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SURVEY OF THE CONSTRUCTIONS AND WORKING ELEMENTS OF THE ROAD SWEEPERS AND STREET SWEEPING ATTACHMENTS FOR THE DUSTCARTS

Analyzing scientific literature, the paper presents the survey of the constructions and working elements of the road sweepers to determine the ways of their improvement. In particular, improvement of street sweeping attachments for dustcarts which expand functional possibilities of the road sweepers. This is relevant for small towns or settlements, where the maintaining of several municipal motor vehicles, performing different functions is a burden on the local budget. Aim of the given paper is the overview of the constructions and working elements of the street sweeping machines and sweeping attachments for the dustcarts in order to determine ways for their improvement.

Drive of the working elements of the sweeping attachments is hydraulic, its source of supply is pumping station of the dustcart. The body of the dustcart is used as the hopper-waste collector. The paper presents the characteristics of road sweeping machines. Schemes of the domestic and foreign road-sweeping machines and their equipment are shown in the paper. As it is noted, the general drawback of this class of machines is that they are equipped with the hydraulic drive on the base of one fixed pump. That is why, if it is necessary to regulate the speed of working elements motion, part of the pump working fluid loss will enter the hydraulic vessel under high pressure via safety valve, causing considerable unproductive power losses. It is established, that one of the ways of improving sweeping attachments for the dustcarts is the application of the scheme, sensitive to loading, which will enable to minimize power losses during hydraulic drive operation, providing the increase of the efficiency factor of the control system of the working elements hydraulic drive in various operation modes.

Key words: *construction, working element, road sweeping machine, sweeping attachments, dustcarts.*

Introduction

Nowadays sweeping of the streets, road side walks and collection of solid municipal waste is performed by separate utility vehicles: sweeping-cleaning machines [1, 2] and dustcarts [3], correspondingly. Usage of sweeping cleaning machines is rather inefficient (low loading factor) as they are used mainly in autumn and spring [4]. At other times sweeping of the streets and side walk is carried out by the caretakers, who work in harmful conditions. That is why, in the study [5] it is suggested to solve these problems in complex, creating on the base of the dustcart ecological machine by developing the attached sweeping devices to equip the dustcarts. This will expand the functional possibilities of the dustcart and greatly reduce the expenditures of the municipal services. It is very important for small towns and settlements where the maintenance of several utility vehicles, which perform different functions, is a burden for the local budgets.

Problem set-up

According to the Resolution of the Cabinet of Ministers of Ukraine № 265 [6] one of the priority directions of SMW management in Ukraine is the application of modern highly-efficient dustcarts, their functions can be expanded by means of the attached sweeping equipment. Thus, the overview of the constructions and working elements of the sweeping-cleaning machines and attached sweeping equipment for dustcarts to reveal ways of their improvement is relevant scientific technical problem.

Objective and task of the paper

Objective of the paper is the overview of the constructions and working elements of sweeping-cleaning machines and attached sweeping equipment for the dustcarts to reveal ways of their improvement.

Methods and materials

Method of the analysis of scientific literature sources is used in the study.

Main part

Sweeping-cleaning machines [7 – 11] perform mechanical sweeping of hard-surface roads and airfield [12, 13], cleaning of urban territories with simultaneous trash collection and its further transportation to the storage sites. Road pollution increases wheels slippage of the motor vehicles. Quality cleaning of the road surfaces can increase the adhesion coefficient of the wheels with the road surface by 12 – 15 % and average speed of the motor vehicles, decrease unproductive energy losses due to slipping of the wheels [14].

Most widely spread models of such machines are ПУ-53, КО-304А, КО-309, etc. [15, 16]. Characteristics of sweeping-cleaning machines are given in Table 1.

Table 1

Characteristics of sweeping-cleaning machines

Indicator	Type of the machine			
	КО-304А	КО-309	ПУ-53	Eurocleaner-6RL
Basic chassis	ГАЗ-3309	ГАЗ-3309	ГАЗ-3309	Scania P230
Width of sweeping, mm: – with one tray brush – with two tray brushes	 2150 –	 2250 2800	 2350 2700	 2400 –
Payload, kg	2000	2875	2500	9125
Waste hopper volume, m^3	1.6	2	1.5	6
Working speed, m/s (km/h)	0.86 – 4.6 (3.1 – 16.5)	1.67 – 4.6 (6 – 16.5)	2.2 – 6.3 (8 – 23)	0.83 – 1.94 (3 – 7)
Brush diameter, mm: – tray brush – central brush	 800 490	 800 470	 900 700	 750 400
Dimensions, m: – length – width – height	 5.8 2.6 2.6	 6.19 2.27 2.6	 6.5 2.35 2.44	
Weight, kg: – equipped vehicle – special equipment	 5440 2250	 4875 2285	 5190 2900	 19500

