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DEVELOPMENT OF AUTOMATION OF WASTE SORTING AS AN INTEGRAL PART OF ENVIRONMENTAL PROTECTION

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Abstract. *The paper regards the urgency of creating small - sized systems for automated local sorting of household waste for modern residential complexes based on visual spectrometry. For this purpose, algorithms for system operation were developed and the procedure for designing a functional control scheme for the sorting process with the construction of the necessary contours of automated control was presented.*

Keywords: plastic waste sorting, automated sorting system, sorting system control board, algorithm, functional diagram

ROZWÓJ AUTOMATYZACJI SORTOWANIA ODPADÓW JAKO INTEGRALNA CZĘŚĆ OCHRONY ŚRODOWISKA

Streszczenie. *Artykuł dotyczy pilną potrzebę stworzenia małogabarytowych systemów zautomatyzowanego lokalnego sortowania odpadów komunalnych dla nowoczesnych zespołów mieszkaniowych w oparciu o spektrometrię wizualną. W tym celu opracowano algorytmy pracy systemu oraz przedstawiono procedurę projektowania schematu funkcjonalnego sterowania procesem sortowania wraz z budową niezbędnych obwodów automatycznego sterowania. Przeprowadzono również analizę zastosowania modelu do oceny niezawodności zautomatyzowanego systemu sortowania odpadów.*

Słowa kluczowe: sortowanie odpadów z tworzyw sztucznych, zautomatyzowany system sortowania, tablica sterownicza systemu sortowania, algorytm, diagram funkcjonalny

Introduction

Household waste is the result of human life, the morphological composition of which determines the features of the collection, sorting and subsequent scheme of preparation and processing of waste. Therefore, one of the important characteristics of consumer waste is its morphological composition, which represents the ratio of individual components: packaging, textiles, metal, plastic, construction waste and other types of mixed state. Reliable information on the amount and composition of municipal waste generated in the settlements will ensure effective planning and management, including collection, transportation, disposal, use and safe disposal.

Solid waste is generated from two sources: residential buildings; institutions and enterprises of public purpose (catering, educational, entertainment, hotels, kindergartens, etc.). The composition of solid waste is influenced by factors such as climate zone, the degree of improvement of housing (the presence of garbage, gas, water, sewerage, heating, heating), surface area, type of fuel for local heating, catering, trade culture and, no less important, lifestyle and well-being of the population [2].

Morphologically, solid waste is divided into components: paper, cardboard (waste paper); food waste; tree; metal (black and non-ferrous); textile; bones; glass; skin; rubber; stones; polymeric materials; others.

Separate sorting has recently been increasingly introduced into society, but this decision at this stage of implementation only partially reduces the "flow" of solid waste and does not help in the fight against the elimination of huge landfills. We should not expect that separate sorting will make our cities and air cleaner, this requires a comprehensive approach. There are not many methods of dealing with household waste, and they can be divided into passive and active.

Thus, the issue of collection and further processing of household waste becomes one of the competitive advantages of existing modern and residential complexes under construction [1].

1. Development of algorithms for the operation of small-sized automated sorting system for household waste

Today, many designs of automated sorting systems for household waste are known and they have their disadvantages and advantages. In this paper we consider the development of a small sorting system based on visual spectrometry. After analyzing the existing designs of automated sorting systems, their advantages and disadvantages were proposed the following principle of construction of the sorting system. To avoid unwanted objects on the sorting line, the first step is to grind the material into pieces of adjustable size in the shredder, shafts with carbide plates grind any material. Solid household waste is not a completely dry material, so a special hydrophobic coating must be applied to prevent corrosion and adhesion to the surface in contact with the waste.

The next stage of sorting is sterilization, drying and separation of biological substance from the material. To do this, the crushed waste enters the autoclave, where under the action of high pressure and temperature, moisture evaporates. Paper and leftover food are separated by mixing. After sterilization, the material is dry and disinfected. Next is the process of separating ferrous and nonferrous metals. The next step is to pass through a vibrating screen that separates dust and fine particles, which is relatively clean compost because the temperature in the autoclave does not exceed the decay temperature of the plastics. Macro-lines of the material after the vibrating screen are divided into films and flat materials, as well as three-dimensional shapes, their separation is necessary because the films can interfere with the recognition of smaller particles covering them. A ballistic separator is used to separate the shape. The final stage is the sorting of plastics by type, sorting glass by color. Glass and other materials are in a special vibrating hopper.

