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Improvement of Productivity of Mobile Pneumatic Transporters

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Abstract: The pipe-line transport is widely used in the construction industry and the construction materials producing industry. So, all cement made by cement plants is transported to silos by means of a pneumatic transport. Mobile pneumatic transporters are a component of a pipe-line transport. Researchers propose fundamentally new design of some mobile pneumatic transporter which are widely used now and allow to perform dust handling not only dust handling of flat surfaces (two dimensional) but also three dimensional (volumetric) dust handling in a manual and automatic mode; they have maximum unit capacity per nozzle which is up to hundred times higher than in conventional industrial vacuum cleaners. The 11 designs and 4 formulas for calculation of the flow part of cleaning paths are developed in the research and confirmed by inventions. Implementation of the design will allow to obtain triple ecological effect: to improve essentially economic and technical parameters of installations to increase productivity in some times to mech anize and to automate vacuum cleaning process in perspective.

Key words: Eenergy and resource saving, mobile pneumatic transporters, dust trap cleaning paths and manipulators, mechanized dust handling, Russia

INTRODUCTION

The pipe-line transport is widely used in the construction industry and the construction materials producing industry. So, all cement made by cement plants in Russia is transported to silos by means of a pneumatic transport. Mobile pneumatic transporters are a component of a pipe-line transport. However, now the mobile pipeline installations having mobile long length spatial pipelines, are presented only by concrete pumps. It is proposed to add this range by a series of Mobile Pneumatic Transporters (MPT) and the new name for all class of these machines is represented: Mobile Pipeline Installations (MPI). General views of mobile pipeline installations are shown in Fig. 1 and 2.

The general view of the recommended waste processing plant is shown in Fig. 3. Dry plant debris collected in time from adjoining territories are valuable raw

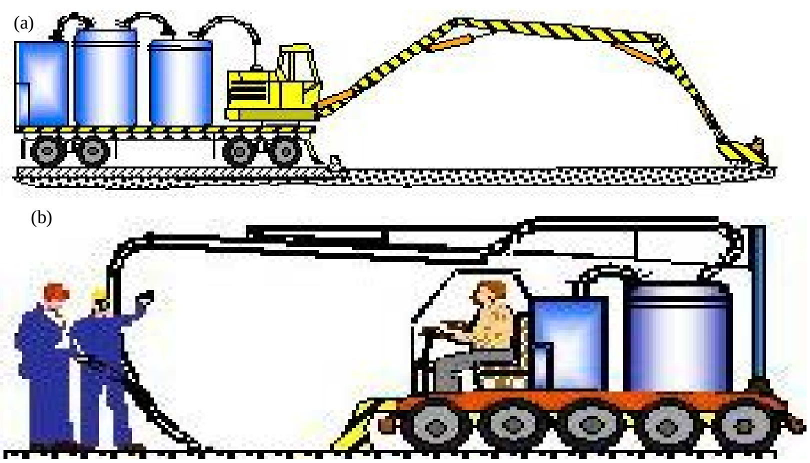

Fig. 1: Mobile Pneumotransport Installations (MPI): a) roads and territories productivity 40 time/h; b) Premises productivity 10 time/h

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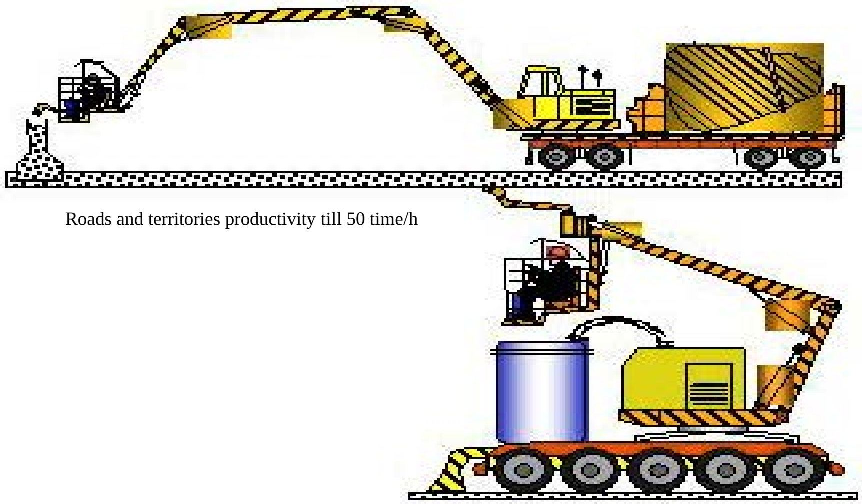