Operational special equipment of sweeping cleaning machines must provide high level of trash collection and minimal or complete lack of dust in the process of machine operation maximal cleaning of the air before the ejection. Machines, manufactured now, provide cleaning of the asphalt concrete cover or cement concrete cover, having flat surface without potholes and mounds. Machines also provide transportation of the collected trash in the places of centralized collection and mechanical unloading.

Separation of the trash from the road surface in modern sweeping-cleaning machines is performed by means of the rotating brushes. As a rule, the machine is equipped with one central brush and one (КО-304А) or two (ПУ-53, КО-309) lateral brushes. General scheme of sweeping-cleaning machine operation is the following: tray brushes separate the pollution and move it into the zone of central cylindrical brush operation, this brush directs the trash in the conveyor, which transports it to the hopper. The brushes are placed in such a manner that not to leave road surface where trash is not eliminated. Tray brushes are suspended so that to provide sweeping of the traffic lane which goes beyond the rear wheel dimensions of the dustcart.

Quality separation of the mud from the road surface is performed at the expense of the brush material (sufficient hardness and elasticity at great abrasion resistance), determined pressing force of

the brushes, that corresponds to their rotation frequency (at a determined speed of the dustcart motion). Construction of the suspension unit of the brush enables to fix constant, pre-adjusted pressing force of the brushes to the road surface. Brushes drive must provide not only variation of the rotation frequency but also their smooth regulation.

At small cars, intended for cleaning the side walks, especially with the attached and trailed equipment, single stage system of trash transportation into the hopper by the bristle of the brush is used, either by direct throwing, when the hopper is located behind the brush (Fig. 1) or reverse throwing «overhead».

