

РАЗРАБОТКА РЕГУЛИРУЕМЫХ СФЕРИЧЕСКИХ АЭРОСТАТИЧЕСКИХ ШАРНИРОВ ДЛЯ ТОЧНЫХ ПРОСТРАНСТВЕННЫХ МЕХАНИЗМОВ ГЕКСАПОДОВ

DEVELOPMENT OF THE MANAGED SPHERICAL AEROSTATICS HINGES FOR THE EXACT SPATIAL MECHANISMS OF GEXAPOD

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Abstract

The ground of choice of basic structural parameters of spherical aerostatics hinges is given for the exact spatial mechanisms of gexapod. The construction of the developed spherical hinge is resulted with the stream system of adjusting of position of sphere. The calculation of descriptions of separate aerostatics supporting knot and spherical hinge is executed on the whole

Keywords: Mechanisms-gexapod, spherical hinge, angular position of sphere, regulation, stream system, power descriptions of support, descriptions of hinge.

INTRODUCTION

Research actuality

A technological equipment on the basis of spatial mechanisms of gexapod is widely utilized in the different areas of technique. Metal-cutting machine-tools, measurings machines, industrial robots and manipulators of such type, are used.

The basic scientific problem of development of equipment on the basis of spatial mechanisms of gexapod is an increase of exactness and inflexibility of equipment. Therefore development of the special facilities and methods of increase of exactness and inflexibility of such mechanisms is actuality.

Raising of problem is in a general view

The increase of exactness of spatial mechanisms of gexapod requires development of on principle new constructions of basic knots, realizing the methods of adaptive control on the basis of the use of the mehatronics systems. By a primary site, determining exactness of mechanisms there are spherical supports. The use as supports of noncontacted spherical hinges (hydrostatical or aerostatics) provides the high indexes of static and dynamic descriptions of mechanisms. Beskontaktnye spherical hinges have low moments of friction, high exactness and inflexibility. The specific feature of noncontacted

spherical hinges is their ability demphing the high-frequency vibrations of mechanisms and reduce a sound-level.

Connection of problem with important scientific and practical tasks

Development of the managed spherical aerostatics hinges enables to create high-fidelity mehatronics control the system spatial mechanisms. An increase of exactness of mechanisms of gexapod is basis of development of progressive constructions of machine-tools of parallel kinematics, measurings machines et al.

Analysis of the last researches and publications

The results of research of spherical aerostatics hinges are resulted in literary sources [1]. Mainly they touch development of constructions of hinges [2]. The questions of calculation of descriptions of hinges of such type are lighted up in separate publications [3]. Information about the spherical managed aerostatics hinges it is not discovered in literary sources. Absent suggestion on the choice of parameters of such devices.

Decision of unsolved before parts of problem

To unsolved before parts of general issue development of methods of increase of exactness and inflexibility of spatial mechanisms of gexapod

behaves by the use of mechatronics control the system, which is based on adjusting of spatial position of all of spherical aerostatics hinges of mechanisms of hexapod. Regulation consists in providing of micromotion of every spherical hinge within the limits of diametral gap. For realization of the regulation moving of hinges development of flexible control the system every hinge is needed.

Determination of purpose and tasks of researches

The purpose of the real research was a choice of basic parameters of the managed spherical aerostatics hinges for the exact spatial mechanisms of gexapod and determination their basic descriptions.

For achievement of the put purpose formulated and decided the followings tasks:

1. The scheme and structural decision of spherical aerostatics hinge and stream system of adjusting of his spatial position is developed.
2. Complex descriptions of exactness of spherical hinge are found on the whole taking into account casual positions of sphere and adjusting of its spatial position.

Exposition of results of researches

Determination of credible positions of spherical hinge and preferable directions of adjusting of position of sphere.

In the process of work of mechanism his working organ (platform) moves on a difficult trajectory changing the transversal-angular position (fig.1).

Developed mechanisms of gexapod from spherical hinges are have high exactness of position of hinges. It is arrived at adjusting of position of supports. The mehatronics systems of adjusting of position of spheres are utilized. Adjusting of position is carried out in some range of $E_m (\pm 50 \text{ mkm})$.

Mechatronics systems has a row of regulative subsystems of the hinges realized in the developed constructions.