Fig. 2: Cars for repair of roads and constructions

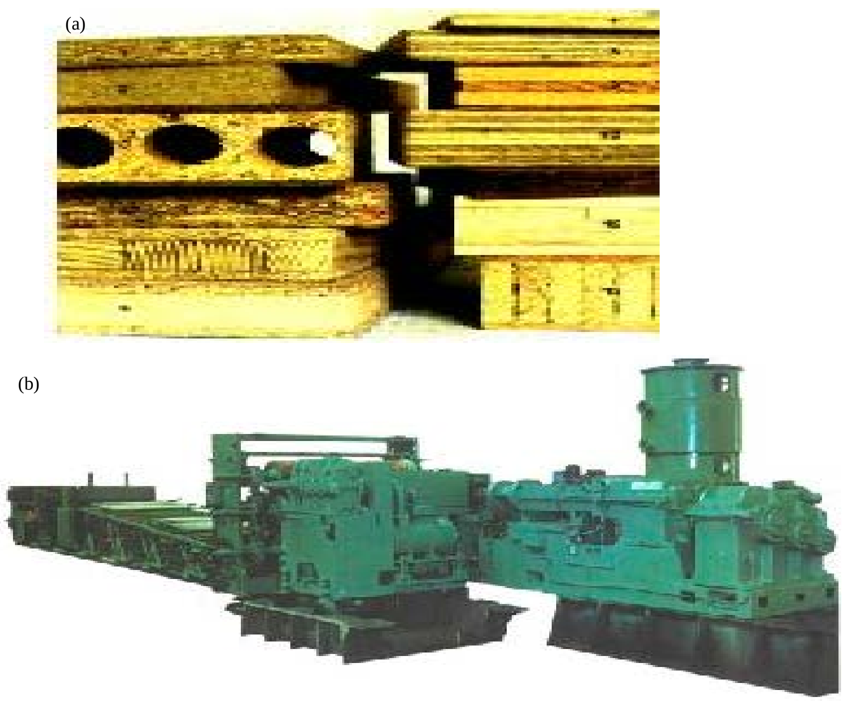


Fig. 3: A malotonnazhnaja line of manufacture of sheet materials from a waste productivity to 1 time/h: a) samples of building and materials from a waste; b) for premises productivity till 10 time/h

material for manufacturing of ecologically friendly new building materials of wood chipboard, wood fiber board or cement wood type (Fig. 3b) (Chertov, 2009a-c, 2006a, b).

As a rule, dust handling by vacuum cleaning systems is carried out using cleaning paths of the various designs allowing optimum conditions and productivity of cleaning to provide depending on circumstances being varied.

MAIN PART

The 11 designs and 4 formulas for calculation of the flow part of cleaning paths are developed in the work and confirmed by inventions; the designed variants are shown in Fig. 4. The cleaning path designs provide "shaving" effect by the air stream entering a cleaning path for a

