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SYNTHESIS OF STRUCTURAL ENSURE VACUUM ION-PLASMA SPRAYED COATINGS DEVICES FOR BLADES OF GAS TURBINE ENGINES

MIKHAYLOV Aleksandr, MIKHAYLOV Dmitriy, HOLUBOV Artem

[1] The Department "Manufacturing Engineering"; SHEI "Donetsk National Technical University"; 58, Artyoma Street, 83001 Donetsk

Corresponding author: HOLUBOV Artem, e-mail: tm@mech.dgtu.donetsk.ua

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Abstract. *The article presents data on structural synthesis of technological maintenance of the vacuum chamber of the ion-plasma installations. It proposed to carry out the creation of the layout scheme based on the principle of the faceplate-structural fashion-li. In principle, the structural model is based on the composition of the structural model of the spatial layout and concept of kinematical motion scheme of functional elements of the faceplate of the vacuum chamber. Rational version-essentially determined by structural models of technical and economic parameters of vacuum ion-plasma system. The work-seemed particularly synthesis of technological support to generate multiple options, fundamentally structural models chucks vacuum chamber.*

Keywords*:* *synthesis, faceplate of the vacuum chamber, structural model, installation productivity.*

1. Introduction

The most loaded details of gas-turbine engines (GTE) defining their resource, shovels [1] are. Elements of shovels in the course of their operation test tension of stretching and a bend from centrifugal forces, tension of a bend and torsion from a gas stream, variable tension from vibrating loadings, frequency and which amplitude change largely, and also thermal tension from thermal loadings. The temperature on shovels of the first step of the turbine can reach 1200 OS [2]. Thus recurrence of sign-variable tension leads to destruction of shovels owing to thermal fatigue because of arising microcracks and change of properties of a material.

And also it is possible to note that shovels of GTE work in the conditions of hostile gas environment at high temperature that in some cases leads to emergence of gas corrosion. Thus humidity and dust existence in an air stream is rendered by chemical and abrasive wear process of elements of shovels, namely surfaces, entrance and target edges of a feather.

Especially considerable wear process of elements of a feather of shovels is shown at GTE of helicopters, for example TV3-117, being maintained in deserts with sandy storms, in districts, with dust and hydrochloric components in the air streams which are forming because of a soil erosion, near active volcanoes with emissions of ashes and to that similar features. It leads to decrease in durability of shovels and GTE as a whole.

Various technological methods and ways of increase in their operational properties are applied to increase of durability of shovels of GTE [3, 4, 5]. In particular to decrease in wear of elements of a feather of shovels apply a vacuum ion-plasma (electro arc) dusting of the special composite coverings formed on a basis nitride of the titan, nitride zirconium of the titan and other connections. At the same time, application of these types of a dusting demands the solution of questions of increase of technical and economic indicators. First of all, increases of productivity and decrease in prime cost of a dusting of vacuum ion-plasma coverings. In practice these questions are solved at the expense of increase of concentration of working positions in the vacuum chamber. However in this case at once there is a number of questions. First of all, how many shovels it is possible to have in the vacuum chamber? What structure of working positions will be the most rational for these or those types of shovels? What spatial communications in an arrangement of shovels are necessary for realizing? And also, it is necessary to provide what kinematics of movements of elements of the adaptation to reduce influence of shadow zones on quality of a sprayed covering. On these and other questions in this article attempt to give answers is made.

The purpose of this work is increase of productivity and decrease in prime cost of a dusting of vacuum ion-plasma coverings on GTE shovels at the expense of further increase of their concentration in the vacuum chamber by realisation of special structure of working positions of industrial equipment, performance of necessary spatial communications between its elements and providing demanded kinematics of movements of its elements from a condition of ensuring uniformity of thickness of a covering on shovel surfaces.

According to a goal, in this work the following research problems are defined: to define necessary options of concentration of products in the vacuum chamber of ion-plasma installation; to offer possible types of structures of an arrangement of working positions of the vacuum chamber; to investigate types of spatial communications of an arrangement of working positions in the vacuum chamber; to analyze kinematics of movements of shovels in the vacuum chamber; to develop the general principles of design of industrial equipment from a condition of ensuring uniformity of thickness of a covering on surfaces of shovels. These tasks are solved in this work.

