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Universal Adaptive Spatial Parallel Robots of Module Type Based on the Platonic Solids

S.N. Sayapin, *Member, IAENG*, A.P. Karpenko, and S.H. Dang

***Abstract*—This paper describes and presents possibilities of robotic mechanisms based on the Platonic solids, wherein each rib may vary along its length. Each of its faces can clamp/unclamp a thing with a closed loop surface of various form as well as put pressure on environmental surface of contact. These properties open new possibilities for its applications in various fields. It is shown that the octahedron is the most perspective modular structure. The octahedral module is a new concept of spatial parallel mechanism with twelve degrees of freedom. It is an adaptive spatial parallel self-moving robot of module type for individual and collective (swarm systems) uses in various fields robotics. We examine design principles of octahedral modular robots, called Dodekapod robots (from the Greek words dodeka meaning twelve and pod meaning foot or its counterpart leg), as future intelligent building blocks for various robotic systems that can self-move and self-reconfigure.**

***Index Terms*—Parallel robot, Platonic solids, self-moving robot, self-reconfigurable robot, swarm systems, modular robot**

I. Introduction

The concept of the modular robotic system has attracted attention over several decades. Modular robotic system consists of homogeneous modules which have combined into a single multilink design, and the connection of these modules allows you to create different structure of the mechanisms [1-4]. Such modules can have an invariable shape (module of serial robot) and a spatial parallel structure with variable geometry of shape (spatial parallel robot of modular type) [5]. The spatial parallel robots versus serial robots have the following main advantages: much higher accuracy and rigidity, higher productivity and reliability, much less sensitive to scaling effect, and ability to manipulate large loads. Compared to the serial robots, the main drawback of hexapods is the smaller workspace [5]. Mobile robots have an unlimited workspace. This may well be reason for the development of their applications [6].

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We examine the prospects and the possibility of effective use of the Platonic solids as universal bases to design for adaptive intelligent spatial parallel mobile modular robots. It is well known that only Platonic solids (tetrahedron, cube, octahedron, dodecahedron and icosahedrons) are regular polyhedrons (Fig. 1). Therefore, the modules based on the Platonic solids versus other polyhedrons contain the same elements and they can to unlimitedly build up along any of the faces.

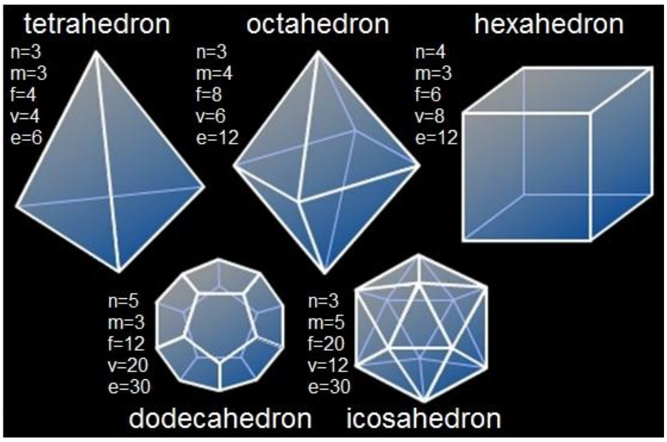

Fig. 1. Platonic solids: f – face; v – vertex; e – edge; n -number of edges per face; m - faces at each vertex.

This paper introduces and outlines the capabilities of a robotic mechanisms based on the Platonic solids where each rib of the can be varied in length. Each of its faces can clamp (unclamp) things with a closed loop surface of various form. These properties open new possibilities for its applications in various fields. Frames with tetrahedral and octahedral forms have the highest rigidity, and a the frame with a cubic form has the lowest rigidity. Frames with dodecahedral and icosahedral forms are of medium rigidity. The tetrahedron and octahedron have the least amount of vertices and edges. Tetrahedral modular robot compared with octahedral robot has less functionality. It is shown that the octahedron is the most perspective modular structure. The octahedral module is a new concept of parallel spatial mechanism with twelve degrees of freedom (d.o.f.). It is an adaptive parallel spatial self-moving modular robot for individual and collective (swarm systems) uses in various fields robotics. The paper describes design principles for our modular robots, called Dodekapod robots (DR), as future intelligent building blocks for various robotic systems that can self-move and self-reconfigure. Such robot versus hexapod with 6 d.o.f. [7] has the larger workspace. Every one of its triangular faces is formed by linear drives that are connected with vertices of octahedron by spherical joints