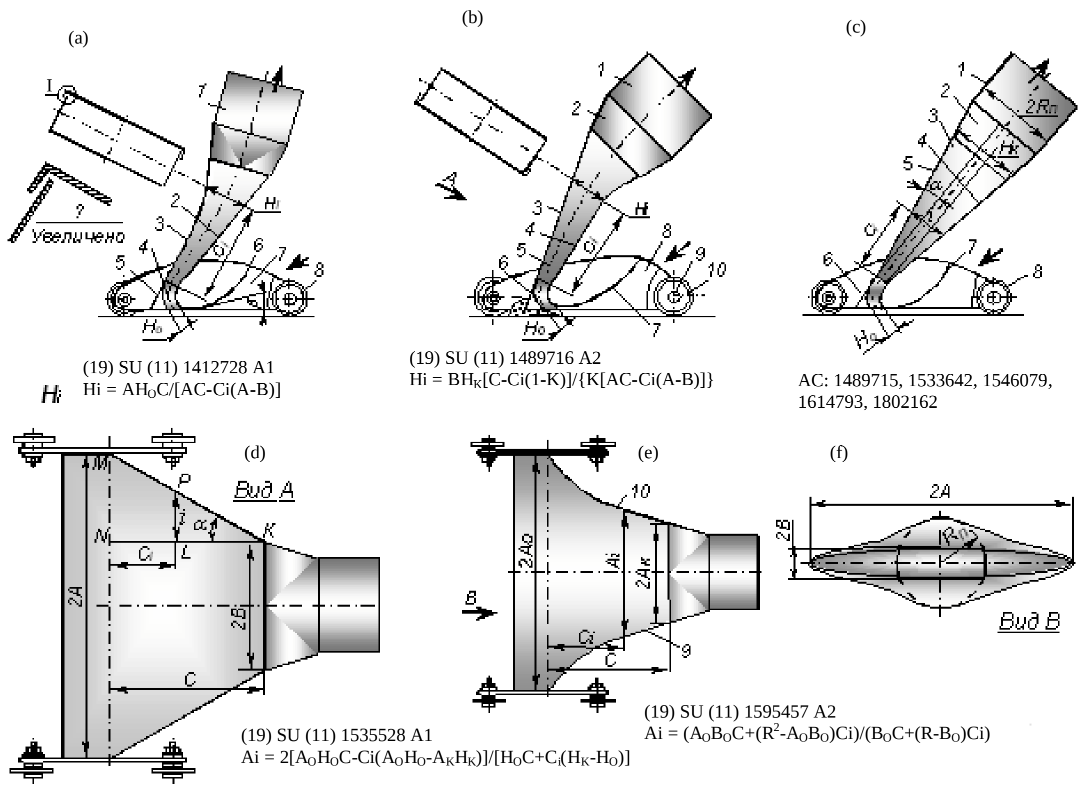


Fig. 4: Designs of high efficiency cleaning paths: a) lobby, b) back curvilinear regiments and c) the top view, d, e) lateral curvilinear regiments, f) volume profiling, 1: branch pipe, 2: adapter, 3: case, 4: cover, 5: channel soaking up, 6: knife, 7: modent, 8: cheek, 9, 10: wheel

layer of the dust preventing its vibration that provides decrease of power inputs in the cleaning path. Together with the optimum flow part, the proposed cleaning paths have the simple design having the form of bent bucket in a cross-section with a cover providing a minimum number of welded and brazed seams, high strength and leak resistance, low weight and high adaptability to manufacture. The shape of a cleaning path flow part depending on its type was carried out under Eq. 1-4:

$$H_i = AH_OC/(AC - C_i(A\text{-}B)) \qquad (1)$$

$$A_i = 2(A_OH_OC - (A_OH_O - A_kH_k))/((H_k - H_O)C_i + CH_O) \qquad (2)$$

$$A_i = (CA_OB_O + (R - A_OB_O)Ci/(CB_O + (R - B_O)C_i) \qquad (3)$$

$$H_i = BH_k(C - C_i(1 - K))/K((AC - C_i(A - B)) \qquad (4)$$

The shown Eq. 4 is correct formula for 3 options:

$$S_s > S_{os}, \Delta > 0, K < 1 \qquad (5)$$

$$S_s = S_{os}, \Delta = 0, K = 1 \qquad (6)$$

$$S_s < S_{os}, \Delta < 0, K > 1 \qquad (7)$$

Where:

- A = The half of length of the sucking slot
- B = The half of width of the case at the air stream outlet
- C = The length of the case
- H_O = The width of the sucking slot at the air stream inlet
- C_i = The current coordinate of length of the case
- H_i = The current coordinate of width of the sucking slot
- R = The radius of the discharge connection
- $S_{s,\ os}$ = The squares of the sucking slot and the outlet cross-section of the cleaning path

Dependence (Eq. 5) considers decrease of the cleaning path cross-section from the inlet to the outlet that is correct for a light dust (wood dust, haydite, coke).

Dependence (Eq. 6) considers the cross-section of the cleaning path from the inlet to the outlet as constant, that is correct for a medium weight dust (sand, soil, rubble, gravel).

Dependence (Eq. 7) considers increase in cross-section of the cleaning path from its inlet to its outlet that is correct for a heavy dust (ore, pyrite, lead concentrate, fraction steel) as in this case the maximum speed is provided at the inlet in the cleaning path where there is a brake-off of dust particles with overcoming a static friction, therefore the maximum power inputs are necessary.

The considered cleaning paths have the similar design. Cleaning paths for clearing flat surfaces (Fig. 4a, d) contain a suction connection, 1 the case, 2 with the cover, 3 forming the sucking slot 4 the knife, 5 fixed in the case, 1 for leveling a dust and the shelf, 6 connected with the case, 2 and placed behind the knife, 5 along the movement of the cleaning path and forming the channel, 7 with a processed surface for air suction from atmosphere. The shelf, 6 has the form flexed to lemniscate. The angle β between a tangent to a matching arc between the case 2 and shelf 6 and a processed surface is equal to 10-12°. The cover 3 is bent aside a longitudinal axis of the cleaning path to a curve described by the equation shown earlier.

Cleaning and transportation of a material inside the cleaning path and inside the consequent pipeline occurs due to an air movement. The material inside the cleaning path and the pipeline cannot be propelled without air that leads to a blockage of a material in the pipeline. Without an air movement inside the cleaning path there is a "choking" phenomenon which is like an avalanche expands to the subsequent pneumatic transport network where the material is deposited and clogs the pipe-line.

The majority of designs of cleaning paths operate with a material from the cleared surface to the polluted one except for the cleaning path for heap removal which is intended for plunging in bulk of a material. That is purpose of the cleaning path for heap removal causes for it the most adverse conditions by "choking" and working capacity of dust handling installation. The observed earlier analogs to the proposed dust handling installations are intended for rather small amount of a removed material. As researches of cleaning paths for heap removal are not shown in the literature, therefore, researches of the specified cleaning paths using the technique developed by us have been carried out. Researches of cleaning paths for heap removal have been carried out with the test bench presented in Fig. 5. The test bench is connected by means of the flexible hose 1 to the pneumatic transport network, the handle 2 with the cleaning path is fastened using the holder 3 to the mobile traverse 4 moved by means of screws 5 operated by the board 6. The cleaning path 7 is immersed into the graduated cylinder 8 with a control fill of sand 9.