2. Features of concentration of products in the vacuum chamber

The main task of synthesis of technological support of the vacuum chamber is determination of necessary concentration of working positions of rotating equipment or capacity of a set of working positions of the vacuum chamber. Thus concentration of working positions or capacity of a set of working positions of the vacuum chamber or the general density of products of the vacuum chamber is determined by the following formula:

$$v = П_Ц T_Ц = \frac{V}{V_0}, \quad (1)$$

where v - capacity of a set of working positions of the vacuum chamber;

$П_Ц$ - cyclic productivity of a dusting of coverings on shovels;

$T_Ц$ - a full production cycle of a dusting of coverings on GTE shovels;

V - total amount of the vacuum chamber;

V_0 - specific volume of the vacuum chamber for an arrangement of one working position (shovel).

It is possible to note that at design of the vacuum chamber process of determination of capacity of a set of working positions depends on necessary cyclic productivity $П_Ц$ of installation. Time of a full production cycle $T_Ц$ of a dusting of a covering for shovels of GTE is usually set previously.

Being set by concrete parameters of cyclic productivity $П_Ц$ and time of a full production cycle $T_Ц$ in expression (1) it is possible to define necessary quantity of sprayed shovels v according to the set entry conditions. When it is necessary to define volume of the vacuum chamber it is possible to use the following expression

$$V = П_Ц T_Ц V_0 .$$

In a case when it is necessary to conduct process of further increase of productivity of installation, with the set volume of the vacuum chamber, it is possible to use the following conditions:

$$\left. \begin{array}{l} v \to \max , \\ V_0 \to \min . \end{array} \right\}$$

Process of definition of a set of working positions of the vacuum chamber has the following restrictions:

- with effect emergence «shadow zones», this effect operates in case of features of a spatial arrangement of shovels relatively each other and in case of features of kinematical movement of a shovel concerning installation cathodes;

- existence of limiting specific density of shovels in the vacuum chamber which is determined by the following formula $P = 1/v$;

- features of structure of technological support, spatial communications between elements of structure and kinematics of movements of shovels in the vacuum chamber.

3. Structural models of industrial equipment of the vacuum chamber

When the capacity of a set of working positions of the vacuum chamber (concentration of working positions) is defined their structure is made. The structure of working positions characterizes the internal organization, an order and creation of industrial equipment and represents set of elements and the relations between them.

The structure of working positions of industrial equipment of the vacuum chamber represents set of the ordered sets y and a which we represent as follows:

$$Str = \{y, a\},$$

where Str - working positions of industrial equipment of the vacuum chamber;

y - set of working positions of industrial equipment of the vacuum chamber;

a - a set of the relations on a set y.

Here sets y also a look like:

$$y = \{y_1, y_2, ..., y_v\},$$

where y_η - η - й a set element y;

$$a = \{a_1, a_2, ..., a_{v_i}\},$$

where a_η - η - e the relation between set elements y.

However for realization of structure of working positions of industrial equipment of the vacuum chamber it is necessary to define parameters of sets y and a.

Process of formation of structure of working positions of industrial equipment of the vacuum chamber of ion-plasma installation (fig. 1) is based on the following.