Due to the specifics of the selected sorting scheme, there is a problem related to the balance of performance in the system, which in case of violation of the sequence of modules can significantly affect the quality of sorting. The main indicator of ensuring balance in the system is the constant accumulation of solid waste at intermediate stages of sorting. It is important to understand that achieving 100% performance on all modules of the system is almost impossible, and the total bandwidth will be equal to the bandwidth of the "weak spot" of the system, ie the module with the lowest performance. In the proposed small-scale system of sorting household waste "bottleneck" is the sterilization module, according to the functional scheme, it is at the beginning and thus sets the rate of sorting to avoid the accumulation of solid waste at intermediate levels of the sorting system (Fig. 1) [4].

The most time-consuming in the full sorting cycle is the procedure of sterilization of the material, to save energy of other modules of the system during downtime, a special procedure was developed to put them in standby mode. The following notations of functional modules of the solid waste sorting system were proposed in the paper: 1 module – shredder; 2 module – autoclave; 3 module – magnetic conveyor (Fig. 2); 4 module – magnetic rotor; 5 module – vibrating screen; module 6 – ballistic separator (Fig. 3); 7 module – optical sorting module; and: bunker 1 – designed for rapid unloading of the autoclave, and uniform supply of material; bunker 2 – designed for storage of plastic and uniform supply of material; bunker 3 – designed for storage of glass and uniform supply of material; conveyor 1 – conveyor for current separation of metals with built-in magnetic rotor; conveyor 2 – conveyor for transporting plastic material to the optical sorting module; conveyor 3 – conveyor for transporting glass material to the optical sorting module (Fig. 4).

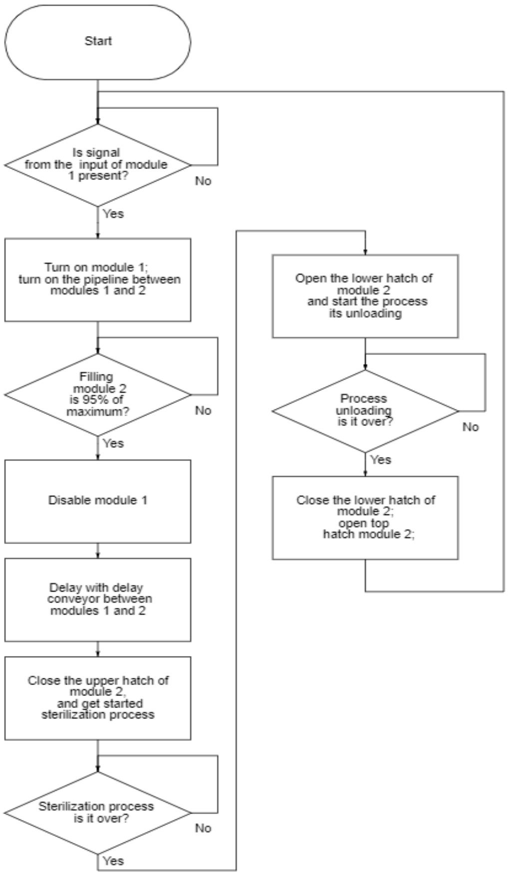

Fig. 1. Algorithm of grinding and sterilization procedure

The sorting system operates according to the following algorithm: Household waste enters the shredder (module 1), where the motion sensor signals the inclusion of a shredder and a conveyor that transports material to the autoclave chamber (module 2). After the autoclave is filled to 95% with the volume sensor, a signal is sent to turn off the shredder (module 1), and the delayed conveyor is switched off, the autoclave (module 2) is closed and the sterilization process begins. After the sterilization process is completed, the conveyor for unloading the autoclave (module 2) is switched on. During unloading, the presence of material inside is monitored in order to start grinding (module 1) of the new batch of material, which will ensure continuous, efficient operation of modules 1 and 2.

Sterilized material from the autoclave (module 2) enters the hopper 1. Then turn on sequentially: feed from the hopper 1, the conveyor for the current separation of metals (conveyor 1), magnetic conveyor (module 3), magnetic rotor (module 4). The trigger for disabling these modules is the absence of material in the hopper 1, and the absence of a signal from the motion sensor after the magnetic rotor (module 3).

