feeding of the tubes, moving them to the zone of spraying and uniformity of spraying, drying. Productivity of the automated line is 1500 products/hour.**

***Index Terms* – Automated line, ultrasound, spraying, anticoagulant, tube.**

I. INTRODUCTION

AT PRESENT aerosol technologies are widely used in various branches of the industry for the solution of industrial tasks requiring high-quality fine-dispersed spraying of various liquids with high performance.

One of such problems is spraying of anticoagulant on inner surface of blood collection tubes preventing blood clotting. The task is complicated by the need of uniform spraying on full inner surface of the tube of strictly dosed amount of anticoagulant, because the discrepancy of concentration of anticoagulant to the volume of blood taken, and also insufficient mixing can result in an inaccurate determination of concentration of cellular elements and distortion of the morphological cell structure [1].

Need of modern medicine in a huge amount of tubes gives necessity of automation process of spraying of liquid anticoagulant into the tubes.

II. PROBLEM DEFINITION

Special vacuum tubes for storing of a certain amount of blood with a sufficient amount of additional reagents: activators clotting, anticoagulants, etc. use at present time for collecting, storing and transporting of blood samples [2].

In Russia mass production of tubes is not organized, and import tubes are purchased in insufficient quantities for provision of health facilities and have a relatively high cost [3].

In this connection it is necessary to create a domestic automated line for ultrasonic spraying of the anticoagulant.

Furthermore, the analysis of capability of existing foreign lines according to reviews of the consumers suggests a number of disadvantages leading to the appearance of defective articles:

- uneven spraying of the anticoagulant;
- crumbling of dried crystals of the anticoagulant from the tubes walls.

These disadvantages take place due to imperfection of physical principles, which are the base of one or other spraying methods [4]. At present in practice following methods of liquids spraying: hydraulic, mechanical, pneumatic, electrostatic and ultrasonic are realized.

At hydraulic spraying method the fluid is crushed by the injection pressure with the free decay of the jet (film or large droplets) ensuing with a high speed from hole of the sprayer nozzle. Hydraulic spraying is the simple and the most economical on energy consumption spraying method (2-4 kW for spraying of 1 ton of liquid). However, this method has serious disadvantages associated with the fact, that jet created at hydraulic spraying is not homogeneous. This method of spraying is characterized by the largest dispersion of formed drops and necessity to control the consumption providing the specified quality of fluid crushing. This method cannot be applied for solving of given task, since it is not able to ensure spraying of fluid with low consumption, spraying of high-viscous liquids and fine-dispersed spraying.

Mechanical spraying is carried out by the mechanisms rotated by the special drive. The advantages of this method are the possibility of spraying of high-viscous and contaminated liquids and broad regulation of performance of sprayer without significant change of dispersity. The main disadvantages are high cost, difficulty in production and operation, large energy consumption (15 kW per 1 ton of fluid) and in addition the presence of the ventilation effect.

In the case of a pneumatic spraying the dispergation is a consequence of the dynamic interaction of the flow of sprayed fluid with the flow of sprayed gas. The advantages of this spraying method are the possibility of producing relatively fine dispersed drops of fluid, less expressed dependence of quality of the spraying from consumption of fluid in comparison with considered methods, reliability in operation, ability of spraying of relatively viscous liquids. The disadvantages of this method are high energy consumption for spraying (50-60 kW per 1 ton of fluids), the need in spraying agent (special equipment for its supply), which significantly reduces the field of application of this method.

At the electrostatic spraying the jet (film) of fluid is supplied in the region of strong electric field. The disadvantages of this method of spraying are the need in expensive equipment, high energy consumption, low productivity and complexity of maintaining of spraying equipment [5].

Thus, using hydraulic, mechanical, pneumatic or electrostatic methods of spraying of liquids it is difficult to implement automated process of qualitative (uniform) spraying of exact amount of anticoagulant on the inner surface of the tube.

In turn, the analysis of capabilities of ultrasonic method of spraying applied to the solution of the problem is allowed revealing it undoubted advantages:

- low energy consumption and high performance of the process;
- the possibility of receiving of fine-dispersed and mono-dispersed spraying;
- high quality and uniformity of formed coatings;
- the possibility of dosed spraying of a very small amount of fluid;
- the possibility of control of ultrasonic spraying allows managing the process and implement it on automated lines.