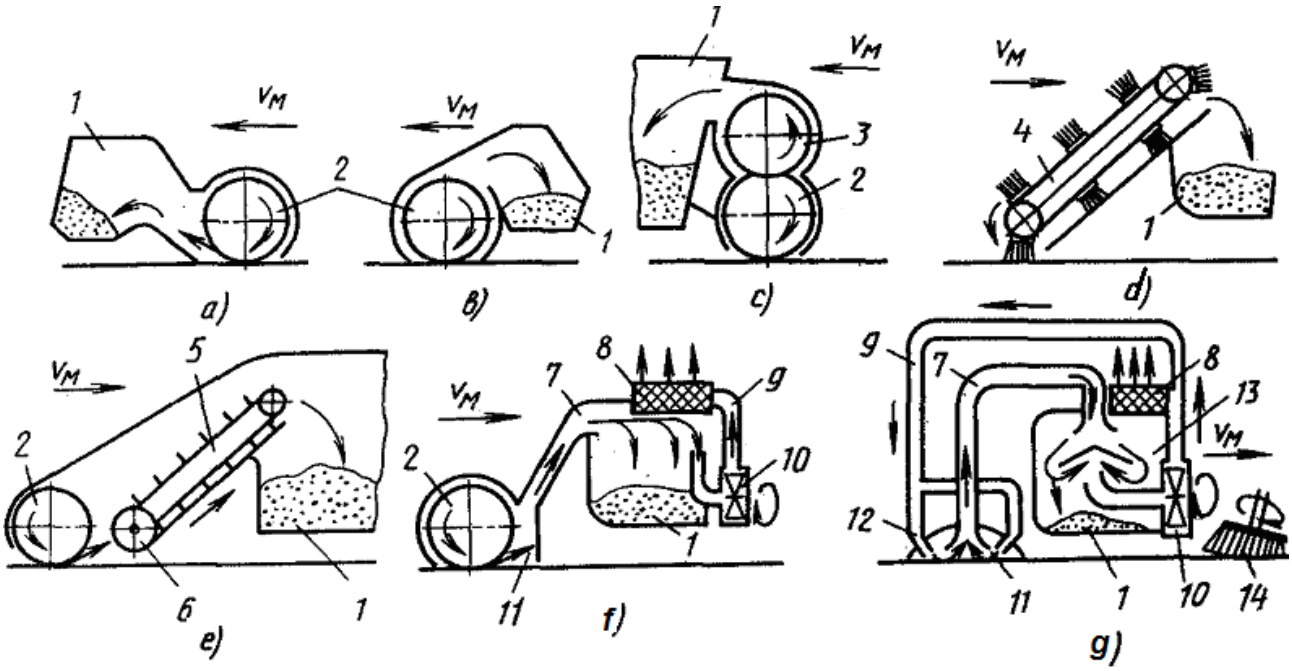

Fig. 1. Diagrams of the working equipment of sweeping-cleaning machines:
a) with direct throwing of the trash; b) with the reverse throwing of the trash; c) with trash throwing by bladed thrower; d) with trash throwing by belt brush; e) by screw and chain-scraper conveyor; f) with brush-vacuum picker and gravity waste separation; g) with jet vacuum pick-up and inertia waste separation; 1 – hopper; 2 – cylindrical brush; 3 – bladed thrower; 4 – belt brush; 5 – scraping conveyer; 6 – screw; 7 – suction line; 8 – filter; 9 – pressure pipeline; 10 – vacuum fan; 11 – vacuum pick-up; 12 – nozzles for blowing; 13 – cyclone; 14 – conical brush

Characteristic feature of these methods is small volume of the hopper (up to 1 m^3). Besides, the latter method requires higher circular speed of the brush and compensation of the bristle wear. Multistage mechanical transportation of waste by means of the screw pick-up, parallel to the rotation axis of the cylindrical brush and chain-scrapping conveyor is most frequently used method. The drawback of such system is its low reliability and high metal consumption [14].

Mechanical transportation of waste into the hopper by means of intermediate bladed thrower is promising. In case of brush-vacuum (pneumatic) transportation auxiliary cylindrical brush of smaller diameter supplies waste into the vacuum pick-up; intermediate conveyor may be installed at the machines. In flow-vacuum picker the brush bristle is replaced by the nozzles for blowing, air flows of these nozzles provide the separation of the pollution from the road surface and transportation to suction line. Separation of the large garbage in the hopper is provided by gravity method.

Ways of unloading of sweeping-cleaning machines are the following: gravity method, when the garbage is emptied from the hopper under the action of its own weight when opening the trap or valves, self-empting by hopper or container rotation; forced – side discharge or back ejection by means of moving – ejector with mechanical or hydraulic drive [17].

In case of small volume of the hopper (up to 2 – 3 m^3) garbage unloading directly on the serviced site is expedient. That is why, certain machines are equipped with standard changeable containers as mechanisms for waste loading or receiving hopper of the dustcart. As additional equipment of

sweeping-cleaning machines the remote vacuum pick-up for collection of the fallen leaves and mud from hard-to-reach places and electro-magnetic beam for picking metal garbage on the roads and air field are used.

Transportation of the garbage from the central brush into the hopper is performed mechanically (directly by the brushes or specialized conveyor), both in the motor vehicle ПУ-53, or pneumatically (due to the vacuum in the hopper), as in motor vehicles КО-304А and КО-309.

All sweeping-cleaning machines, intended for cleaning the city roads, are mounted on the medium duty vehicle chassis (GAZ-3309).

Special equipment of sweeping-cleaning machine КО-309 is mounted on the vehicle chassis GAZ-3309 and consists of brush picker, two end tray brushes pneumatic conveyor hopper-garbage collector, water tank, fan, humidification system (Fig. 2).