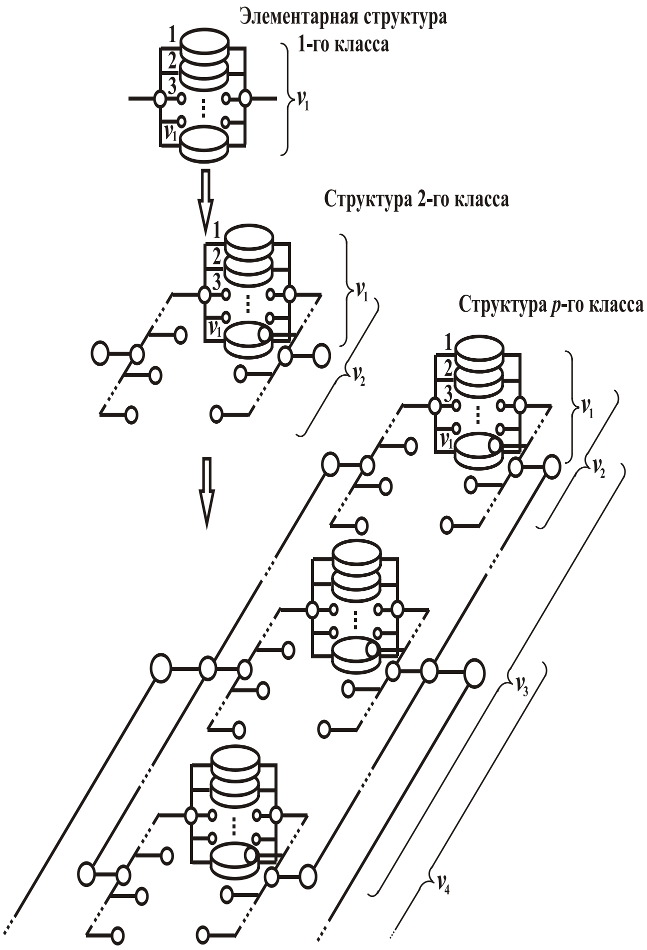


Fig. 1. Features of formation of structure of working positions of industrial equipment of the vacuum chamber of ion-plasma installation

At first the elementary structure of the 1st class is formed, then the structure of the 2nd class is made of these elementary structures, then - structure of the 3rd class, and so on before creation of structure *of R-go* of a class. In this case, the capacity of a set of working positions will be defined on the basis of the following expression:

$$v = \prod_{k=1}^{p} v_k ,$$

where v_{ik} - capacity of a set of elements of a subsystem *of k-go* of a class;
R - quantity of classes of subsystems on a set of working positions of ion-plasma installation.

For the presented structure (fig. 1), cyclic productivity of vacuum ion-plasma installation is determined by the following formula

$$П_Ц = \frac{\prod_{k=1}^{p} v_k}{T_Ц} .$$

The structural model of working positions of equipment of the vacuum chamber on classes of subsystems can be presented as follows:

$$Str = \{Str_1, Str_2, ..., Str_P\},$$

where Str_k - structure of subsystems *of k-go* of a class of industrial equipment of the vacuum chamber of installation.

It is possible to present the general structural model of structure of working positions the following expression

$$Str = \bigcup^{v_P} \cdots \bigcup^{v_2} \bigcup^{v_1} y_\eta .$$

4. Options of spatial models

In the expression (4) presented earlier defining structure of working positions of industrial equipment of the vacuum chamber of ion-plasma installation, the set of the relations *of an* on a set of working *positions y* remains to unknown. Therefore here it is necessary to define the spatial relations between working positions. These questions can be solved on the basis of the spatial models given on fig. 2.

On fig. 2 options of spatial models of industrial equipment of the vacuum chamber are shown, namely: on fig. 2, and - cylindrical, on fig. 2, - the truncated cone, on fig. 2, in - a difficult form, on fig. 2, g - a hemisphere. Here figures have designated the following: 1-a spatial form of model, 2 - working positions of industrial equipment. It is necessary to notice that other options of spatial models are possible also. Process of a choice of this or that model depends on technological features of a dusting of coverings and types of shovels of GTE.

It is possible to note that on the basis of elementary models of industrial equipment it is possible to create their combined options. On fig. 3 options of the combined spatial models of industrial equipment are presented. Here it is shown: fig. 3, and - the cylinder cylinder, fig. 3, - the cylinder - the truncated cone, fig. 3, in - the cylinder - a difficult form, fig. 3, g - the cylinder hemisphere. Figures have designated the following: 1-a spatial form of model of the first level, 2 - a spatial form of model of the second level, 3 - working positions of industrial equipment. Application of similar models possibly for cases of a dusting of coverings on shovels of different types. And also it is necessary to notice that probably whole set of the various combined options of spatial models of equipment which are defined by technological conditions of process of a dusting of coverings.