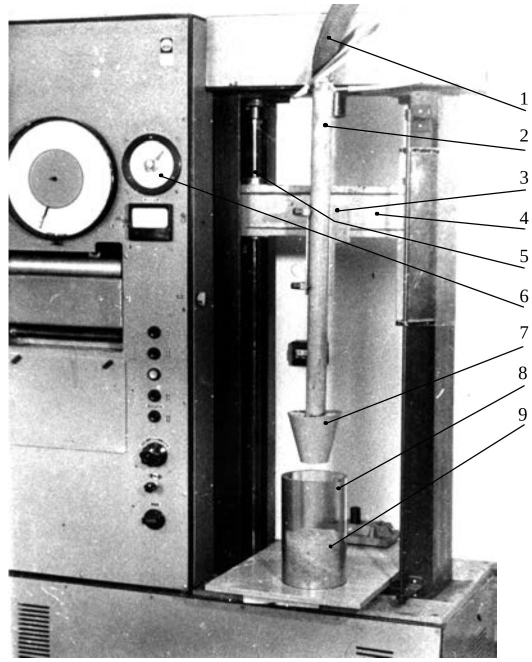


Fig. 5: The test bench attachment for heaps: 1: flexible sleeves; 2: handle; 3: clip; 4: traverses; 5: screw; 6: control panel; 7: cleaning paths; 8: measured cylinder and 9: dust

General view of the cleaning path for dust heap removal and results of its tests are presented in Fig. 6. Coarse moulding sand according to GOST 2138-74, group 063 with the basic sieve residue 1: 0.63; 0.4 mm and average bulk density of 1500 kg/m^3 was used in researches of the cleaning path.

The Central Compositional Rototable Design (CCRD) of 4-factorial experiment has been realized to obtain the mathematical dependence which makes it possible to conduct a quantitative estimation of geometrical parameters of cleaning paths. Pre-elaboration of CCRD results has allowed the regression equation to obtain in the polynomial form:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_1^2 + b_6x_2^2 + b_7x_3^2 + b_8x_4^2 + b_9x_1^3 + b_{10}x_2^3 + b_{11}x_3^3 + b_{12}x_4^3 \quad (8)$$

Where:

y = The response function
b_0 = The absolute term of the equation
b_i, b_{ij}, b_{ii} = According factors at interaction terms
x_i = The values of variable factors

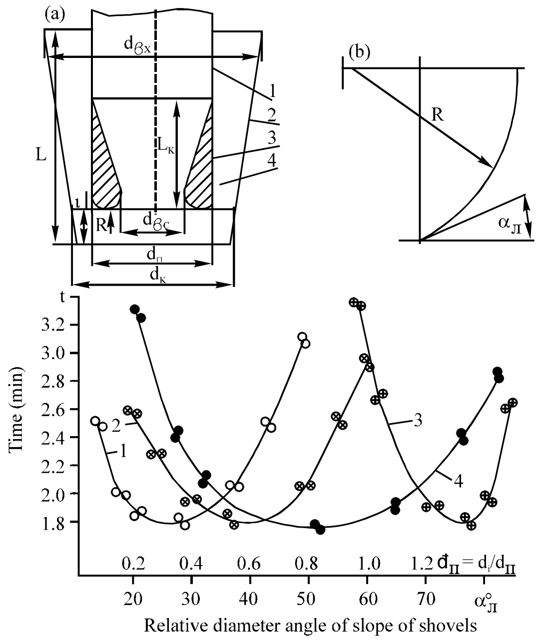


Fig. 6: Characteristics attachment for heaps: a) The settlement scheme; b) shovel development; 1: branch pipe; 2: a cone; 3: diffusors; 4: shovel (1: $t = f(\iota)$; $a_К = 40°$ $\alpha_Л = 45°$; $d_{BC} = 0.6d_П$; $d_K = 1.3d_П$; 2: $t = f(d_{BC})$; $\iota = 0.3d_П$; $a_K = 40°$; $a_Л = 45°$; $d_K = 1.3d_П$; 3: $t = f(d_K)$; $\iota = 0.3d_П$; $a_K = 40°$; $a_Л = 45°$; $d_{BC} = 0.6d_П$; 4: $t = f(a_Л)$; $\iota = 0.3d_П$; $a_K = 40°$; $d_{BC} = 0.6d_П$; $d_K = 1.3d_П$)

After implementation of the experiment design, factors of the regression Eq. 10 have been calculated and their significance was estimated according to a student criterion. Adequacy of the obtained equation to experimental data was verified by means of a Fisher's ratio test at a significance value of 5%.