After receiving a signal from the motion sensor located behind the magnetic rotor (module 4), the conveyor-conveyor, vibrating screen (module 5), ballistic separator (module 6), conveyor for transporting materials after sorting and conveyor 2 and 3 for optical sorting are switched on, hoppers 2 and 3 supply of sorted materials for optical sorting, optical sorting module (module 7).

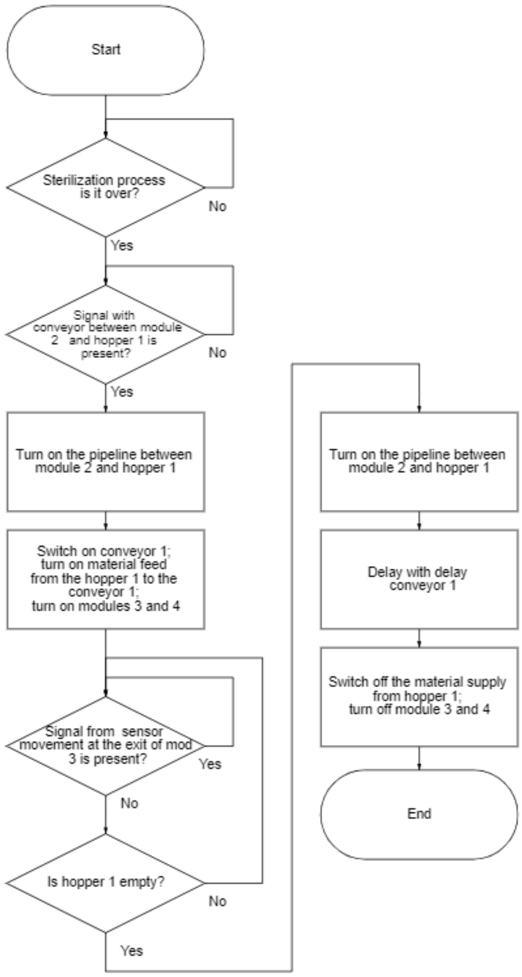

Fig. 2. Algorithm of metal separation procedure

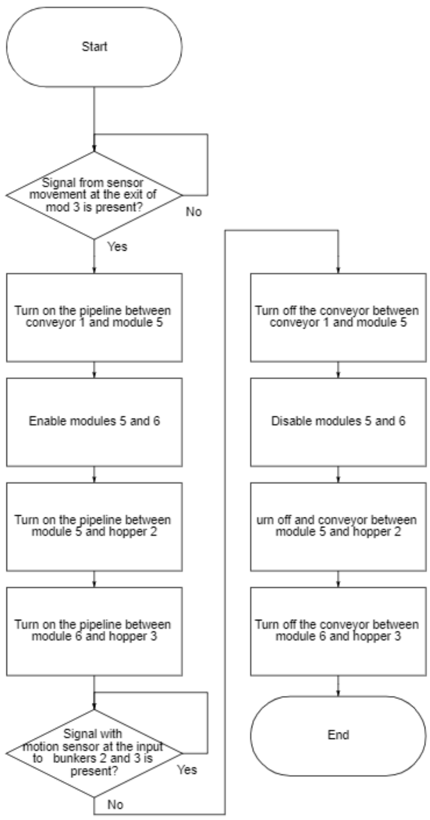

Fig. 3. Algorithm of the procedure of sorting by physical inhomogeneity

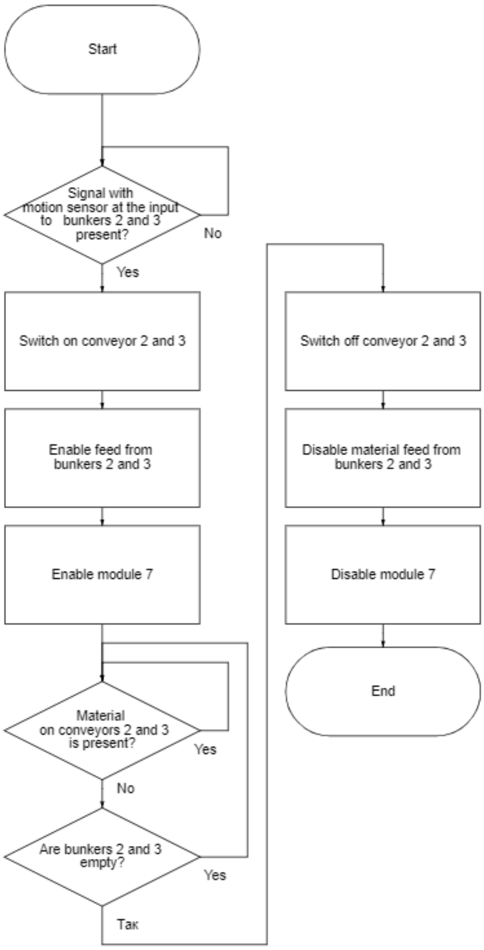

Fig. 4. Algorithm of optical sorting procedure

At the input and output of the vibrating screen (module 5) and the ballistic separator (module 6) the presence of material is detected by a motion sensor, the absence of a signal is a trigger to disable these modules and associated conveyors. The operation of the optical sorting module is controlled by sensors for the presence of material in hoppers 2 and 3, as well as optical control of the presence of material in the recognition area. For the correct operation of all modules, each shutdown of the functional elements of the sorting system solid waste is carried out with a delay. The functional diagram of the system also shows the main parameters of the modules, which will be displayed on the control monitor during operation, and can also be adjusted automatically or manually [5].

2. Development of a functional diagram of a small-sized automated system for sorting household waste