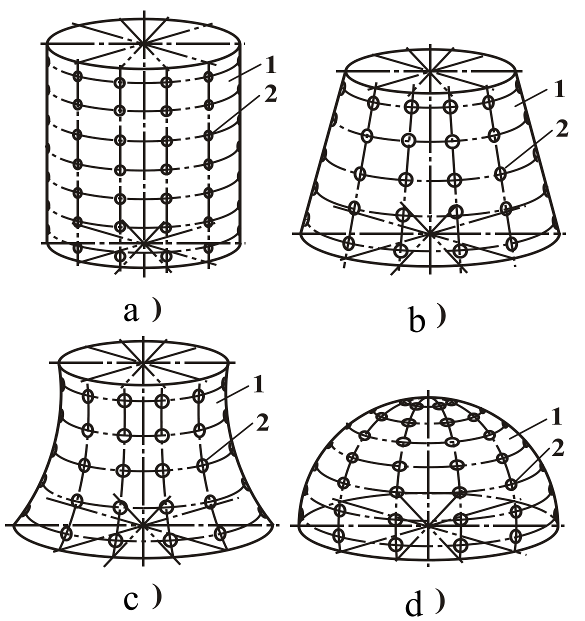


Fig. 2. Options of spatial models of industrial equipment of the vacuum chamber: a - cylindrical, b - the truncated cone, c - a complex form, d - a hemisphere

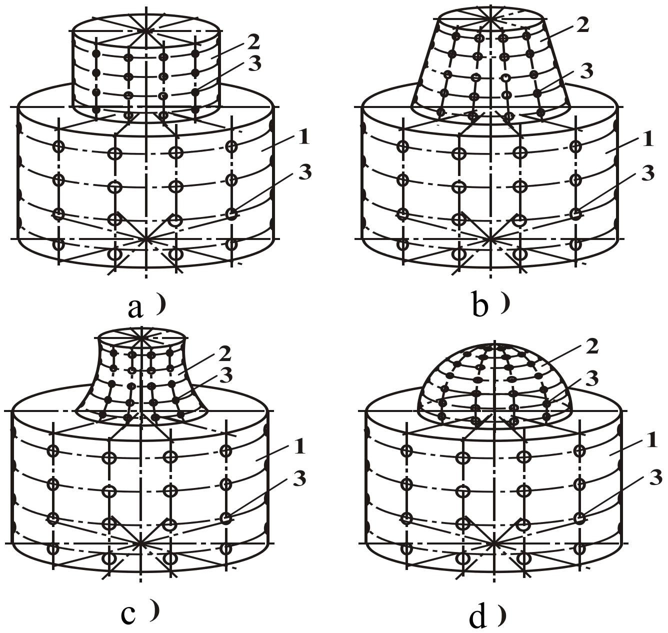
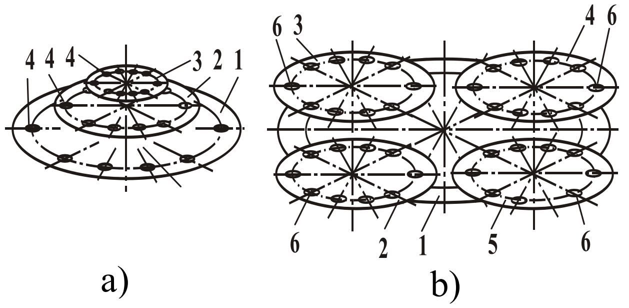


Fig. 3. Options of the combined spatial models of industrial equipment: a - the cylinder cylinder, b - the cylinder - the truncated cone, c - the cylinder with complex form, d - the cylinder hemisphere

On fig. 4. other options of spatial models of industrial equipment of the vacuum chamber are presented, namely: fig. 4, a - multilevel, fig. 4,b - birotor, fig. 4, c - globoid form. On fig. 4, and figures have shown the following: 1, 2, 3 - levels of an arrangement of working positions in industrial equipment; 4-working positions of equipment (each level is intended for shovels of the set look). On fig. 4, it is shown: 1, 2, 3, 4, 5 - elements of a birotor faceplate; 6-working positions of equipment. On fig. 4, in the globoid form model is presented, here is shown: 1-a toroidal surface of model, 2 - a globoid form curve of a trajectory of movement of a working position, 3 - working positions of equipment.



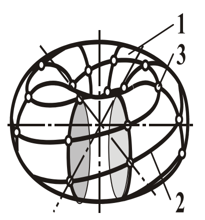


Fig. 4. Options of spatial models of industrial equipment of the vacuum chamber: a - multilevel, b - birotor, c - globoid form

It is possible to note that creation of trajectories of movement of a product in the vacuum chamber is solved on the basis of composition of transformations of the Cartesian systems of co-ordinates and transformations of movements in these systems of co-ordinates.