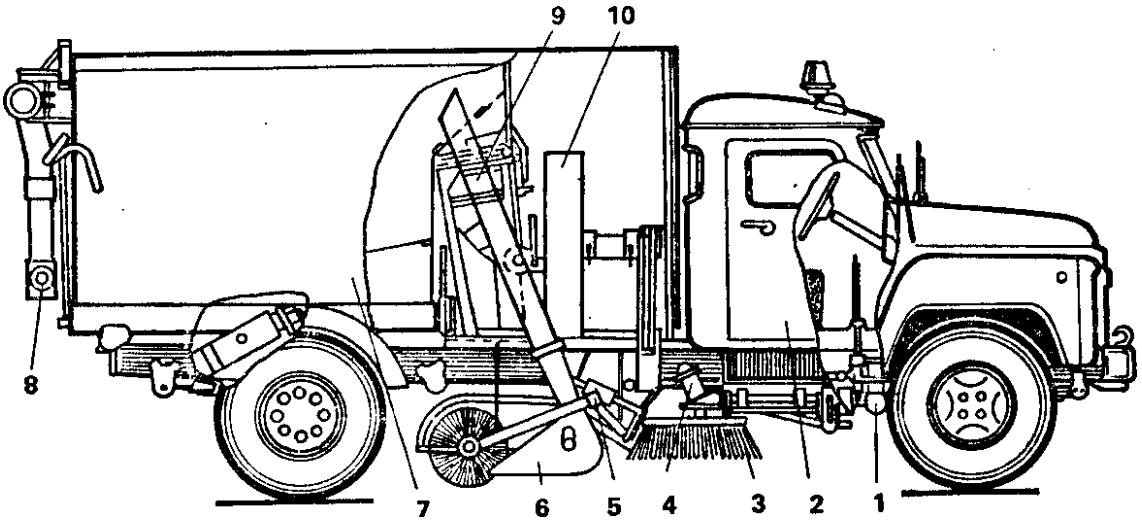

Fig. 2. Sweeping-cleaning machine КО-309:
1 – engine dependent PTO; 2 – chassis GAZ-3309; 3 – tray brush; 4 –hydraulic system; 5 – humidification system; 6 – brush picker; 7 – hopper-garbage collector; 8 – auxiliary picker; 9 – pneumatic conveyor; 10 – fan

Brush garbage picker of this machine is of the combined type with two-stage garbage supply into the pneumatic conveyor. First the garbage is fed into the intermediate tray by the brush, then it is supplied by the screw to the suction nozzle of the pneumatic conveyor, connected hermetically with the hopper-garbage collector. Efficiency of cleaning is considerably enhanced and reaches the value of 0.9 at the level of initial pollution 500 g/m^2.

The scheme of foreign analog of sweeping machine is shown in Fig. 3.