Consider the functional diagram of a small system of sorting household waste. In order to facilitate the presentation of information, the functional diagram was divided into several contours [3].

Contour of grinding and sterilization. At the discrete signal from the controller (pos. 1-1), the shredder (module 1) is switched on and enters standby mode. Analog motion sensor (pos. 1-2) monitors the presence of material at the inlet to the shredder, when solid waste enters the area of the motion sensor (pos. 1-2), the conveyor and shredder go from standby mode to operating mode. The shredder shaft speed is monitored by an analog speed sensor (pos. 1-3) and controlled by a discrete controller (pos. 1-4). Similar sensors (pos. 2-2, 2-3) were used to control the conveyor speed. Filling the autoclave (module 2) is measured by an analog acoustic level sensor (pos. 3-6), after filling the autoclave by 95%, a discrete signal is given to turn off the shredder (pos. 1-1), as well as turning off the conveyor with a delay -1). After the conveyor stops working, the autoclave closes and the sterilization process begins. The pressure in the autoclave chamber is controlled by means of an analog pressure sensor (pos. 3-2). In combination with the temperature sensor (pos. 3-3) the autoclave maintains a constant temperature. The speed of mixing of household waste is controlled by the analog speed sensor (pos. 3-5), and regulation by the discrete controller (pos. 3-6). After sterilization and unloading of the autoclave is completed, the autoclave level sensor (pos. 3-6) sends an electrical signal to the autoclave controller (pos. 3-1) and the shredder controller (pos. 1-1), which puts them in standby mode (Fig. 5) [4].