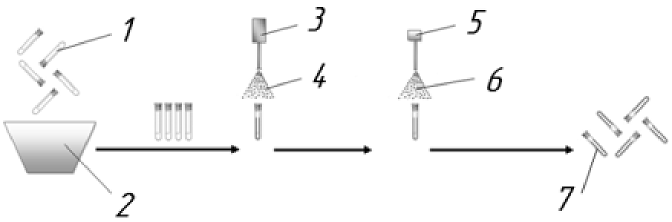
Thus, among the considered methods of spraying ultrasonic method is most effective and promising to provide uniformity of spraying coating (anticoagulant).

III. Structure And Principle of Operation of Automated Line

The process of spraying of anticoagulant on the inner surface of the tube in designed device consists of the phases, which are shown in Fig.1.

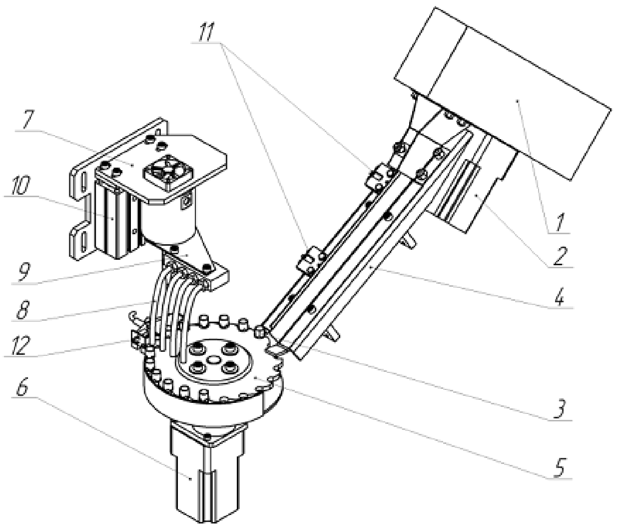
It includes:

- the step of loading of required number of tubes into hopper – piece dosing unit;
- the step of tubes moving in spraying zone (under working tool of the sprayer);
- the step of moving of the sprayer of vibrating system into tube;
- the step of ultrasonic spraying of the anticoagulant with simultaneous lifting of the ultrasonic sprayer (time and performance of the spraying can be regulated);
- the step of drying of sprayed coating in the tubes;
- the step of unloading of finished tubes.

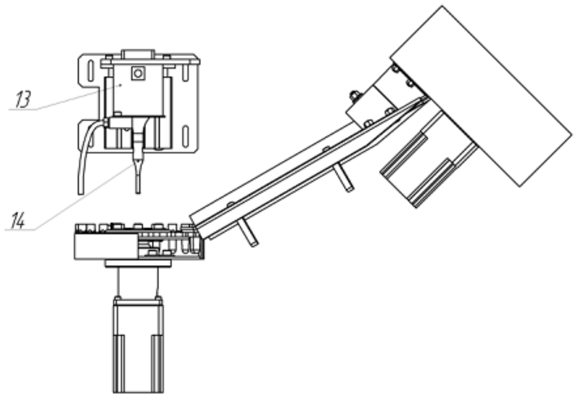


1 – tube; 2 – receiving hopper; 3 – ultrasonic sprayer; 4 – anticoagulant; 5 – device of air supply;
6 – air; 7 – finished product
Fig. 1. Scheme of the ultrasonic spraying process of anticoagulant in the tube

The structure of main mechanical part of developed automated line for spraying of the anticoagulant in blood collection tubes is shown in Fig.2 and Fig.3.



1 – hopper, a piece dispenser of the tubes; 2 – electric motor; 3 – tube; 4 – directing runners; 5 – disc for moving of the tubes; 6 – electric motor; 7 – sprayer; 8 - pipes for the supply of drying agent; 9 – footlights for supplying of drying agent; 10 – device of vertical movement; 11 – optical detector for the control of the tubes on directing runners; 12 – optical detector for the positioning of the disc
Fig. 2. The design of the mechanical part of the device for spraying of anticoagulant (isometry)



13 – piezoelectric transducer; 14 – horn
Fig. 3. The design of the mechanical part of the device for spraying of anticoagulant (side view)

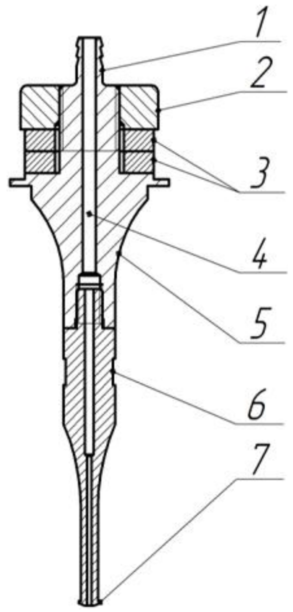
Developed device consists of the hopper, a piece dispenser of tubes 1, which is rotationally driven by the electric motor 2 and it is intended to load the tubes 3 and supply them using directing runners 4, which also provide the proper orientation of the tubes in the node of the tubes moving.