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(link balls). These faces can clamp/unclamp a thing with a closed loop surface of various form as well as put pressure on environmental surface of contact. DR is modern stage of development in the field of spatial parallel robots [7]-[8]. Currently, many modern multifunctional concepts are needed to expand functional capabilities of DR. References [8]-[10] shows novel functional capabilities of DR, such as the self-movement, the diagnostics of contact surfaces, and other ones. References [7], [10] show kinematics analyses of dodekapod manipulator. First time carried out a study of algorithms for movements of DR in the pipes of constant and variable cross-sections. We aim at merging technologies from information technology, special requirements in various branches industry, e.g. methods of transportation, space engineering, swarm robotics, rehabilitation medicine, spatial active vibration protection systems and robotics in order to design adaptive and intelligent robots. New functionality of DR is represented below.

II. Description of Dodekapod Robot

We present novel concept of the adaptive parallel spatial self-moving modular robot, called Dodekapod robot, where we aim at merging technologies from information technology, special requirements in various branches industry, e.g. rehabilitation medicine, space engineering, methods of transportation, spatial active vibration protection systems and robotics in order to design adaptive and intelligent robots. DR is an octahedral parallel spatial mechanism. Every one of its triangular faces is formed by linear drives that are connected with vertices of octahedron by spherical joints. This feature opens new functionality of DR versus a hexapod and others parallel spatial robots. The schematic view of the monomodule DR (a) and the simplified structural scheme of the control system (b) are shown in Fig. 2. The structural scheme includes maximal number of sensors, radial stops and grippers. This number is dependent on the applications and it may be decreased. DR is executed as the octahedral module 1. All ribs of the octahedron are executed as the rods with the linear drives 2 each of which have the axial force sensor 3, the medial force sensor 4, the relative displacement sensor 5, and the relative velocity sensor 6. The ends of the adjacent ribs are connected by the spherical joints in the points of octahedral module 7 of the octahedral module 1. The points of octahedral module 7 contain the radial stops and the middles of the rods contain the grippers (on Figure were not shown) each of which have the temperature sensor 8. The octahedral module 1 has 12 d.o.f., which is a spatial farm as soon as all linear drives 2 are turned off. All points of octahedral module 7 have the spatial position sensors 9 which are integrated with the three-axial acceleration sensors 10. The control system (CS) 11 includes: the neural computer 12, the software 13 and the digital-analog converter (DAC) 14. The inputs of CS 11 are connected to outputs of the analog-digital converter (ADC) 15 of sensors 3 and 4, ADC 16 of sensors 5, ADC 17 of sensors 9 and 10, ADC 18 of sensors 6, and ADC 19 of sensors 8. Outputs of CS 11 are connected to inputs of the software 13 and DAC 14. The outputs DAC 14 are connected to the power amplifier 20 which is connected to each of the linear drives 2.

The octahedral module 1 may be used as a base element not only at the monomodule DR, but also at the

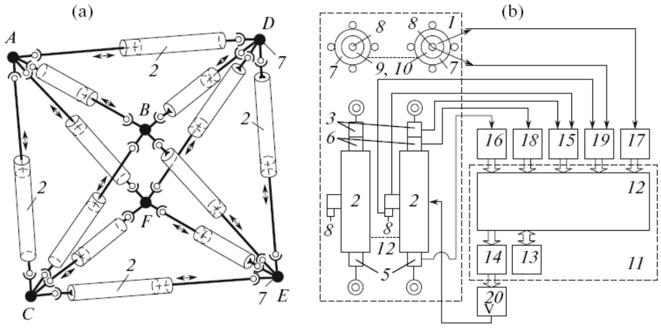

Fig. 2. Octahedral module of adaptive mobile parallel spatial robot (a) and its structure (b).