The got areas of credible transversal-angular positions of hinges served basis for the choice of directions of the most effective regulation micromotion of hinges.

Mekhanizm-geksapod (fig.1) has precision drives of change of length of barbells. Therefore regulation of position of sphere of hinge in the direction of ax of barbells is not effective. Effective directions of adjusting of position of every hinge are moving $\vec{E}_i$ inplane, perpendicular nominal position of ax of barbell. A possible range of adjusting of position of sphere is an ellipsoid with the most radius of E_m , the plane of diametral section of which is perpendicular the most credible transversal-angular position of barbell. For an overhead hinge position of hinge is most credible answers corners $\gamma_0 = 15,5^\circ$ at $\eta_0=0$ [4]. For a lower hinge does the most credible angular position of hinge in relation to the plane of platform make $\beta_0 = 74^\circ$ at $\alpha_0=0$.

Scheme and structural decision of the developed managed spherical aerostatics hinge

In the process of the executed works the technical decision of aerostatics spherical hinge is realized [5]. A hinge is intended for perception of efforts to 1kH and adjustings of position of sphere in space within the limits of maximal diametral gap which makes 100 mkmm.

A hinge has a corps 1 (fig. 2), placed on the platform of spatial mechanism.

With a corps a lid is connected 2, which has drives 3,4 for its relative spatial adjusting moving in relation to a corps. A corps and lid have a cavity as areas of exact spherical surfaces which engulf a mobile sphere 5. A mobile sphere is connected with a barbell 6 spatial mechanism.

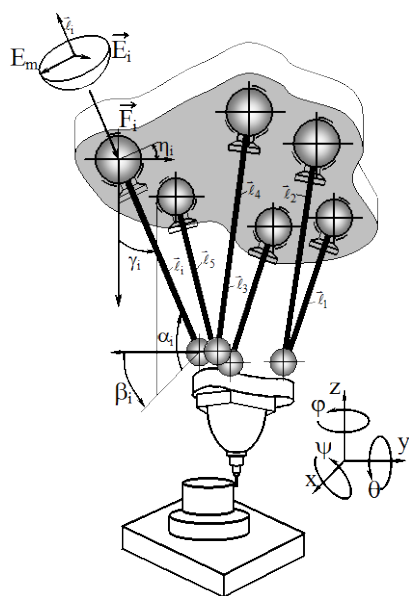


Fig. 1. Chart of mechanisms of gexapod with changeable length of barbells and managed spherical aerostatics hinges

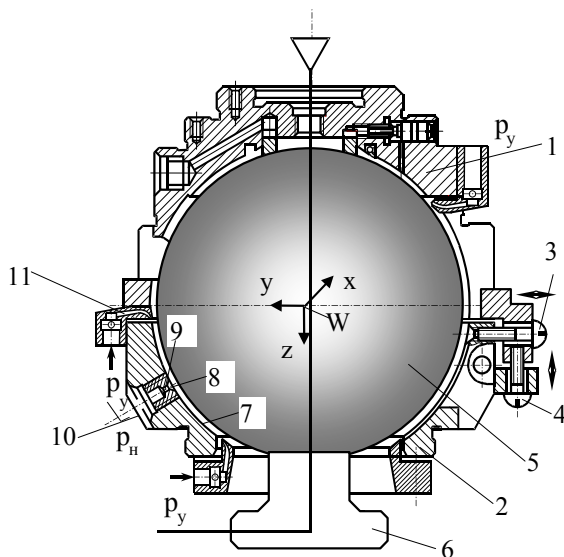


Fig. 2. Structural realization of the developed managed spherical aerostatics hinge

A mobile sphere is set in a corps and lid on aerostatics supports. Supports 7 located evenly on a spherical surface. Supports have pockets 8, in which through throttles 9 a working environment is given from a highway 10.

Supports have on the periphery the system of nozzle devices 11, which serve for the hydrodynamic locking of crack on the output of aerostatics support.