For definition of rational option of industrial equipment of the vacuum chamber of ion-plasma installation generating of a full set of various options of models is carried out and on this set the rational or dominating option of the adaptation is defined.

5. Kinematical schemes of movements of elements of industrial equipment

At the schematic image of technological system or equipment, the principle of its work is shown by means of the schematic kinematical diagram on which elementary movements in the relevant systems of coordinates are represented. The schematic kinematical diagram is the scheme on which by means of symbols elementary movements, their quantity, structure and a spatial arrangement are represented. Elementary movements are understood as two types of movements: forward (Trans) and rotary (Rot) movement. Thus the kinematics of industrial equipment can have elementary or difficult structure and specific features of its realization.

Design of industrial equipment of the vacuum chamber of ion-plasma installation is based on a basis of schematic kinematical diagrams. According to the accepted schematic kinematical diagram, technological elements and subsystems, in the course of work of all system of industrial equipment, move relatively each other on trajectories of relative movement. Thus these movings are carried out with the speeds predetermined by modes and parameters of a dusting of coverings on products, existence of shadow zones, structure of industrial equipment and features of a design of a shovel of GTE.

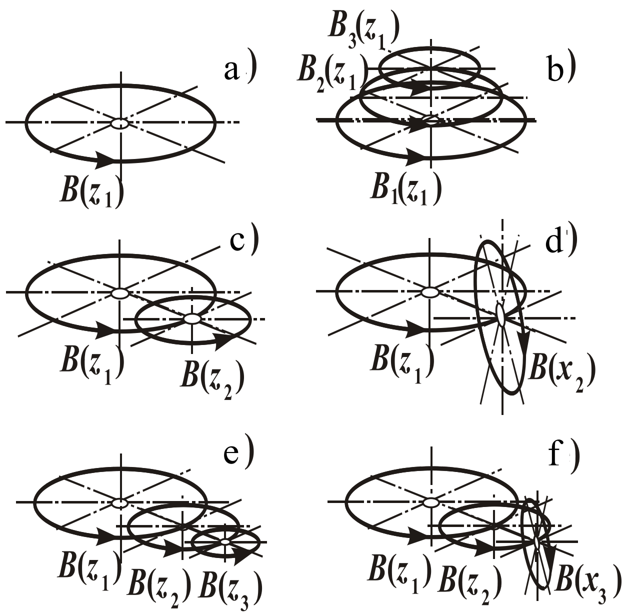


Fig. 5. Schematic kinematics diagrams of movements of elements of industrial equipment:
a - one rotary motion; b - three rotary motions round *the z1 axis*; c - two rotary motions round *the z1 and z2 axes*; d - two rotary motions round *the z1 and x2 axes*; e -three rotary motions round *the z1, z2 and z3 axes*; f -three rotary motions round *the z1, z2 and x3 axes*

On fig. 5 some versions of schematic kinematical diagrams of movements of elements of industrial equipment are presented. These schematic kinematical diagrams are made on the basis of the following elementary movements: fig. 5, and - one rotary motion; fig. 5, - three rotary motions round *the z1 axis*; fig. 5, in - two rotary motions round *the z1 and z2 axes*; fig. 5, g - two rotary motions round *the z1 and x2 axes*; fig. 5, д - three rotary motions round *the z1, z2 and z3 axes*; fig. 5, e - three rotary motions round *the z1, z2 and x3 axes*.

Generally the kinematics of movements of the schematic kinematical diagram can be presented by the following set:

$$a = \{a_1, a_2, ..., a_P\},$$

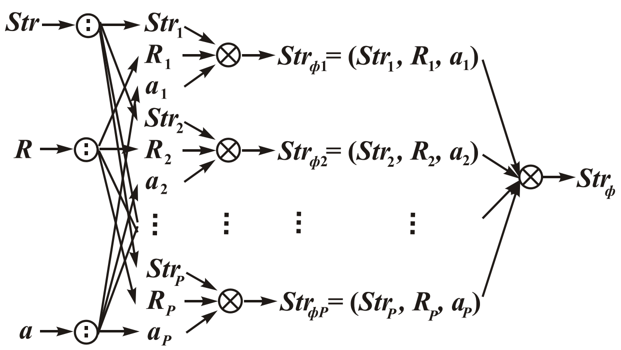
where a_k - elementary movement of a subsystem of industrial equipment *of k-go* of a class.