The regression analysis of the characteristics obtained for cleaning paths has been executed after conducting of experimental researches. Regression analysis by the obtained experimental data has allowed to deduce following analytical forms for calculation of geometrical parameters of some cleaning paths:

Relative positive allowance: $\bar{I} = 4.74t^2-3.56t+2.47$
Optimum: $\bar{d}_П = 0.40$; $\alpha_Л = 30°$; $t_{min} = 1.80$; $S^2 = 0.042$ (9)

Relative suction diameter: $\bar{d}_{BC} = 4.28t^2-7.1t+4.83$
Optimum: $\bar{d}_П = 0.80$; $\alpha_Л = 40°$; $t_{min} = 1.88$; $S^2 = 0.0132$ (10)

Relative cone diameter: $\bar{d}_K = 11.2t^2-28.5t+19.9$
Optimum: $\bar{d}_П = 0.80$; $\bar{d}_K = 1.30$; $\alpha_Л = 50°$; $t_{min} = 1.74$; $S^2 = 0.045$ (11)

Entrance blade angle: $\alpha_Л = 2.79t^2-4.44t+3.43$
Optimum: $\bar{d}_П = 0.80$; $\bar{d}_k = 1.30$; $t_{min} = 1.66$; $S^2 = 0.04$ (12)

Figure 7 shows graphical dependences of the executed regression analysis of the obtained characteristics of cleaning paths for collecting dust heaps.

The obtained values of the sum of root-mean-square deviations between design and experimental dependences <5% testify to adequacy of the executed regression analysis.

After the cleaning path the dust air stream enters the flexible hose which is used for manipulation of the cleaning path. According to recommendations of Sanitary Engineering Institute "Santekhproekt" there should be chosen light-weight rubber flexible hoses with an internal webbing in the form of a metal spiral and diameter of a sleeve no more 50 mm. Whereby increase in a sleeve diameter more 50 mm makes it inconvenient for operation that is the flexible hose is a headache when collecting dust.

We have develop 5 types of supporting devices for flexible hoses and for 3 of them patents on inventions were taken out, the devices provide increase in productivity of a single cleaning path of the manipulator up to 10 times and of the main cleaning path of MPT multiply in comparison with cleaning paths of centralized industrial vacuum cleaners.

Table 1 shows the developed classification of manipulators and their brief constructive characteristic. The classification includes telescopic, expandable tubular, hose with a support, combined telescopic and combined pendulum manipulators.

Telescopic manipulators are most compact and have the minimum resistance in the fold position as their length is automatically chosen depending on dust circumstances and subject to the minimum length their resistance also will be minimum. A deficiency of telescopic manipulators is complexity of precise manufacturing and also corrosion durability of telescopic parts of the manipulator in dry friction conditions. This problem can be solved by application of advanced designs of self-lubricated seals and corrosion-resistant coats that in turn increases cost of telescopic manipulators. Owing to their high cost, telescopic manipulators should be recommended for application of small productivity MPT for work inside of premises where they can provide rather high working capacity and justify greater expenses. Small sizes of telescopic manipulators also have great value for small productivity MPTs.

Unlike the telescopic, expandable tubular manipulators have constant length and consequently a higher flow resistance. The general view of the

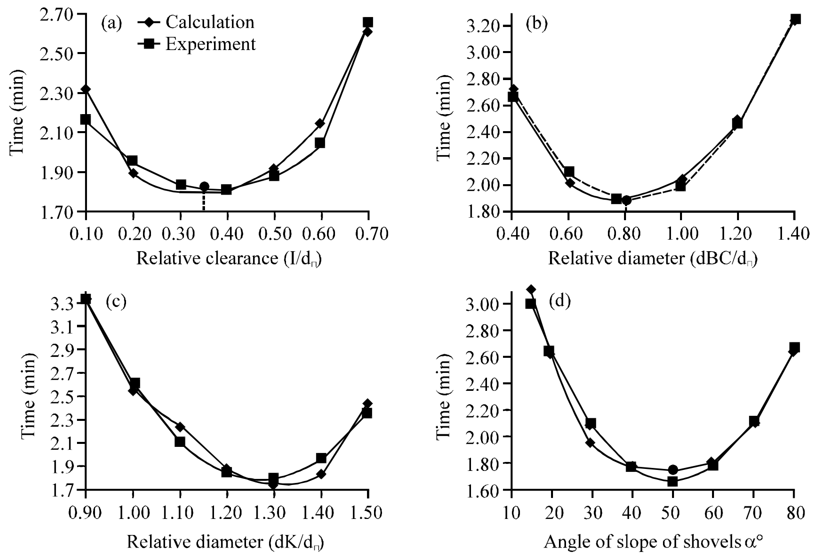
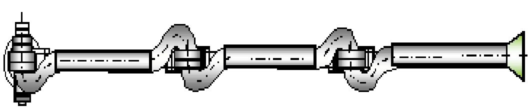
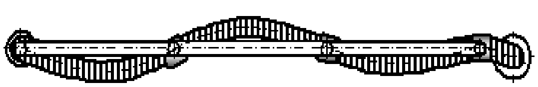
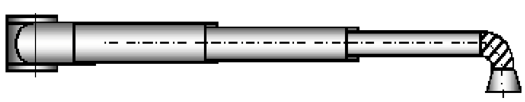
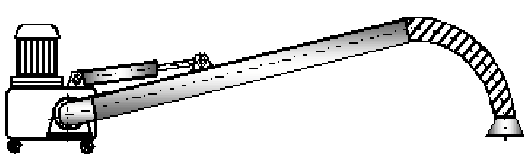