Regulation of position of sphere is carried out in number of different ways: by the change of mutual position of corps and lid by the special drives of micromotion; by deformation of details of supporting knot (corps and lids) by the special devices; heating of separate areas of details of knot with the purpose of change their geometry by termostrain by the change of position of separate workings areas of knot moving of the special insertions; by introduction or disconnecting of additional aerostatics supports, by the change of size of streams of working environment on separate areas; by the change of thermodynamics parameters (in particular temperatures) of separate streams of working environment; hydrodynamic locking of output cracks of aerostatics supports. The last shift is most effective.

Most flexible and effective is regulation of position of sphere by the change of parameters of stream on an exit from the cracks of aerostatics supports [6]. It is arrived at the hydrodynamic locking of crack by the streams of working environment. Streams are formed in little size nozzle devices, made the method of

laser stereolithography. Nozzle devices are set on periphery of aerostatics support (fig. 3).

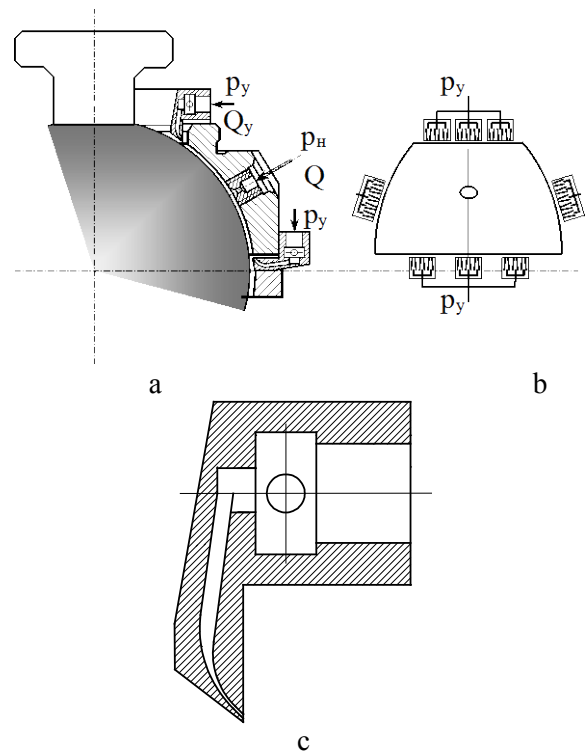


Fig. 3. Chart of placing of nozzle devices for peripheries of aerostatics support (a, b) and nozzle device for forming of stream of working environment (c)

At the serve of working environment under constraint P_{y1} , P_{y2} in nozzle devices the area of enhanceable pressure is formed in the section of crack (points A, B) (fig. 4).

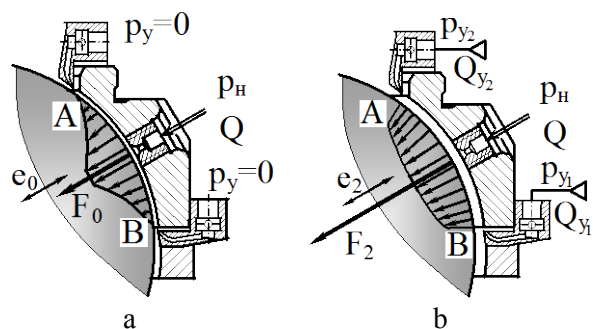


Fig. 4. Change of epures of pressure in the section of supporting knot at the hydrodynamic locking of output of crack the streams of working environment: a - epure of pressure in default of managing streams; b - epure of pressure at the hydrodynamic locking of cracks

Determination of complex descriptions of spherical hinge on the whole

General bearing strength (reaction) of the managed spherical hinge is the result of

general action of all of separate supporting knots (fig. 5).

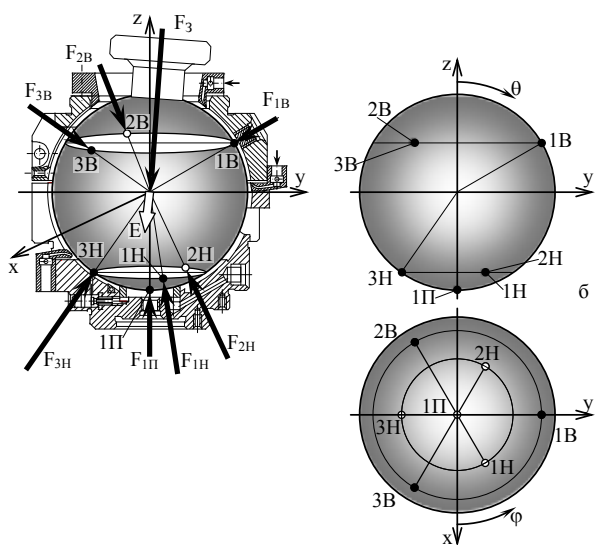


Fig. 5. A layout of separate supporting knots chart is in a spherical aerostatics hinge