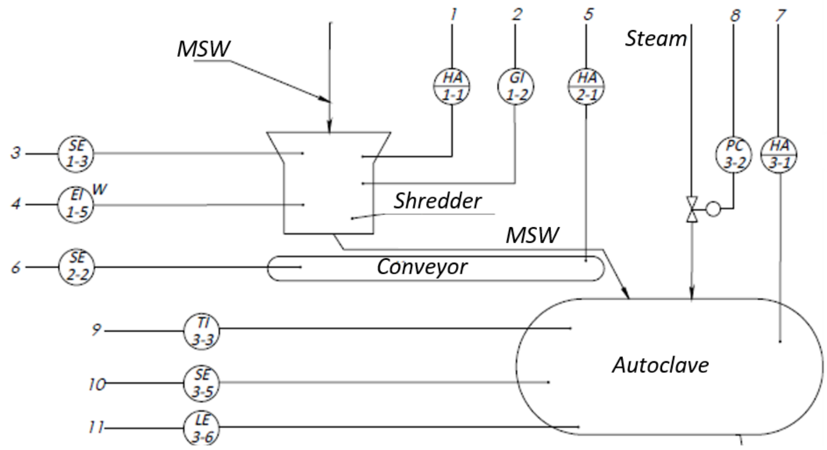

Fig. 5a. Contour of grinding and sterilization

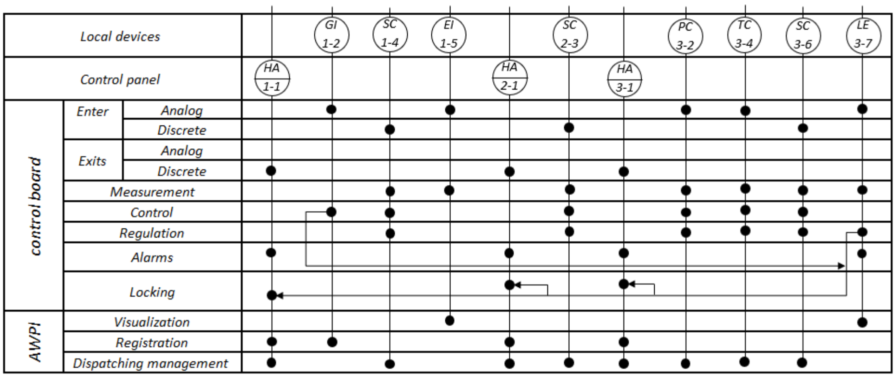

Fig. 5b. Contour of grinding and sterilization

Metal separation contour. The level sensor (pos. 3-6) sends a switch-on signal to the conveyor controller (pos. 4-1). To control the speed of the conveyor used sensors (pos. 4-4,4-5), similar to those described above. Analog motion sensor (pos. 4-4) monitors the presence of material on the conveyor belt, if any, sends a signal to: controller (pos. 5-1) of the hopper of the dispenser (hopper 1), controller (pos. 6-1) of the modified conveyor (conveyor 1) with magnetic rotor (module 4) and controller (pos. 7-1) of the magnetic conveyor (module 3) (Fig. 6).

The control of the feed rate from the dispenser hopper is carried out by an analog speed sensor (pos. 5-3), and control by a discrete controller (pos. 5-4). The speeds of the modified conveyor (pos. 6-2, 6-3), the magnetic rotor (pos. 6-4, 6-5) and the magnetic conveyor (pos. 7-2, 7-3) are controlled similarly. The signal to turn off the modules of the metal separation contour is formed from the logical multiplication of signals from the motion sensor (pos. 4-4) at the inlet to the hopper of the dispenser, and the signal of no material on the modified conveyor coming from the sensor (pos. 6-6).