Fig. 7: The regression analysis of characteristics attachment for heaps of a dust

Table 1: Classification of manipulators

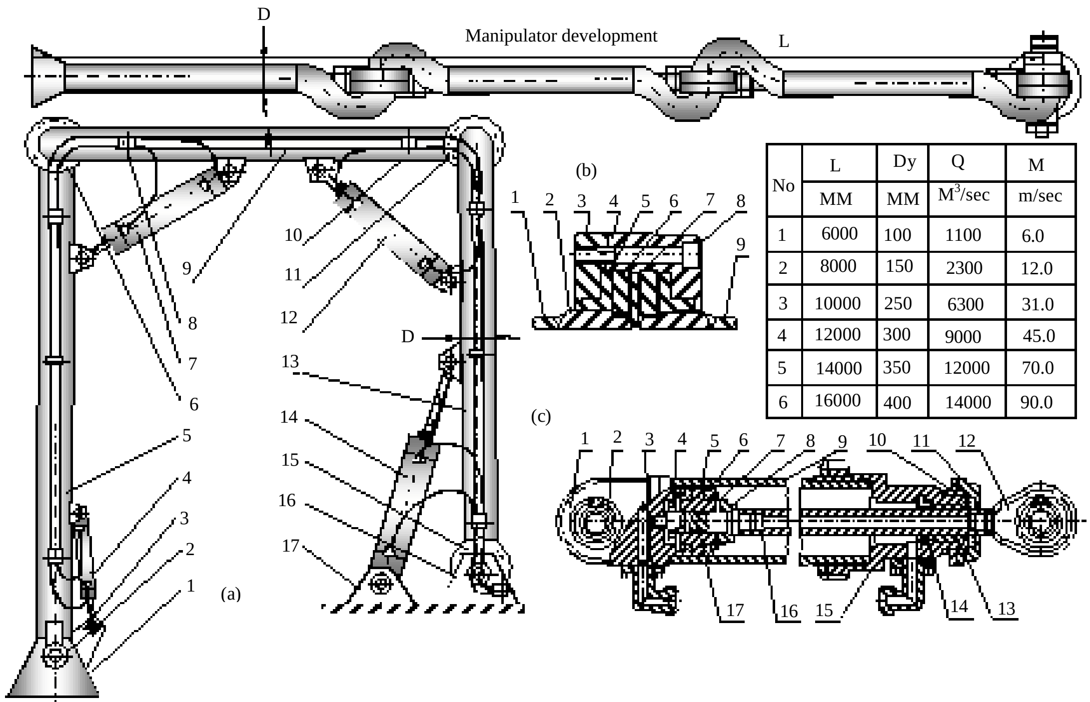
General view of the manipulator	Type of manipulator	Feature of design
	The telescopic	The difficult design the minimum resistance
	Collapsible tubular	The difficult design, average resistance
	Hose with support	The simple design, the maximum resistance
	The combined telescopic	The difficult design, average resistance
	The combined pendular	The simple design, average resistance

expandable tubular manipulator with a designation of the basic units is shown in Fig. 8. Productivity of the manipulator depends on diameter of an applied pipe and a standard size of installation. The manipulator provides manual and automatic control of cleaning path movement by means of hydraulic cylinders and the automation system.

Operation of the expandable tubular manipulator is carried out by means of hydraulic cylinders which cross section is presented in Fig. 8. Basic parts of the hydraulic cylinder are; 1: the cylinder eye; 2: the spherical bearing; 3: the connecting piece; 4: the nut; 5: the piston; 6: the piston seal; 7: the lid; 8: the spigot; 9: the cylinder; 10: the scraper; 11: the scraper cover; 12: the stock eye; 13: the spigot; 14: the stock seal; 15: the cover; 16: the stock; 17: the stock tip.

The hose manipulator with a support has the most simple design but also the maximum hydraulic resistance which provides a rubber sleeve applied.