multimodule ones. The radial stops and the grippers (on Fig. 1 were not shown) provide the transmission of the efforts from linear drives toward the internal and external contact surfaces. The force sensors 3, 4 and temperature sensors 8 provide the operative control of these efforts and temperature in the contact places. The spatial position sensors 9 with three-axial acceleration sensors 10 provide the operative control of the spatial position of points of octahedral module 7 and of vibration along each of axes of rods with linear drives 2. The relative displacement sensors 5 and the relative velocity sensors 6 of the linear drives 2 register their relative movements and velocities. Before using it we will have to place the octahedral module 1 in the inside or the outside of the closed surface and then carry out the necessary movements depending on requirement. The linear drives 2 and the CS 11 fulfill herewith the coordinated changes of the rib lengths of the octahedral module. As a result the points of octahedral module 7 have got spatial movement concerning a base system of coordinates. A geometrical invariability of the octahedral module 1 allows to define the spatial coordinates of all points of octahedral module 7 as a result of the measurement of the lengths of all rods and to control their spatial movements like as in Stewart's platform [11]. The sensors of the spatial position 9 allow herewith elevating a precision of these measurements. The neural computer 12 and the software 13 provide the control of real time. The conditions and the algorithms for movements of DR in straight pipes of constant and variable cross-sections (Fig. 2) are represented below.

III. The Algorithms for the Movements of Dodekapod Robot in the Pipes of Constant and Variable Cross-Sections

A. Basic parameters of Dodekapod

The dodekapod (Fig. 3, a) contains 6 spherical joints (vertices *A, B, C, D, E, F*) and 12 rods (ribs *AB, BC, AC, DE, EF, DF, AD, AE, BD, BF, CE, CF*) with linear drives.

The vertices *A, B, C* and *D, E, F* form two parallel triangular faces (*ABC* and *DEF*). The vertices *A, B, C* and *D, E, F* are dodekapod's stops for a moving in the pipe. When one of the faces in the pipe is fixed, the other face moves by simultaneous changes in the lengths of rods *AD*, *AE*, *BD*, *BF*, *CE*, *CF* (Fig. 3, b). It is assumed that during the motion dodekapod no slippage between stops and the pipe.

Basic notations (Fig. 3, a, c):

l_0, l_m - the minimum and maximum lengths of the rods of dodekapod;

δ - the diameter of the spherical joints of dodekapod;

l_S – the rod lengths of faces *ABC* and *DEF* at the time of contact their vertices with the inner surface of a pipe;

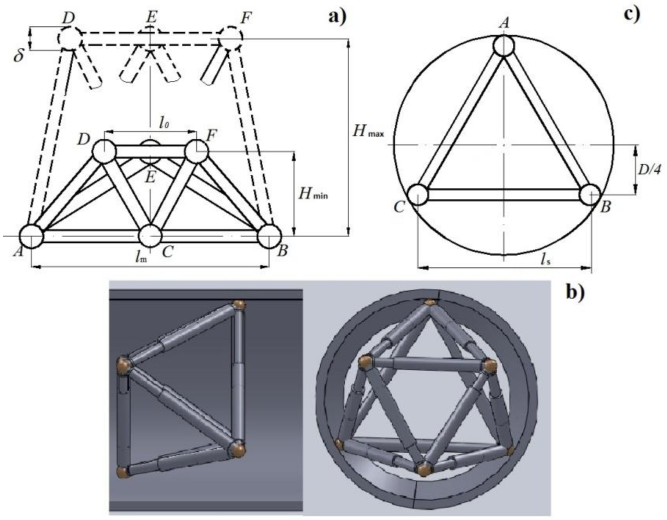

Fig. 3. Structure and basic notations of dodekapod in pipe constant cross-sections.

H_{min} - the minimum distance between the faces *ABC* and *DEF* (the length of the side rods reaches the minimum length);

H_{max} - maximum distance between the faces *ABC* and *DEF* (the length of the side rods reaches the maximum length);

h_s - step of the movement of dodekapod, $l_0<l_s<l_m$.

B. The Algorithm for the Movement of Dodekapod in Pipe of Constant Cross-Section

There are a cylindrical pipe with an internal diameter *D* and length *L*. A fixing of the dodekapod in the pipe in its motion provided by alternately fixing the faces (*ABC* or *DEF*) in the pipe by increasing the length of the rods. A fixed face should be an equilateral triangle and perpendicular to the axis of symmetry of the pipe (Fig. 3, c). A condition moving of the dodekapod in the pipe: the value l_s is in the range of possible lengths of the rods ($l_0<l_s<l_m$); $l_s=3^{0,5}D/2$ (from Fig. 3, c). As a result we obtain the condition:

$$2l_0/\sqrt{3} \le D \le 2l_m/\sqrt{3} \qquad (1)$$

The algorithm for the movement of the dodekapod in pipe of constant cross-section (Fig. 4):