It is possible to note that on fig. 5 only some versions of schematic kinematical diagrams of movements of elements of industrial equipment are presented. Here probably whole set of their various options. The set scheme is defined by features of design of industrial equipment, and necessary options can be formed on the basis of methods of the morphological analysis.

6. General features of design of industrial equipment

Process of design of technological systems including industrial equipment of the vacuum chamber, it is process of consecutive accumulation of complexity of the equipment. Therefore usually technological systems are designed for some stages, level of complexity of designed system thus is gradually increased. An important design stage of technological system is the process based on base of basic and structural models. The basic and structural model is formed on the basis of composition of structural model, spatial configuration and the schematic kinematical diagram of movements of functional elements of a faceplate of the vacuum chamber.

The developed general scheme of design of basic and structural models of industrial equipment of the vacuum chamber is based on operations of decomposition of structural model, spatial model and the schematic kinematical diagram on subsystems and *the elements k-go* of a class, composition from these subsystems and elements of a set of elementary trains, then compositions from these trains of the general basic and structural model. As a whole this process is based on a principle of composition which it is possible to present the following expression:



where Str, Str_k, $Str_{фk}$ и $Str_ф$ - structures of the general, *k-go* of a class, functional *k-go* of a class and the functional general, respectively;

R и R_k - structures of the general and *k-go* of a class of spatial models, respectively;

a и a_k - structures of the general and *k-go* of a class of kinematical schemes, respectively;

$\odot$ and $\otimes$ - operations of decomposition and composition of elements in model, respectively.

As a whole process of synthesis of basic and structural models of industrial equipment of the vacuum chamber can be realized on the basis of the morphological matrix presented on fig. 6. Here process of design of basic and structural models is realized on the basis of composition of structural models, spatial models and kinematical schemes. By means of basic and structural model the layout scheme of industrial equipment of the vacuum chamber of ion-plasma installation is formed.

On fig. 7 the general view of some options of industrial equipment of the vacuum chamber of ion-plasma installation is presented. Here the following options are shown: fig. 7, and - traditional, fig. 7, - combined,
fig. 7, in - spherical, fig. 7, g - cylindrical.

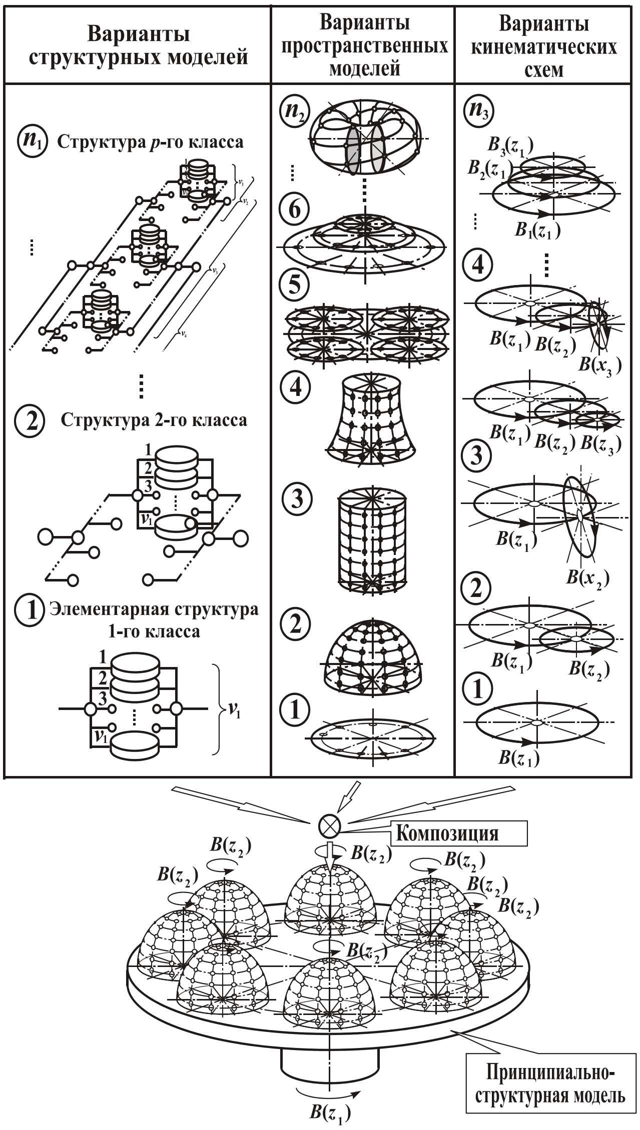


Fig. 6. Morphological matrix of synthesis of basic and structural models of industrial equipment of the vacuum chamber