The combined telescopic and pendulum manipulators are provided with flexible sleeves on the end which ensure automatic copying of a complex profile of a cleaned



No	L	Dy	Q	M
	MM	MM	M^3/sec	m/sec
1	6000	100	1100	6.0
2	8000	150	2300	12.0
3	10000	250	6300	31.0
4	12000	300	9000	45.0
5	14000	350	12000	70.0
6	16000	400	14000	90.0

Fig. 8: The general view of the manipulator of the big productivity; a) 1: nozzles, 2; knot of turn, 3: arm a nozzle, 4: hydrocylinder a nozzle, 5: console, a console 6: support, 7: hydrocylinder of the console, 8: a switch of the console, 9: power highway, 10: perekla-dyne, 11: support of a crossbeam, 12: hydrocylinder of the console, 13: column the basic, 14: hydrocylinder column, 15: support of a column, 16: arm of a column, 17: arm of the hydrocylinder of a column surface. The most simple by design combined pendulum manipulator should be recommended for application in small productivity MPTs; b) basic knot and c) the power hydrocylinder

Resistance of the dust handling installation pipeline depends on material transportation distance. The feature of the mobile industrial vacuum cleaners being developed is the minimum material transportation distance that in turn provides its minimum hydraulic resistance and power inputs of the installation.

Application of computer technologies allows power inputs for pneumatic transporters to optimize and in perspective to carry out automatic cleaning in elimination of ecological catastrophe aftereffects and in harmful conditions. The technological and automation level of modern gas-turbine plants is a source of pride and a peak of evolution of the industry.

Figure 9 presents the design of air turbo-blower developed in BGTU on the basis of serially manufactured turbo-compressor for diesel supercharging. Air turbo-blowers have a simple design and allow low cost and economic control modes to implement depending on the dust loading that offers the possibility to reduce power input in dust handling systems up to 2 times.

The design of the air turbo-blower uses high technology achievements, high rpm values which allow high efficiency and discharge head for one step to obtain, they have flexible shaft which provides self-balancing of a rotor to eliminate the residual unbalance. Blowing machines with turbine drive have the centrifugal wheels manufactured by metal mold casting that reduces weight and labor content of manufacturing of wheels and the blowing machine as a whole by 2 orders almost without waste. Decrease in weight in a finished article by 1% reduces power inputs in its manufacture by 2%.

Active magnetic bearings are applied in modern designs of domestic and foreign gas turbines of low power and the shaft of the power turbine-driven set is directly connected to the generator that eliminates a complex and fire-dangerous lubrication system and increases reliability, working capacity, provides the interactive control and monitoring, reduced power consumption and improves technical parameters of the unit (Chertov, 2009d; Komarov, 1994; Schweitzer *et al*., 1994; Carrere *et al*., 1994; Zhuravlyov, 2000; Lin, 1993; Nonami and Ito, 1994; Schob and Bichsel, 1994; Shpak, 1995). Application of magnetic bearings allows automatic balancing of a rotor when running to perform, optimally to