1) The initial lengths of rods and initial position of the spherical joints are assigned from conditions: $l_{AB}=l_{BC}=l_{CA}=l_{DE}=l_{EF}=l_{DF}=l_S=3^{0,5}D/2$; $l_{AF}=l_{BF}=l_{BD}=l_{CD}=l_{CE}=l_{AE}=l_m$.
2) The reduced length of rods *AB*, *BC*, *CA* from l_s to l_0.
3) The reduced length of rods *AD*, *AE*, *BD*. *BF*, *CE*, *CF* from l_m to l_0.
4) The increased length of rods *AB*, *BC*, *CA* from l_0 to l_s.
5) The reduced length of rods *DE*, *EF*, *DF* from l_s to l_0.
6) The increased length of rods *AD*, *AE*, *BD*. *BF*, *CE*, *CF* from l_0. to l_m.
7) The increased length of rods *DE*, *EF*, *DF* from l_0 to l_s.
8) A repeat of steps from second to seventh.

C. The Algorithm for the Movement of Dodekapod in Pipe of Variable Cross-Section

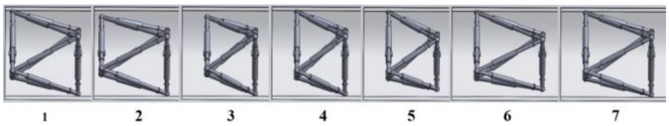

Fig. 4. The algorithm for the movement of the dodekapod in pipe of constant cross-section.

Regarded pipe has three sections (Fig. 5). Two extreme sections have constant cross section (diameters *D*, *d* and lengths L_1, L_2), and the middle section has a variable cross-section (length Δ). The complexity of the problem is the possibility of collision of dodekapod with the inner wall of pipe in transition. It is therefore necessary to determine the ratio between the radii of the platform base and the steps of movement.

The conditions for the movement in the transition: l_s is in the range of possible lengths of the rods ($2l_0/3^{0,5} \le D$; $d \le 2l_m/3^{0,5}$); $d_{I/OY} < d/2$.

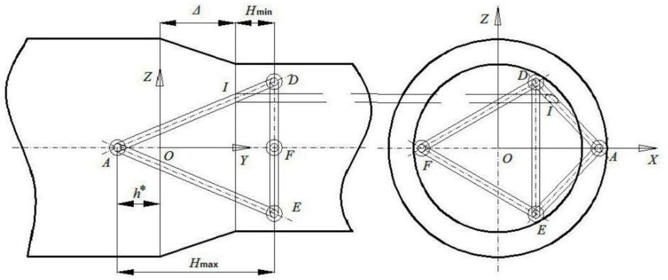

Fig. 5. The dodekapod in the middle section of pipe.

Coordinates of spherical joints *A*, *D*:

$$A\left(\frac{D}{2}-\frac{\delta}{2},-h^*,0\right)\ D\left(\frac{d-\delta}{2},\Delta+H_{min},\frac{\sqrt{3}}{4}d-\frac{\delta}{2}\right); \qquad (2)$$

$$\overrightarrow{AD}=\left(\frac{d}{4}-\frac{D}{2},\Delta+H_{min}+h^*,\frac{\sqrt{3}}{4}d-\frac{\delta}{2}\right);$$

$$\overrightarrow{AI}=\frac{h^*+\Delta}{h^*+\Delta+H_{min}}\overrightarrow{AD}=(\frac{h^*+\Delta}{h^*+\Delta+H_{min}}\left(\frac{d}{4}-\frac{D}{2}\right),$$

$$\Delta+h^*,\quad \frac{h^*+\Delta}{h^*+\Delta+H_{min}}\left(\frac{\sqrt{3}}{4}d-\frac{\delta}{2}\right));$$

$$\overrightarrow{OI}=\overrightarrow{OA}+\overrightarrow{AI}=\frac{h^*+\Delta}{h^*+\Delta+H_{min}}\left(\frac{d}{4}-\frac{D}{2}\right)+\frac{D-\delta}{2},$$

$$\Delta,\frac{h^*+\Delta}{h^*+\Delta+H_{min}}\left(\frac{\sqrt{3}}{4}d-\frac{\delta}{2}\right));$$

$$d_{I/OY}=\sqrt{(\frac{2\Delta-H_{min}}{\Delta}\left(\frac{d}{4}-\frac{D}{2}\right)+\frac{D-\delta}{2})^2+(\frac{2\Delta-H_{min}}{\Delta}\left(\frac{\sqrt{3}}{4}d-\frac{\delta}{2}\right))^2}<\frac{d}{2}; \qquad (3)$$