The node of the tubes moving is made in the form of the disc 5 rotating from the electric motor 6 and intended for moving of tubes into spraying zone, drying and unloading of finished product. At the side surface of the disc semicircular notches for loading and fixation of tubes are made.

Tubes loaded into the disc are moved to the sprayer 7 and pipes 8 for supplying of heated drying agent.

The pipes are connected to the general footlights 9 for supplying of drying agent. Sprayer and footlights are mounted on pneumatic device of the vertical movement 10 that ensure their introduction on depth not exceeding the longitudinal size of the tube, and removing of sprayer from tube during spraying at a speed providing uniform spraying of a predetermined amount of anticoagulant on the inner surface of the tube.

The sprayer is designed as a piezoelectric transducer 13, acoustically and mechanically connected with the horn 14 made in the form of a hollow rod, inner channel of which is intended to supply the spraying anticoagulant. External diameter of the hollow rod gradually decreases, so that the end part of it at a length equal to longitudinal size of the tube 3 has a cylindrical shape and finishes spraying end configured as a cone (see Fig.4).



1 – fitting for fluid supply; 2 – reflecting plate; 3 – piezoelectric elements; 4 – channel for fluid supply; 5 – horn; 6 – horn-waveguide; 7 – spraying end
Fig. 4. Ultrasonic vibrating system

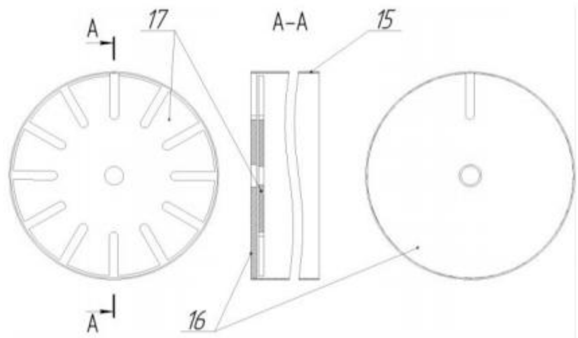
Optical detectors 11 designed for monitoring the presence/absence of the tubes on the runners are mounted on the directing runners.

At the presence of a signal from the upper detector 11, which determines maximum number of tubes on the runners, i.e. excludes the situation of overflow, the stop of the process of tubes supplying from the hopper (the electric motor 2 turns off) and the start of boot process of the tubes into the disk for moving of them (the electric motor 6 turns on) take place.

At the absence of a signal from the lower detector 11, which determines minimum number of tubes on the runners, the electric motor 2 is turned on and the electric motor 6 is turned off.

The optical detector 12 is used for monitoring of the presence of the tubes located in the disc, and for accurate positioning relative to the horn of the sprayer in time of approaching to a spray zone, and also for counting of number of the finished tubes.

The structure of the hopper for supplying of the tubes is shown in Fig.5.



15 – hollow cylinder, 16 – fixed disc; 17 – movable disc
Fig. 5. The design of the hopper for tubes supplying

The hopper is made in form of a thin-walled hollow cylinder 15. At the lower base of the cylinder two discs 16 and 17 are successively placed. The bottom disc 16 is fixed, and the top disc 17 is mechanically coupled to the electric motor 2 providing its rotation relative to the fixed disk. In the upper part of disc 16 one notch is made, and several of radial notches are made in the movable disc 17, the length and the width of which correspond to the length and the outer diameter of the tube.

Directing runners for vertical orientation and tubes supply into the node of tubes moving are attached to the notch of the fixed disc 16.

Principle of the operation of the automated line is following: tubes are loaded into the hopper manually or using special automatic devices to fill not less than half of the hopper capacity. Then by the operator's command the electric motor is turned on ensuring rotation of the movable disc of the hopper. Herewith the tubes fill the notches in the movable disc and they continue movement together with the disc.

When combining the notches in fixed and movable discs, the tube leaves the hopper and falls on the runners, where acquires a vertical orientation.