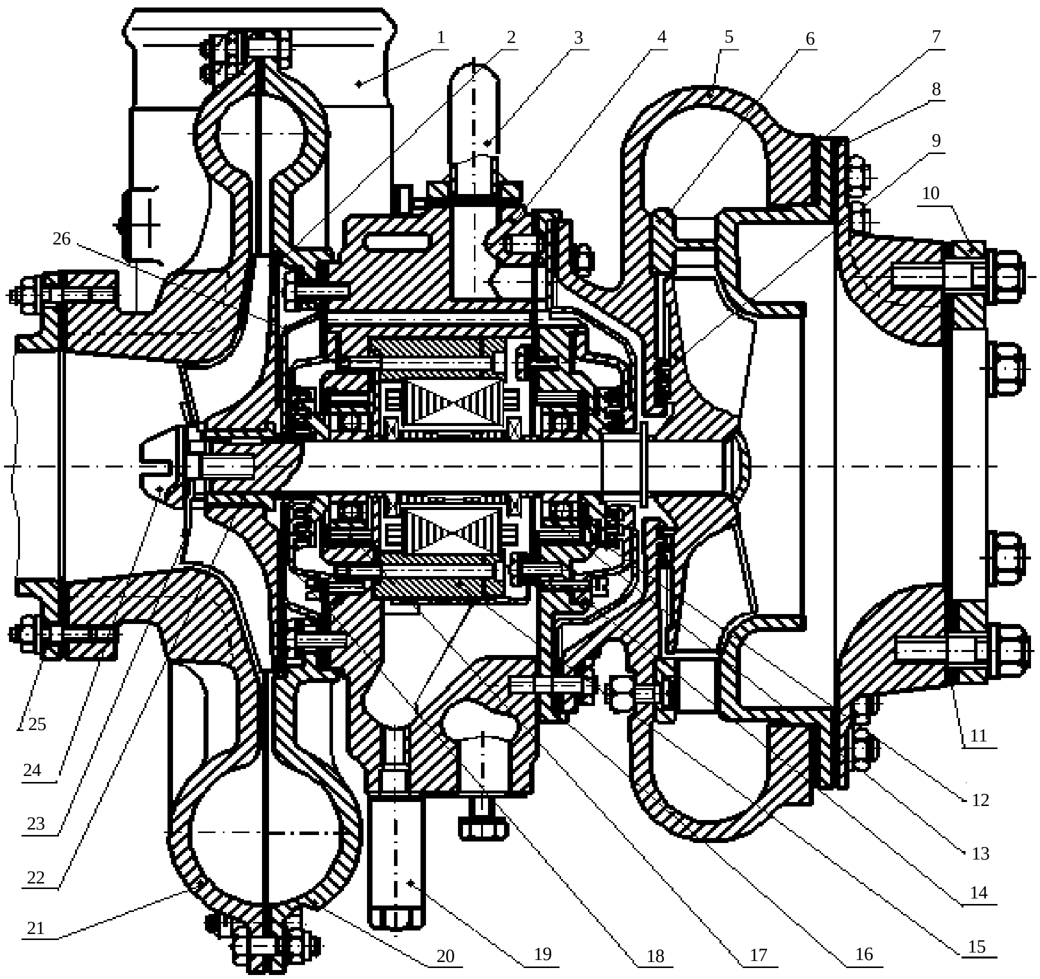


Fig. 9: A BSTU turbocompressor with magnetic bearings: 1: an exhaust branch pipe of a supercharger; 2: krylchatka a supercharger; 3: the pressurisation pipeline; 4: the case of a supercharger; 5: case of the turbine; 6: the wreath snuffled; 7: a turbine flange; 8: exhaust branch pipe of the turbine; 9: the turbine with shaft; 10: flange of the exhaust turbine; 11: a lining; 12: turbine consolidation; 13: the safety bearing; 14: acover of consolidation of the turbine; 15: bearing magnetic; 16: aflange of ball-bearings; 17: lining spring; 18: consolidation of a supercharger; 19: a stopper oil plum; 20: a snai of supercharger; 21: a cover of a supercharger; 22: plug of a supercharger; 23: a lock washer; 24: screw of a supercharger; 25: an entrance branch pipe of a supercharger; 26: cover of consolidation of a supercharger

set practically any rpm value which upper limit is restricted to mechanical strength of materials of a rotor that is characteristic for low power turbines (Truston, 1991; Voronkov and Denisov, 1994; Williams *et al*., 1994; Zhuravlyov, 1998, 2000; Andrejev, 1994; Biswas and Ishizuka, 1995; Childs and Noronha, 1997).

FINDINGS

Now there is no serial production of MPT in Russia. Implementation of proposals on serial manufacturing of mobile pneumatic transporters is actual for the entire industry, it allows to obtain multiple social, ecological and economic benefit; duly volumetric dust collection which allows to exclude build-up and falling of blocks of a packed material and breakdowns of the equipment and personal injuries of the personnel related with it; mechanization and automation of dust removal and utilization process in the entire volume of a premise; flexible round-the-clock operation of installations and increase returns on assets; application of the developed in BSTU low power consuming MPT equipment; multiple reduction of a distance for pneumatic transportation of a material; movement of the manipulator over the entire volume of a premise expands its functionalities, reduces capital outlays and has much less energy demands than the entire machine; a mobile installation substitutes several stationary ones; application of the developed complex of 10 MPT and SVCD standard sizes providing optimum 2-level modes of process regulating of dust collection by the installation depending on distribution of a material and its amount by operative number of working installations; duly high-duty cleaning of the volatile dust is much less expensive than handling of set and packed dust; preventive maintenance and elimination of aftereffects of technogenic accidents and catastrophes; exclusion of salt from the process of road cleaning from ice build-up in relation to significant economic and ecological damage caused by pollution of potable water tables; high-grade salvaging of a cleaned material without loss of its properties using the proposed technology and the waste processing equipment upon cleaning of adjoining territories and useful secondary waste use that additionally increases efficiency of installations; development of a serial production of mobile pneumatic transporters provides busyness for science and manufacture, saves and mechanizes heavy hand work, essentially improves maintenance practice of roads, adjoining territories and constructions, brings additional profit to the region in conditions of an economic slack.

CONCLUSION

The results of the theoretical and patent researches presented by the work, the taken patents on inventions and formulas for calculation of parameters, provide increase in productivity of the mobile pneumatic transporters, the developed, manufactured, studied and implemented installations, automation of the entire process on creation of the most complex element of the blowing machine rotor wheel within the range from calculation to manufacture and they are a methodological basis of design, manufacture and implementation of mobile pneumatic transporters of new type. The developed designs, edited and approved computation programs allow optimization calculations of the equipment to make by various parameters and the manufacturing programs are suitable for a serial production.

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