In all a spherical hinge has six managed and one *нерегулируемый* (1П) supporting knot. Three knots of 1B, 2B, 3B form the overhead bearing belt of spherical hinge, and three knots of 1H, 2H and 3H is a lower bearing belt [8].

For small displacements of sphere the change of gap in every point of sphere in radial direction depends only on one parameter (corner of θ_e) and determined dependence

$$\delta = \delta_0 - |\vec{E}| \cdot \cos \theta_e, \quad (1)$$

where δ_0 - initial gap; $\vec{E}$ - a vector of moving of sphere; θ_e - corner between the vector of moving of sphere and radius by the vector of point of surface of sphere a current gap is determined in which δ .

In projections on the ax of co-ordinates of x, y, z have the system of three equalizations of equilibrium, which link loading and moving of mobile sphere

$$\begin{aligned} F_{3x} + \sum_{i=1}^N F_{ix} &= 0 \\ F_{3z} + \sum_{i=1}^N F_{iz} &= 0 \end{aligned} \quad (2)$$

where F_{ix}, F_{iy}, F_{iz} are projections of efforts i supporting knot; $N=7$ is a general amount of supporting knots in a spherical hinge.

For the decision of the nonlinear system (2) the special method is offered. Effort in every supporting knot accordingly formulas (1) depends on a gap which in same queue is determined through the vector of moving in obedience to a formula (9). Accordingly effort in every supporting knot

$$\vec{F}_i = \vec{F}_i(\delta_i), \quad \delta_i = \delta_i(e_x, e_y, e_z), \quad (3)$$

where e_x, e_y, e_z are projections of vector of moving $\vec{E}$.

Putting in the system of equalizations the value of power descriptions of every supporting knot in obedience to a formula (3) for a gap will get calculation dependences for determination of vector of effort in a spherical hinge, which answers the set vector of moving of sphere $\vec{E}$.

Results of calculations of the module of vector of effort for the different values of direction of moving of sphere depending on the module of vector of moving are nonlinear (fig. 6).

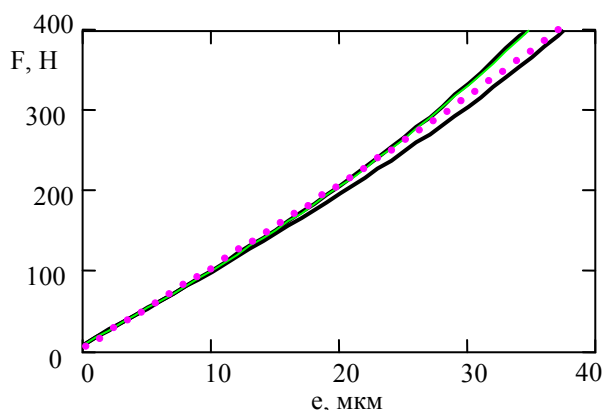


Fig. 6. Dependence of the module of supporting reaction (continuous curves) on the module of vector of moving of sphere, expected for different directions of vector of moving within the limits of corners $0..20^\pm$

Taking into account that dependences for different corners little differ from each other, the results of calculations are approximated a polinomial function[7] (dotted curve on fig.6). Approximate a function is set in a kind:

$$F_3 = \alpha_0 + ae + be^3.$$

In all of range of possible changes of direction of vector of moving of rejection of dependence as a polinomial from a calculation is insignificant and 5% does not exceed.

The calculation resulted higher determines loading in support as a function from the vector of moving of mobile sphere. For the decision of reverse task, that finding of vector of moving of mobile sphere on the vector of loading, the special method is developed. It is based on application of stochastic methods, thus on every the interconnection of parameters is set on the basis of methods of Monte Carlo.