When overflow of tubes happens or their insufficient amount on the runners corresponding optical detectors 11 generate controlling signals for the switch-off/on of the electric motors 2 and 6.

At the next stage the tubes are loaded into the disc for moving of the tubes. The tubes loaded into the disc are moved to the sprayer and to the pipes supplying heated drying agent. Movement is performed intermittently, so after each rotation of the disc under the sprayer and the pipes tubes appear.

When approaching the tubes in a spraying zone the detector 12 generates control signal and the electric motor 6 is turned off.

Then the device of vertical movement lowers the pipes and the sprayer into the tube with a depth not exceeding the length of the tube. The supply of drying agent through the pipes is realized, ultrasonic sprayer is turned on and carried out removing of the tubes and sprayer with speed providing uniform spraying of a predetermined quantity of the anticoagulant on the inner surface of the tube. The supply of the drying agent is stopped and ultrasonic sprayer is turned off.

Further another turning of the disc for tubes moving occurs and described cycle of the operation is repeated.

After the sprayer the tubes are consistently moved between the pipes for the supply of drying agent, each of which drops into the tube and it is removed out of it simultaneously with the supply of drying agent. Thus, drying cycle is repeated required number of times, which provides by the set of required numbers of the pipes.

Upon the completion of the drying process the tubes are come out the disc.

IV. The Control Algorithm of Automated Line Operation

The control algorithm of automated line operation can be represented as a block-diagram (see Fig.6).

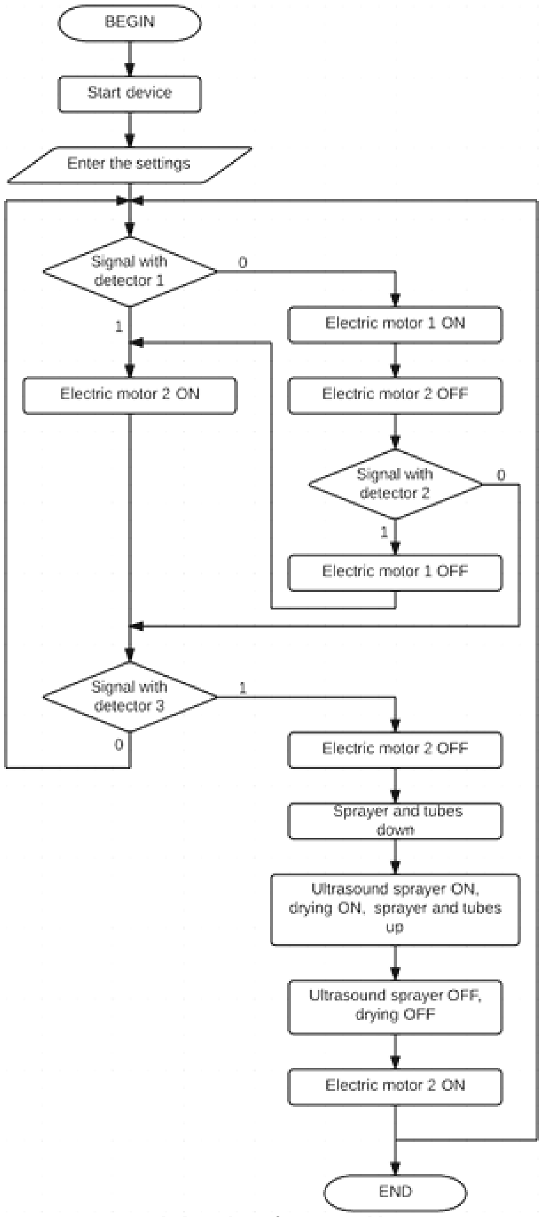


Fig. 6. Control algorithm of automated line operation

In presented block-diagram the detector 1 is the lower optical detector of the tubes control on directing runners, the detector 2 is the upper optical detector for tubes control on directing runners, the detector 3 is the optical detector for the disc positioning for moving of the tubes, the electric motor 1 is the motor for the hopper rotation, the electric motor 2 is the motor for the disk rotation.

V. The Interface of The Operator of Automated Line

The main operating interface on the touch panel of the operator of the line displays the information about the number of manufactured products (tubes), operation time of the line, contains control buttons of working and setting of automated line parameters and also indicators for notification about warnings occurring during the operating process of the line (see Fig.7).