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If $h^{*} \geq 0$ $(H_{min} \leq \Delta)$, then $h^{*} = \Delta - H_{min}$ and from (3):

$$d_{I/OY} = \sqrt{\left(\frac{2\Delta - H_{min}}{\Delta}\left(\frac{d}{4} - \frac{D}{2}\right) + \frac{D-\delta}{2}\right)^2 + \left(\frac{2\Delta - H_{min}}{\Delta}\left(\frac{\sqrt{3}}{4}d - \frac{\delta}{2}\right)\right)^2} < \frac{d}{2}; \quad (4)$$

If $h^{*} < 0$ $(H_{min} > \Delta)$, then $h^{*} = H_{min} - \Delta$ and from (3):

$$d_{I/OY} = \sqrt{\left(\frac{d+2D-4\delta}{8}\right)^2 + \left(\frac{\sqrt{3}d-2\delta}{8}\right)^2} < \frac{d}{2}. \quad (5)$$

The algorithm for the movement of the dodekapod in pipe of variable cross-section (Fig. 6):

1) The movement of the dodekapod near the middle section: the number of steps $N=L_1/h_s$, $h_s=H_{max}-H_{min}$; the length of rods of the faces *ABC* and *DEF* $l_{AB}=l_{DE}=3^{0,5}(D-\delta)/2$ $l_{AF}=l_m$ - the length of the side rods.
2) The movement of the dodekapod forward with a step $h_{s1}=L_1-Nh_s$; $l_{AB}=l_{DE}=3^{0,5}(D-\delta)/2$. The face *DEF* of the dodekapod is installed in leading edge of middle section of pipe (Fig. 6, a).
3) If the conditions (2)-(5) are satisfied, then the dodekapod moves through the middle section of the pipe with step $h_{s2}=\Delta+H_{min}$; $l_{AB}=l_{DE}=3^{0,5}(d-\delta)/2$ (Fig. 6, b, c, d).
4) The dodekapod moves in through the extreme section of the pipe with step $h_s=H_{max}-H_{min}$; $l_{AB}=l_{DE}=3^{0,5}(d-\delta)/2$ (Fig. 6, e).

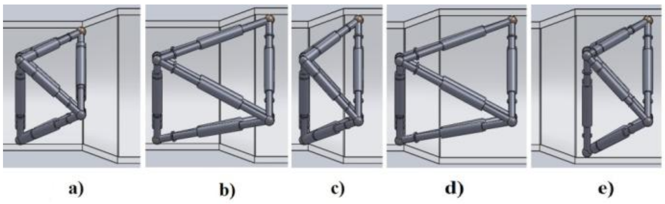

Fig. 6. The algorithm for the movement of the dodekapod in pipe of variable cross-section.

IV. Other Capabilities of Dodekapod Robot

The novel concept of DR may be used also in many other fields. The examples of applications DR and the new functional capabilities of DR are established, e.g.:

1) Possibility of control over of physical-mechanical properties, geometrical shape of contact surface and displacement trajectory (Fig. 7).
2) Travel of object in pipe with possibility of vibroprotection and positioning (Fig. 8).
3) Travel of long objects in pipe (Fig. 9).
4) Possibility of hole drilling in the end of pipe wall (Fig. 10).
5) Possibility of battering in pipe of wall end (Fig. 11).
6) Dodekapod robots can connect together, forming some novel mobile self-reconfigurable structures (swarm systems) for various applications [10].

Monitoring of the geometric shape of the internal and external contact surfaces (Fig. 7). In the motion of the octahedral module *ABCDEF* (module 1, Fig. 2) of the adaptive mobile parallel spatial robot (shown in Fig. 7), each longitudinal displacement of the rear face Δ*ABC* and frontal face Δ*DEF* is preceded by alternating discrete rotations in both directions, with specified increment, relative to the direction of motion. For each discrete position, mechanical contact is established between the radial limiters at points 7 (Fig. 2) of those faces and the internal contact surface or between the radial limiters at the midpoints of the rods in the frontal and rear faces and the external constant surface. Their coordinates are determined in the basic coordinate system. These values permit judgments regarding the geometric form of the internal or external contact surfaces. The specified contact forces with the internal surface are determined from the readings of sensors 3; and the specified contact forces with the external surface are determined from the readings of sensors 4. The position of points 7 of the frontal and rear faces (Δ*ABC*, Δ*DEF*) are determined from the readings of the relative displacement sensors 5 of linear drives 2 for the rods of the lateral faces and position sensors 9 at points 7.