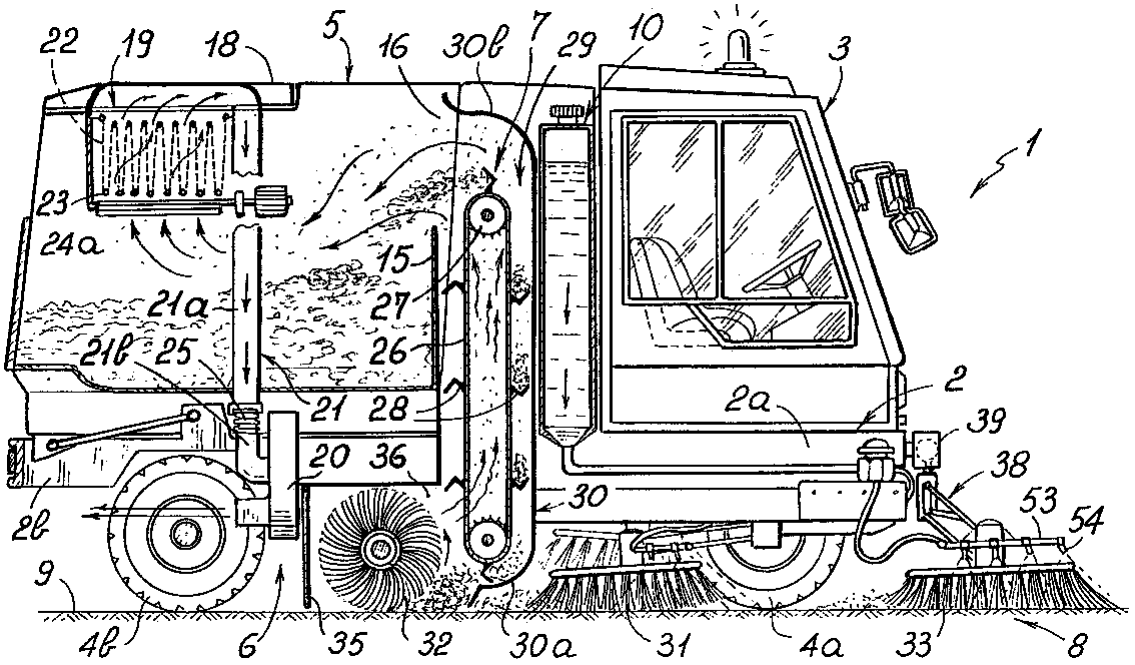

Fig. 3. Street sweeping machine for garbage collection [18]:
1 – sweeping machine; 2 – body; 3 – control cab; 4 – wheels; 5 – garbage container; 6 – dust suction module; 7 – conveyor; 8 – brushes; 9 – street surface; 10 – water tank; 15 – protection wall; 16 – window; 18 – dispenser; 19 – filter; 20 – turbine; 21 – suction line; 22 – porous tissue; 23 – rods; 24a – crossbar; 25 – hermetic trap; 26 – chains; 27 – sprocket; 28 – blades; 29 – transport channel; 30 – housing; 31 – side brushes; 32 – main central shaft; 33 – front brush; 38 – lever; 39 – guide; 53 – chute; 54 – nozzles

Sweeping-cleaning machines Nilfisk have hopper volumes from 0.5 m^3 to 2.2 m^3 and have corresponding performance from 13000 m^2/hr to 21000 m^2/hr [12]. These machines widely use volumetric hydraulic drive (VHD) for motion, steering, and working elements.

Fig. 4 shows the structural diagram of VHD of Nilfisk MV4500 [13], it contains 12 hydraulic motors, 26 hydraulic cylinders, 3 pumps, 36 hydraulic distributers and 20 pressure valves, regulated in the interval from 2.5 to 35 MPa. In VHD of motion closed circuit of working fluid circulation with regulated axial-piston pump gerotor hydraulic motor in each wheel was used. Maximum pressure in VHD is 35 MPa, in supply system 2.6 MPa. VHD provides maximum transport speed of the machine – 32 km/hr and in technological mode – up to 19 km/hr.

Four hydraulic motors of OMSB type, manufactured by the company Sauer danfoss with the working volume of 200 cm^3 develop maximum total torque 2600 N·m, if the pressure is 30 MPa and rotation frequency up to 240 min^{-1}. Hydraulic motors of 18 kg of weight are equipped with the drum brake.

Operation of the working equipment is provided by the gear pump H2 with the working volume of 52 cm^3, power steering drive is served by the pump H3 with the working volume of 28.2 cm^3.

Due to the priority valve steering pump supplies working fluid (WF) to the operation equipment during the straight motion of the motor vehicle. For the vacuum cleaner rotation the hydraulic motor with the working volume 25 cm^3 and rotation frequency up to 2600 min^{-1} is used. For brushes rotation gerotor hydraulic motors with the working volume 200 cm^3 are used, if maximum rotation frequency is 150 min^{-1}.