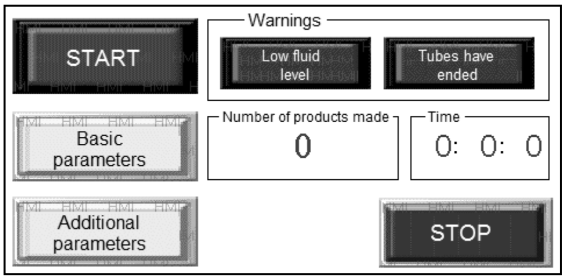


Fig. 7. Main working interface of the operator of the line

The settings, which are available for the user, are:

- basic parameters: amplitude of the ultrasonic vibrations, drying time, rotation speed of the hopper, period of direction change of the hopper rotation (see Fig.8);

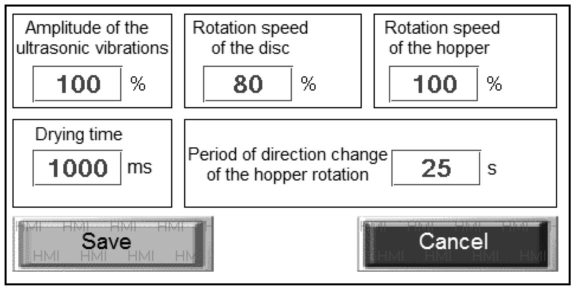


Fig. 8. Basic parameters of the setting

- additional parameters: spraying time of liquid into measuring tube, spraying time of liquid into the tube in operating mode and volume of the liquid sprayed into the tube (see Fig.9).

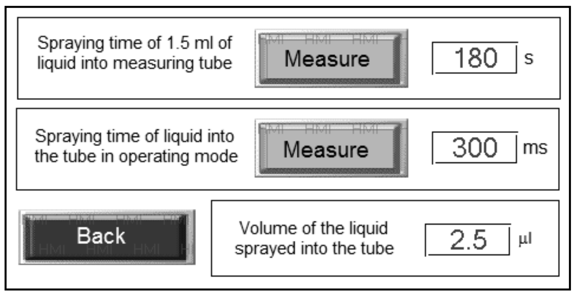


Fig. 9. Additional parameters of the setting

If during the operation of the automated line any error occurs, the images with text of the error and work procedure to solve the task appear on the touch panel.

VI. DISCUSSION OF RESULTS

The appearance of the developed automated line of ultrasonic spraying of the anticoagulant into the blood collection tubes is shown in Fig.10.

Fig. 10. Appearance of the automated line

The main technical characteristics of the line are presented in Tab. I.

TABLE I
MAIN TECHNICAL CHARACTERISTICS

Maximal power consumption of the line, W	150
AC voltage, V	220±22
Frequency of mechanical vibrations, kHz	44±3.3
Overall dimensions (WxDxH), mm	505x650x560
Performance, products/hour, no less	1500
Working pressure, MPa, not more	0.4
Air Flow, liter/min, no less	30
Volume of anticoagulant spraying in one tube (at dry residue), mcg	0.24 – 0.6

The main advantages of the developed automated line for the ultrasonic spraying of the anticoagulant are:

- uniform and homogeneous coating of the inner surface of the tubes with an anticoagulant;
- ensuring of required dispersion characteristics of the spraying process;
- low power consumption and high efficiency of the process;
- improved cost and mass and dimensions parameters, and also increasing of compactness of the equipment.

The proposed device was designed and tested in production conditions of "Center of ultrasonic technologies" company. In production conditions it was ensured the performance no less than 1500 products/hour.

VII. CONCLUSION

As a result of carried out studies it was designed and manufactured automated line of the ultrasonic spraying of the anticoagulant to the inner surface of the blood collection tubes.

At the development of automated line the following problems were solved:

- on the basis of the analysis it was revealed that ultrasonic method is the most effective for spraying of the anticoagulant on the inner surface of the tubes;
- it was proposed and implemented method of process automation of moving of the tubes into the spraying zone;
- it was developed the construction and manufactured ultrasonic sprayer ensuring uniform spraying of the anticoagulant on the inner surface of the tubes;
- it was made piezoelectric ultrasonic vibrating system and electronic generator for its power supply;
- it was developed the unit of moving of the working tool of the sprayer into the internal volume of the tube.

Produced tests showed, that developed automated line provided required technical characteristics of productivity and uniformity of spraying.

The work is carried out under the support of the grant of «Participant youth research and innovation competition" of the Foundation for assistance to small innovative enterprises in scientific and technical sphere (contract number 0002639).

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