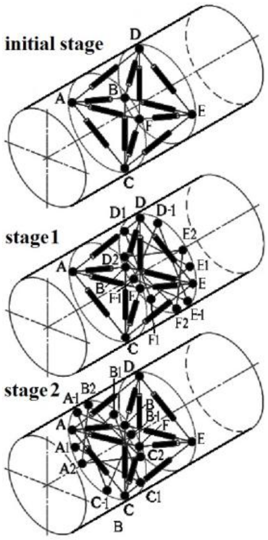

Fig. 7. Possibility of control over of physico-mechanical properties, geometrical shape of contact surface and displacement trajectory.

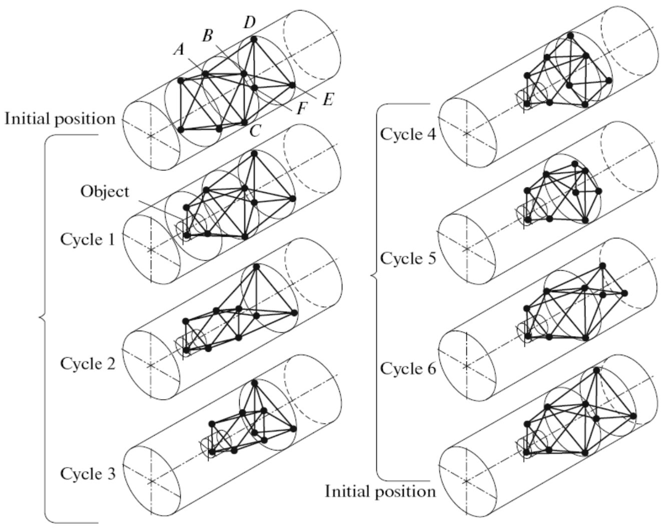

Fig. 8. Cyclic operation of double octahedral module within a closed surface, with simultaneous positioning and vibrational protection of the object.

Monitoring of the physicomechanical properties of the contact surface by means of octahedral module *ABCDEF* (Fig. 8). In this mode, the radial limiters at points 7 (Fig. 2) of the faces come into contact with an internal surface, with a force specified by the readings from sensors 3. Then, their position is determined in the basic coordinate system on the

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basis of the readings from sensors 5 and 9. Next, the force on the radial limiters is increased to another specified value, and their position is determined in the basic coordinate system. This procedure is then repeated with the initial force. The difference between the coordinates of the radial limiters at points 7 permits judgments regarding the elastoplastic properties of the contact surface. At specified contact force between the radial limiters and the internal surface, the temperature is measured by means of sensors 8, and the electrical resistance between them is recorded. These readings permit judgments regarding the physical properties of the contact surface. Analogously, the temperature and electrical resistance may be recorded for an external surface. Vibrational diagnostics may also be organized for an internal contact surface, with identification of the presence of mechanical defects (such as cracks in pipes). In that case, periodic acceleration of linear drives 2 for the rods of the rear or frontal faces permits impact and vibrational influence on the radial limiters at points 7 of these faces at the contact surface. Vibrational diagnostics of the object may then be based on the readings of acceleration sensors 10.