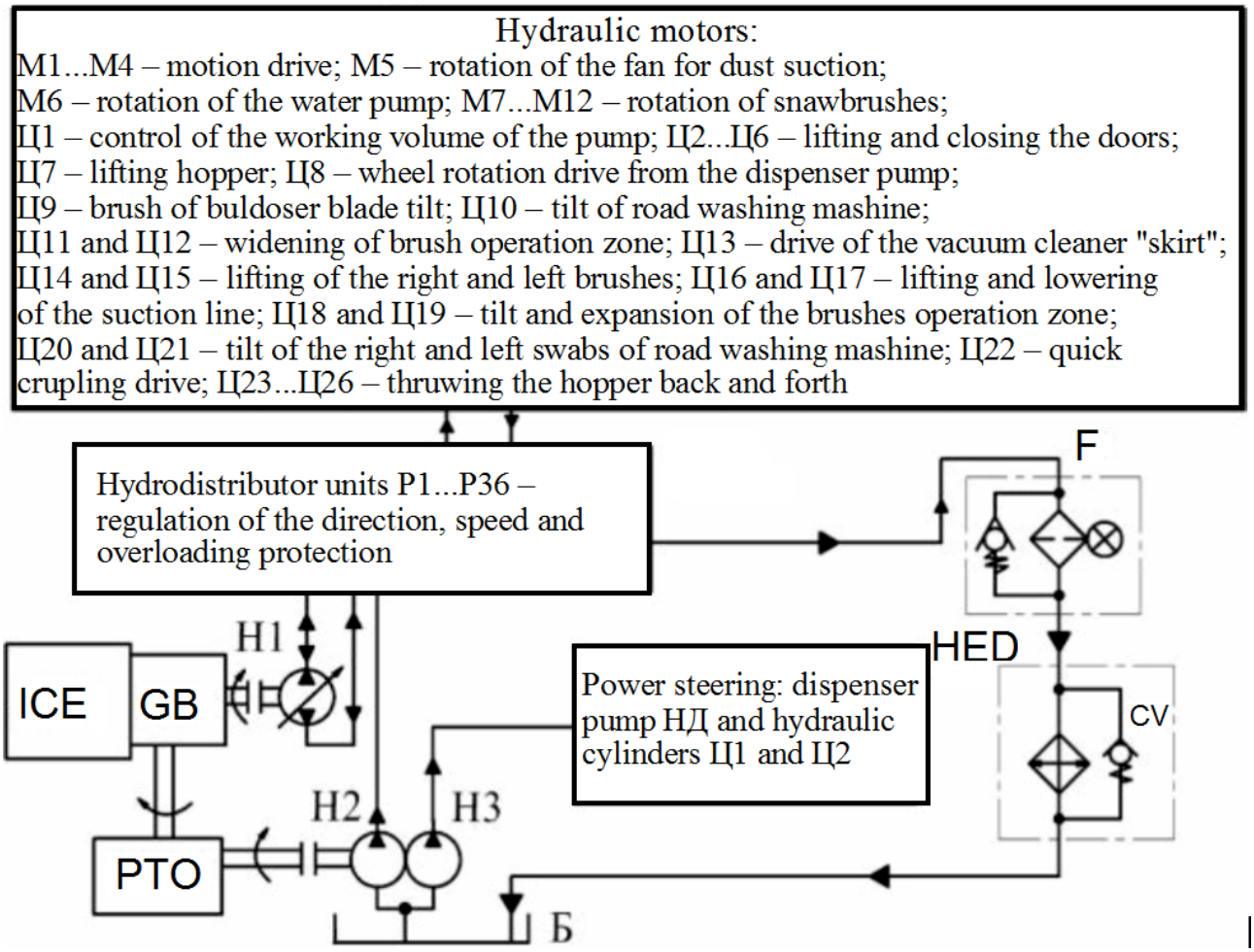

Fig. 4. Structural diagram of VHD of the utility vehicle Nilfisk

General drawback of this class of machines is low utilization factor, as they are needed mainly during seasonal city cleaning (in spring and autumn), greater part of time they either stand idle or little used. That is why, this work in the cities of Ukraine are performed manually un rather harmful conditions, that is unacceptable in the civilized society.

As a result of analysis of the available construction of the dustcarts and sweeping-cleaning machines, the author of the paper [19] elaborated the construction scheme of street sweeping attachments (SSA) for the dustcart (Fig. 5), it is protected by the utility model patent of Ukraine 45362 U.

It is suggested to use the hydraulic drive as the drive of the working elements of SSA, the pump station of the dustcart will be used as a supply source, the body of the dustcart is used as a garbage collection hopper.

Street sweeping attachment contain 5 brush turning hydro cylinder 1, screw hydrocylinder 2, screw conveyor 3, cylindrical brush 5, all these components are located in a single housing 8, hydraulic motor of the screw conveyor 6 and hydraulic motor of cylindrical brush 7. Receiving hopper 4 is located in the rear part of sweeping machine body.

Street sweeping attachments (SSA) operate in the following way: in operating position cylindrical brush 5 rotating sweeps the garbage into screw conveyor 3, by means of the conveyor trunk the garbage enters the receiving hopper 4 and is periodically compressed by the pressing plate of the dustcart.

Hydraulic diagram of SSA is shown in Fig. 6. Hydraulic diagram of SSA consists of hydraulic distributor 14 (Fig. 6), hydraulic pump 10, filter 11, oil tank 12, safety valve 13, hydraulic cylinder of the screw 2, hydraulic cylinder of the brush turning 1, hydraulic motor of the cylindrical brush 6, hydraulic motor of the screw conveyor 7, throttle 15. Hydraulic system of SSA is connected with hydraulic system of the dustcart.