It is possible to note, the industrial equipment presented on fig. 7, and fig. 7, in is intended for shovels of the directing device GTE of the TB3-117 model. Thus concentration of working positions of equipment fig. 7, in 2 times above, than the equipment presented on fig. 7, and. The industrial equipment presented on fig. 7, and fig. 7, g, is intended for shovels of the GTE compressor of the TB3-117 model. Here, concentration of working positions of equipment fig. 7, g in 1,6 times is higher, than the equipment presented on fig. 7, B. On the basis of it, productivity of a dusting nitride of titanic coverings on NNV 6.6-I1 installation increases by shovels of GTE according to the applied equipment. It is also possible to note that the executed researches of process of a dusting of coverings on shovels have allowed to establish that sprayed coverings on working surfaces of shovels with use of the developed adaptations have uniform thickness within the set admission.

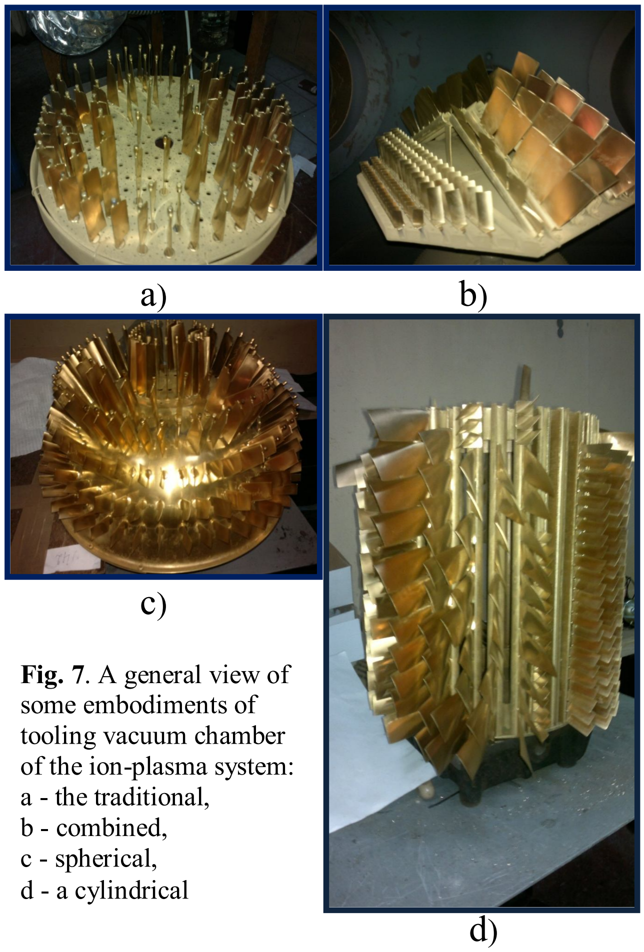


Fig. 7. A general view of some embodiments of tooling vacuum chamber of the ion-plasma system:
a - the traditional,
b - combined,
c - spherical,
d - a cylindrical

7. Conclusion

Thus, the bases of design of industrial equipment of vacuum ion-plasma installations developed in this work allow to create the high-efficiency equipment and to reduce prime cost of a dusting of coverings on GTE shovels at the expense of concentration of working positions. The executed researches have allowed solving the following:

- to define necessary options of concentration of products in the vacuum chamber of ion-plasma installation;

- to offer possible types of structures of an arrangement of working positions of the vacuum chamber;

- to investigate types of spatial communications of an arrangement of working positions in the vacuum chamber;

- to analyze kinematics of movements of shovels in the vacuum chamber;

- to develop the general principles of design of industrial equipment from a condition of ensuring uniformity of thickness of a covering on surfaces of shovels.

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