In Fig. 9, we show examples of the motion of round or oval objects by octahedral module *ABCDEF* without (a) and with (b) a guide system. In this mode, octahedral module 1 (Fig. 2) moves within a closed surface and fixes the frontal face (Δ*DEF*, say). The end of the extended object (such as pipe, rod, or cable) is placed in the rear face Δ*ABC* (Fig. 9, initial position), and linear drives 2 are turned on in reverse. The length of the rods in the rear face is reduced until the object is captured by force specified by the readings of the force sensors 4 at the radial limiters at the midpoints of the rods in rear face Δ*ABC*. Then, at a command from control system 11, linear drives 2 are switched off, and the coordinates of points 7 are determined, in the basic coordinate system. After the object is fixed (Fig. 9, cycle 1), coordinated decrease in length of the rods in the lateral faces (Δ*ABD*, Δ*BDE*, Δ*BCE*, Δ*CEF*, Δ*ACF*, Δ*ADF*) shifts the rear face Δ*ABC* together with the object into the closed surface by some fixed distance, which is recorded with respect to the basic coordinate system (Fig. 9, cycle 2). Then the length of the rods in the rear face is increased until the radial limiters at the midpoints, together with the object, are completely released (Fig. 9, cycle 3) and the object is unable to move in the opposite direction (Fig. 9a, cycle 3). Then the length of the rods in the lateral faces is increased to its initial value (Fig. 9, initial position). Thereafter, the motion of the object is repeated as many times as is necessary, and the total length traversed at the end of the process is determined. Note that the motion of the object may be conducted without (Fig. 9a) or with (Fig. 9b) a guide system. Without a guide system, additional effort is required to prevent inverse motion of the object in cycle 3. With a guide system (Fig. 9b), that is unnecessary. If required, motion in a combination of modes 1 and 4 is possible. In that case, the object will move with simultaneous independent motion of octahedral module 1 within the closed system. In contrast to mode 4 (Fig. 9b), the length of the rods in the rear face Δ*ABC* increases not until the object is released but until fixing of points 7 of the rear face Δ*ABC* at the closed internal surface with specified force, in accordance with the readings of sensors 3. Then linear drives 2 are switched off, and the coordinates of points 7 are calculated from the readings of sensors 5 and 9. Next, at a command from control system 11, linear drives 2 of rods in the frontal face Δ*DEF* are switched on in reverse, and their length is reduced until capture of the object by the radial limiters at the midpoints of these rods, with a force specified by the readings from sensors 4. Then linear drives 2 are switched off, and the coordinates of points 7 are calculated from the readings of sensors 5 and 9. At that point, the length of the rods in the lateral faces is increased, and the object is moved within the closed surface. Then the length of the rods in the frontal face Δ*DEF* is increased until the points 7 of the rear face Δ*ABC* are fixed at the reduced length of the closed internal surface with specified force, in accordance with the readings of sensors 3. Then linear drives 2 are switched off, and the coordinates of points 7 are calculated from the readings of sensors 5 and 9. Thus, in this mode, not only the extended object but the octahedral

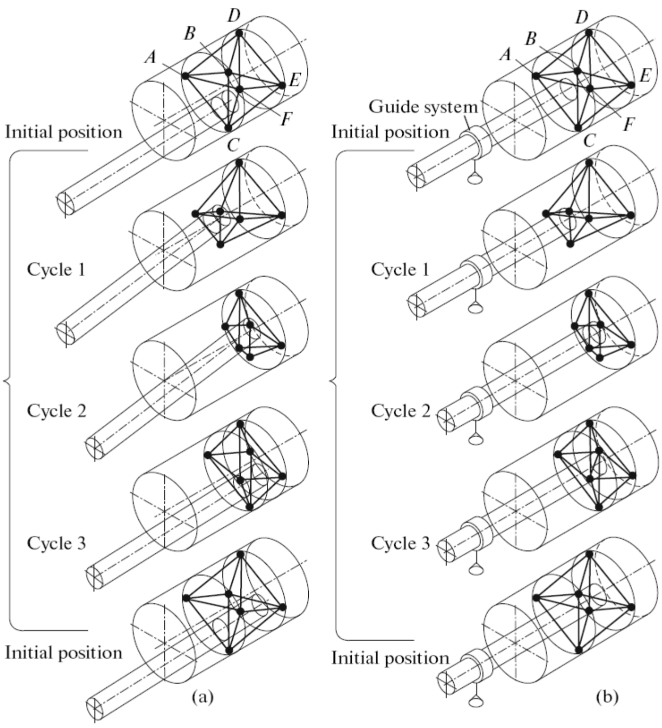

Fig. 9. Motion of extended rounded objects within a closed surface by the octahedral module *ABCDEF*.

module 1 will be moved. As a result, the distance traveled by the object relative to the closed internal surface will be increased, with a fixed number of cycles (operations).