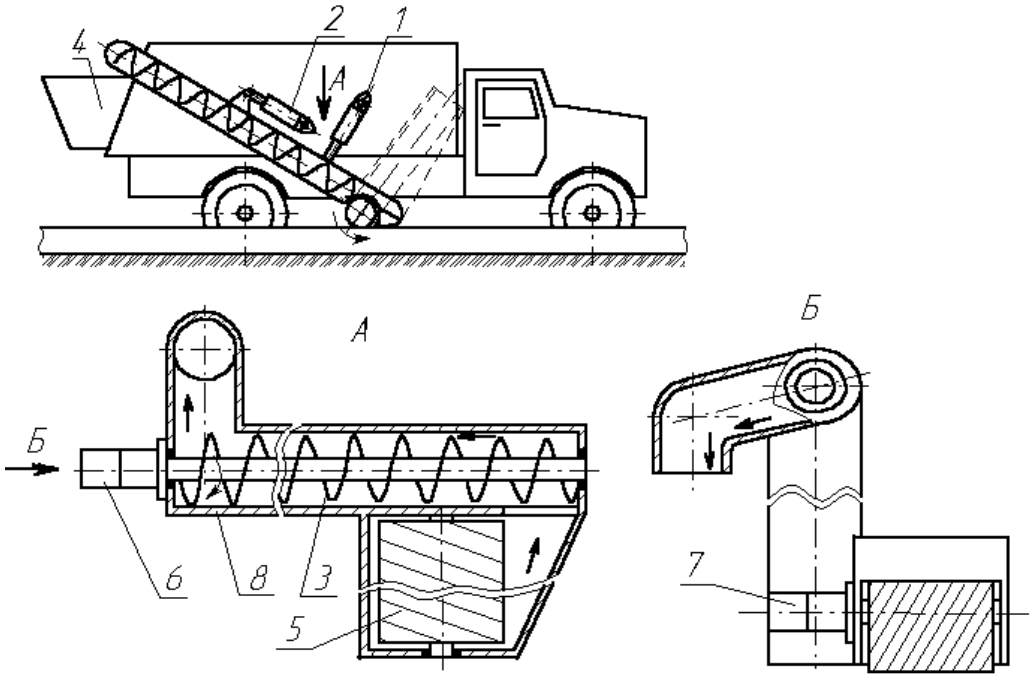

Fig. 5. Structural diagram of SSA for the dustcart

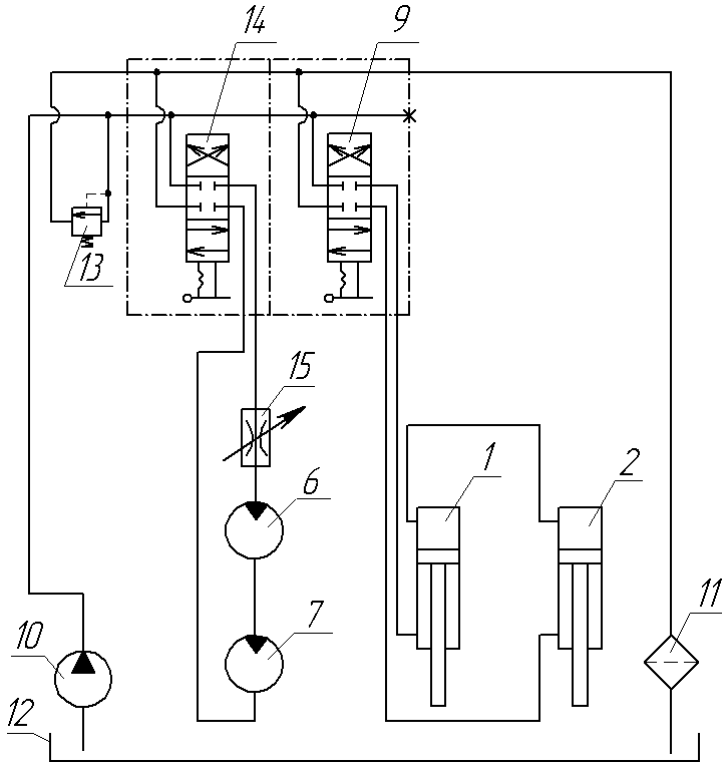

Fig. 6. SSA hydraulic drive diagram

Drive of the working elements of SSA is performed by means of hydraulic motors 6 and 7. Operational position of SSA over the surface of the road (sidewalk) is provided by the hydraulic cylinder of the screw 2. Brush can be brought into transport position by means of hydraulic cylinder 1. ПBody of the conveyor and trunk rotate, enabling to perform smoothly unloading of the gabage.

Non-linear mathematic model of SSA is suggested in the paper [20], it enables to investigate numerically the dynamics of the drive, as a result, it was revealed that the suggested hydraulic drive of SSA for the dustcart during start will operate stable qualitive transient processes.