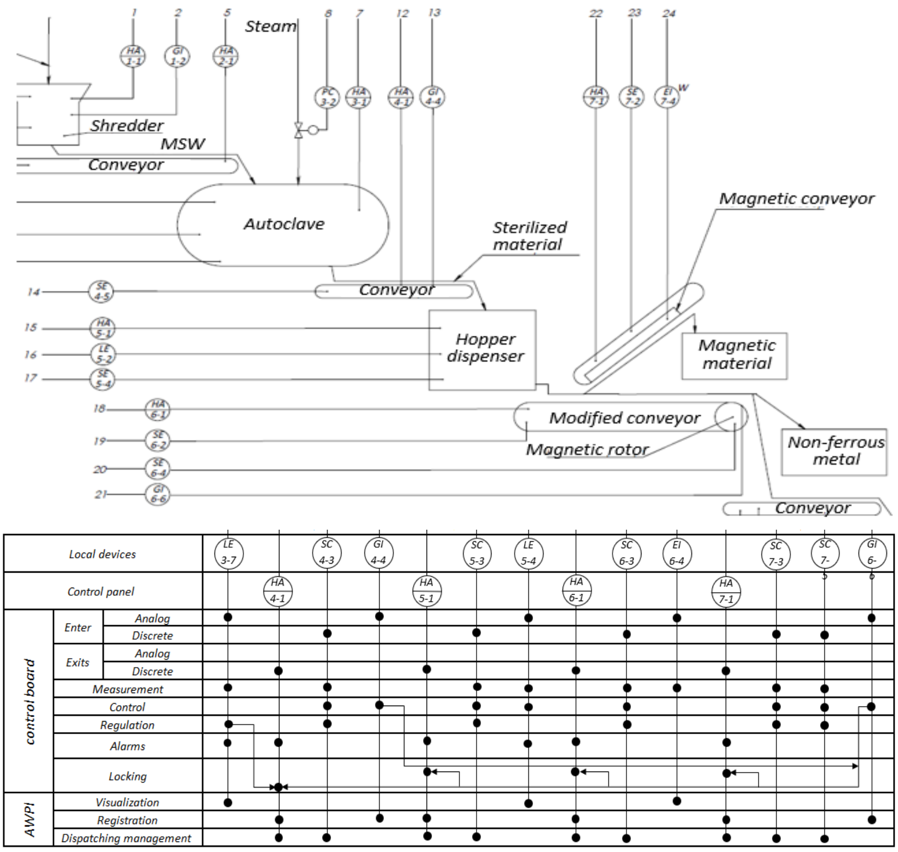

Fig. 6. Metal separation contour

Sorting contour according to the physical heterogeneity of the material. The motion sensor on the modified conveyor (pos. 6-6) sends the activation signal to the controllers of the modules of the sorting contour according to the physical heterogeneity of the material: conveyor controller (pos. 8-1), vibrating screen controller (module 5) (pos. 9-1), controller ballistic separator (module 6) (pos. 10-1) and controllers of plastic selection conveyors (pos. 11-1) and glass (pos. 12-1) (Fig. 7).

To control the speed of the conveyors in this contour of sorting modules by physical inhomogeneity of the material used sensors: (pos. 8-2, 8-3) for the conveyor before the vibrating screen, (pos. 11-2, 11-3) for the plastic selection conveyor and the selection conveyor glass (pos. 12-2, 12-3). Regulation and control of physical parameters of the vibrating screen and ballistic separator is carried out by controlling the speed of electric motors. Accordingly, for the vibrating screen this function is performed by sensors (pos. 9-2, 9-3), and for the ballistic separator sensors (pos. 10-2, 10-3) Motion sensors on the plastic selection conveyor (pos. 11-4) and motion sensors on the glass selection conveyor (pos. 12-4) are responsible for the transfer of modules and conveyors included in the physical inhomogeneity sorting contour. If there is no material on the conveyors, the operation of the modules will be stopped.

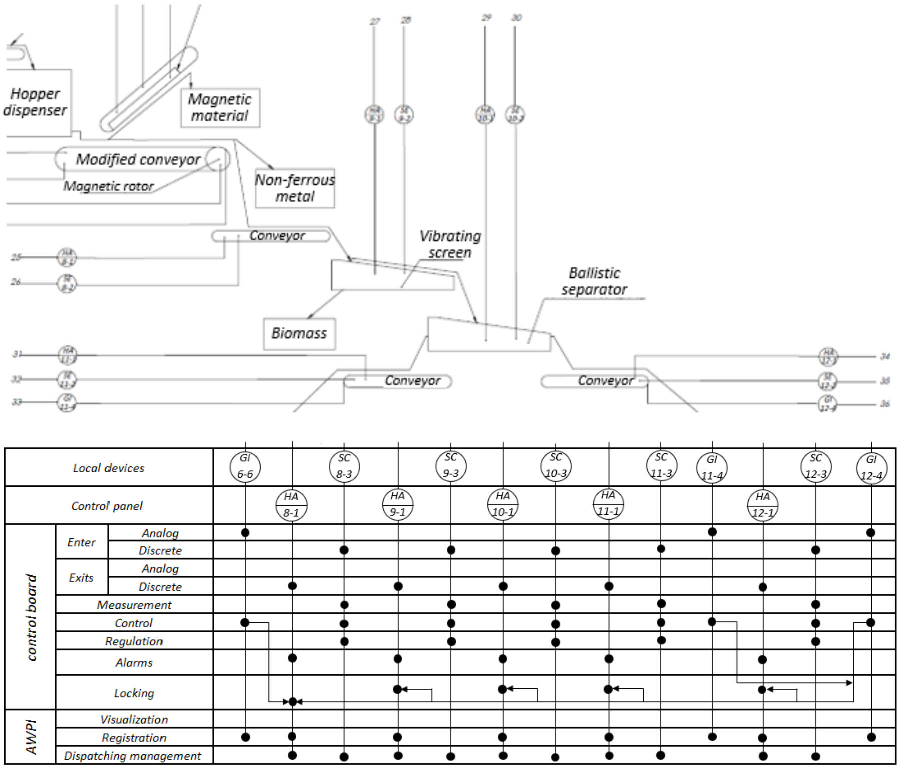

Fig. 7. Sorting contour according to the physical heterogeneity of the material

Optical separation contour. After passing the material through the motion sensors (pos. 11-4 and pos. 12-4) on the conveyors, on the controllers of the optical separation contour modules, an on signal is given: plastic supply from the plastic hopper (hopper 2) is switched on (controller pos. 13-1); the supply of glass from the hopper for glass material (hopper 3) (controller pos. 14-1) is switched on; as well as the plastic transportation conveyor (conveyor 2) (controller pos. 15-1) and the glass transportation conveyor (conveyor 3) (controller pos. 16-1); optical sorting module (module 7) (controller pos. 17-1) (Fig. 8).