Rotation and supply of a machining tool (a drill or bit, for instance) by means of octahedral module ABCDEF (Fig. 10). In this case, the tailpiece of the tool takes the form of a crankshaft with a rotating bush at the end that is incapable of axial motion. (The rotating bush is not shown in Fig. 10.) The rotating bush is clamped by the radial limiters at points of the rods in the frontal face. Each limiter may be rigidly connected with one section of a three section bush intended for capture of the rotating tailpiece bush. The required force is determined on the basis of the sensors 4 in the frontal face. The radial limiters at the rear face are fixed at the internal contact surface, as in previous modes. Then,

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coordinated change in the length of the rods at the lateral faces brings the cutting section of the tool to the machining point, fixes the axis of tool rotation, and ensures the required cutting force, determined from the readings of sensors 3 at the rods of the lateral faces. Next, coordinated change in the length of the rods at the lateral faces moves the axis of rotation of the clamped bush over a circle perpendicular to the axis of rotation; the circle radius is equal to the crankshaft radius. In tool rotation, coordinated increase in length of the rods at the lateral faces ensures its longitudinal supply with specified force; the generation of impact and vibration effects is possible in combination with tool rotation. In that case, the spatial position, cutting force, and impact and vibration effects are monitored by means of sensors 9 and 10 at the radial limiters of the frontal face and

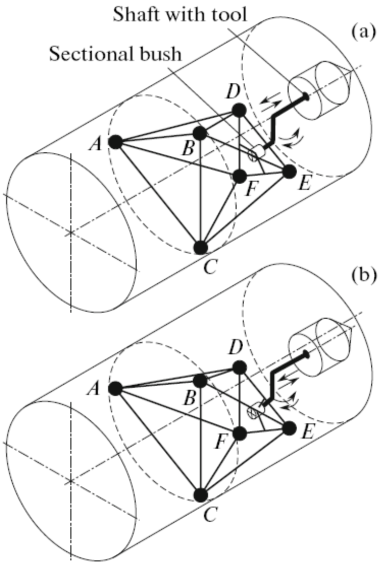

Fig. 10. Rotation of a machining tool by means of octahedral module *ABCDEF*: (a) rotation coaxial with the module's symmetry axis; (b) eccentric rotation.

sensors 3, 5, and 6 at the rods in the lateral faces. The axis of tool rotation may be coaxial with the symmetry axis of octahedral module 1 (Fig. 10a) or eccentric (Fig. 10b).

Organization of impact and vibration effects of a slotting tool on the end surface of a tubular profile by means of octahedral module 1 (Fig. 2, 11). In this mode, the slotting tools are established at each point of the frontal face. (The clamping of the slotting tool's tailpiece is not shown in Fig. 11.) The radial limiters of the rear face are fixed at the internal contact surface as in previous modes. Then, coordinated change in the length of the rods at the lateral faces brings the working sections of the slotting tools into contact with the end surface at the machining site, and machining begins at specified frequency, amplitude, and force. During machining, further change in the length of the rods at the lateral faces permits one time (Fig. 11b), double, or triple (Fig. 11a) action of the slotting tools. In one time or double action, where necessary, the sequence of action may be modified. In each case, the spatial position, cutting force, and magnitude of the tools' impact and vibration effects are monitored by means of sensors 9 and 10 at the radial limiters of the frontal face and by sensors 3, 5, and 6 at the rods of the lateral faces. Real time operation is possible

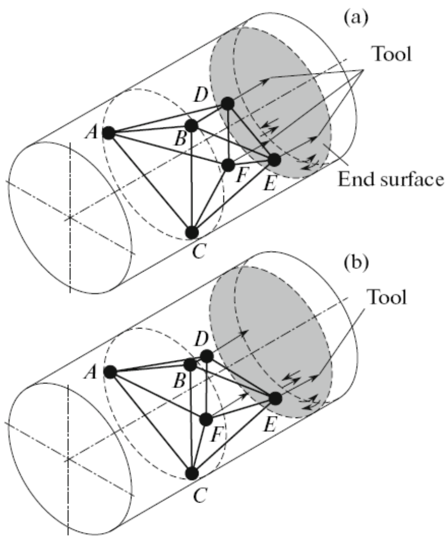

Fig. 11. Organization of simultaneous impact and vibrational effects on the end wall by slotting tools (a) and one time impact (b).

thanks to the use of a control system 11 based on neural computer 12 and corresponding software 13.

The proposed adaptive mobile parallel spatial robot may be used at the macroscopic level for use on land, underground, underwater, in medicine, and in the aerospace industry. It may also be used at the microscopic level. This research provides the basis for the development of up to date parallel spatial robots and for the expansion of their functional capabilities.

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