Materials of the study [21] contain adequate regression equations for nominal values of pressure and

angular velocity of the hydraulic motors of cylindrical brush and screw conveyor, depending on the area of regulated throttle opening, which are used for the development of the technique of the engineering solution of SSA parameters for the dustcart [22].

In the paper [23], linearized mathematical model of group hydraulic drive with a series connection of the hydraulic motors of SSA of the dustcart is suggested, the model enabled to obtain approximated analytical dependences of pressure at the inputs of hydraulic motors and angular velocities of the hydraulic motors shafts on time and basic parameters 2of the hydraulic drive, as well as, main power and kinematic characteristics of dustcart SSA hydraulic drive in a stable operation mode, that was used in the process of design calculations of new constructions of the dustcarts with expanded functional possibilities [22].

General drawback of this class of machines is that they are equipped with the hydraulic drive on the base of one fixed pump. As a result, if it is required to regulate the speed of the working elements part of the working fluid (WF) of the pump under the high pressure will enter the hydraulic tank across the relief valve, stipulating considerable unproductive power losses. Unproductive losses during regulation of speed modes of working elements decrease in the hydraulic drives, built on the principle «sensitive to loading» [24].

The improvement of the support-rotational device hydraulic drive with the hydraulic motor of the rotational type on the base of the scheme, sensitive to loading is proposed in the research [25], this improvement enables to minimize power losses of the hydraulic drive operation, it provides the enhancement of the efficiency indices of the control system of the hydraulic drive various operation modes. Fig. 7 shows the diagram of the improved hydraulic drive of the support-rotational device with the hydraulic motor of the rotational type.

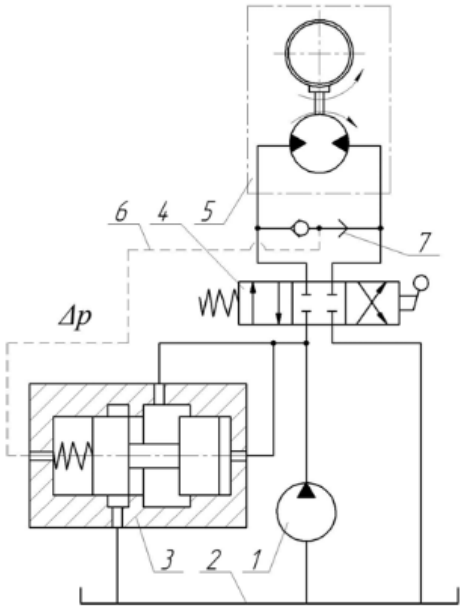

Fig. 7. Diagram of the improved hydraulic drive of the support-rotational device

Hydraulic device comprises hydraulic pump 1, tank 2, safety valve 3, hydraulic distributor 4, mechanism of support-rotational mechanism 5 and logic valve 7. This hydraulic drive is characterized by the enhanced efficiency indices of the steering system, as this hydraulic drive is improved by means of application of the scheme, sensitive to loading introducing the additional control line 6, connected with logic valve 7, which connects the hydraulic lines at the input and output of the hydraulic motor of support-rotational device. As a result, during the regulation of the hydraulic motor speed the support of balancing pressure difference Δp is performed by means of the safety valve, connected via control line with the loading line. The excess of the working fluid during throttling is drained across the safety valve into the tank. As the control line is connected with the loading line and the values of the balancing pressure difference Δp remains constant, then independent on the loading control of hydraulic

motor consumption is provided. Thus, hydraulic drive at small values of hydraulic motor speed and loading pressure provides minimization of power losses, that depends on the value of the balancing pressure difference Δp and hydraulic pump supply.

In our opinion, one of the ways of improving street sweeping attachments for the dustcart is the application of the scheme, sensitive to loading, which will enable to minimize power losses in hydraulic drive operation, this provides enhancement of the efficiency indices of the control system of working elements of hydraulic drive at different operation modes.

Conclusions

Overview of the constructions and working elements of sweeping-cleaning machines is carried out to identify the ways for their improvement, in particular, of street sweeping attachments for dustcarts. It was determined that one of the ways for the improvement of sweeping attachments for the dustcart is the application of the scheme, sensitive to loading, it will enable to minimize power losses of hydraulic drive operation. This provides the enhancement of the efficiency indices of the control system of the working elements hydraulic drive at different operation modes.

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