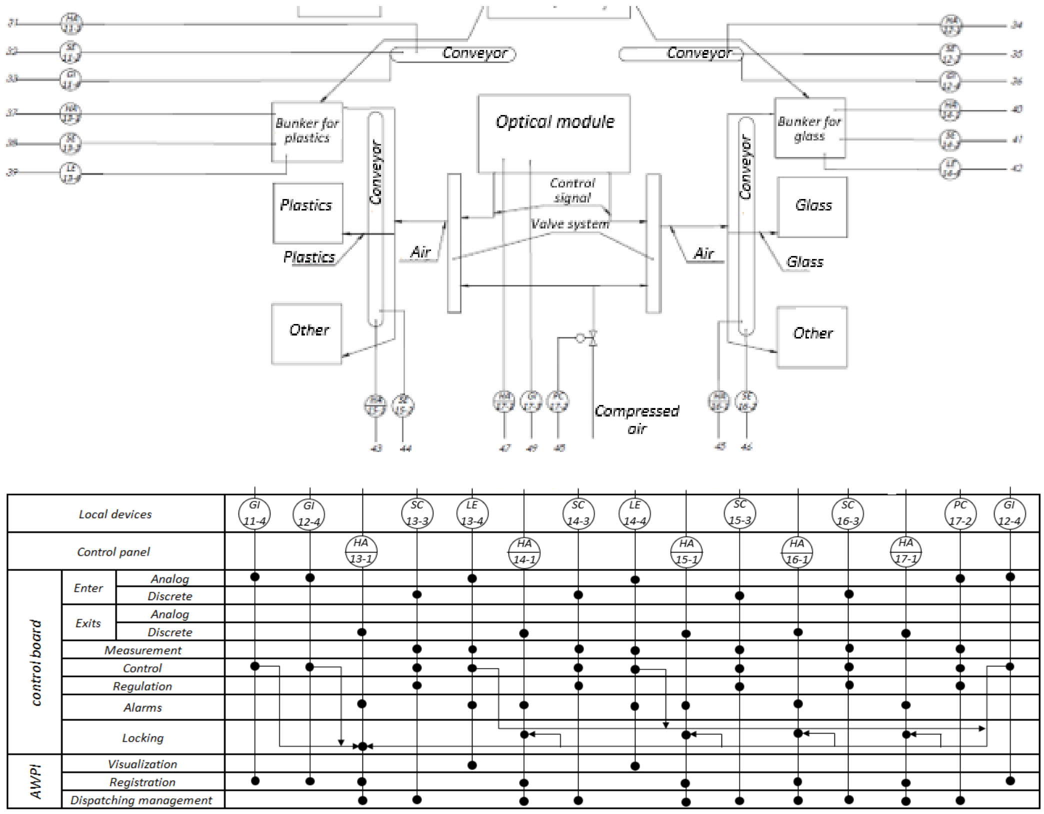

Fig. 8. Optical separation contour

Control of conveyor speeds in this contour is carried out by means of the corresponding sensors: for the conveyor of transportation of plastics (sensors pos. 11-2, 11-3), for the conveyor of transportation of glass (sensors pos. 12-2, 12-3). Also in the optical module there is a pressure control (pressure gauge pos. 17-2) of compressed air for sorting valves. The signal about the absence of material in the hoppers of glass and plastic with level sensors (pos. 13-4 for the hopper with plastic and pos. 14-4 for the hopper with glass), in combination with the signal about the absence of material on the conveyors, form a command to switch to expectations for all components of the optical separation contour.

3. Summary

Algorithms and a functional diagram of a small-sized solid waste sorting system have been developed. The absence of increased requirements for the positioning accuracy of the system modules makes it possible not to use highly qualified workers during installation work. Automation and high quality components of the sorting system provides high reliability and durability. In addition, the technological design of the modules allows you to quickly replace worn parts, which improves the efficiency and performance of the system as a whole. Under normal use, the small sorting system is able to work around the clock, and the quality of the sorted material does not decrease over time. In the perspective of further research, it is advisable to improve the hardware part of the management in order to increase the efficiency of the sorting system.

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