Accordingly methods some area of change of angular coordinates of vector of moving is examined $\vec{E}$. An area of change of corners is twolink and engulfs two spherical belts

$$0 \leq \theta_e \leq \theta_{\max}, \quad \frac{\pi}{2} - \theta_{\max} \leq \theta_e \leq \frac{\pi}{2}, \quad 0 < \varphi_e \leq 2\pi$$

where $\theta_{\max}$ is a maximal corner of rejection of ax of mobile sphere ($\theta_{\max} \cong 0.3$).

Within bounds of the considered area of change of angular co-ordinates of vector of moving the stochastic array of points is set.

A stochastic array is formed as a casual vector the angular co-ordinates of which are up-diffused on an even law (coordinates φ_e) and normal law (co-ordinates of θ_e) for every spherical belt separately (fig.7).

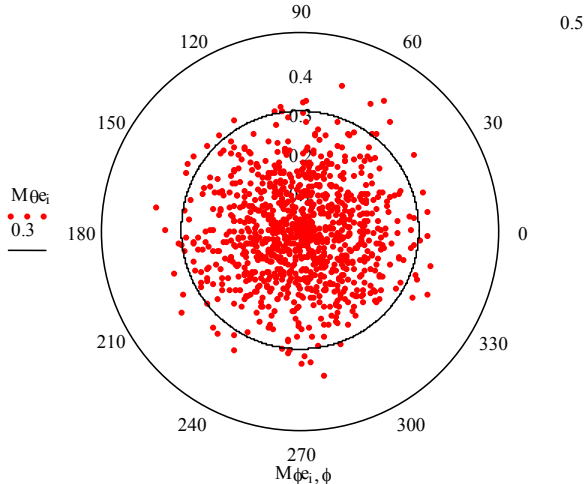


Fig. 7. Location of points which answer a casual array from directions of moving of sphere for one of spherical belts of change of corners θ

The stochastic array of points is processed with the purpose of his sorting. The got array of points is an unexpressly certain great number part of which (on condition of $\theta_e < 0$), eliminated

from consideration, and part $\theta_e > \theta_{\max}$ is unimportant. An array over of points is brought to the type of stochastic matrix.

Stochastic matrices, certain for every spherical belt, form the system of matrices, which determines the arguments of the system of vector-function which link the great numbers of vectors of moving and proper by him vectors of loadings in a spherical hinge.

Thus every I one after another $(\varphi_{ei}, \theta_{ei})$ put the set of co-ordinates of vector of moving $(\varphi_{ei}, \theta_{ei})$ in accordance of co-ordinate of vector of effort $(\varphi_{Ri}, \theta_{Ri})$. For this binary system of angular co-ordinates the spatial matrices of projections of moving and loadings are certain in spherical hinges. Both spatial matrices are the functions of stochastic matrix of angular co-ordinates of vector of moving $(\varphi_{ei}, \theta_{ei})$. The elements of the binary system answer the pair of points on-the-spot spheres through which the lines of action of stochastic vector of moving pass and proper this moving of vector of efforts (fig. 8).

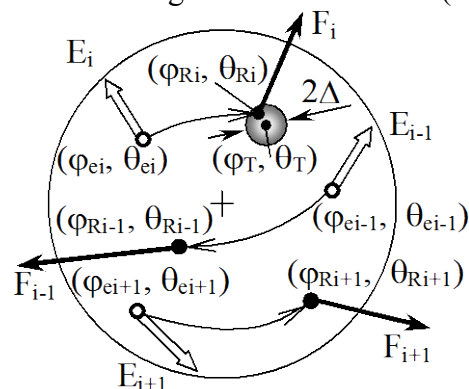


Fig. 8. Location of points on a sphere, which answer diaereses to the pair of angular co-ordinates of vector of moving and vector of effort

Finding of vector of moving on the set vector of loading consists in the choice of element of spatial matrix, which determines the projections of casual vector of loadings on the set co-ordinates of vector of effort which operates on spherical support.

A choice is carried out a linear search all the component of spatial matrix. For direction of action of effort which is set co-ordinates $\varphi T, \theta T$ (see of fig. 8), there is the nearest direction from the matrix of realization of co-ordinates of vector of loadings. The condition of presence of the nearest direction is set in a kind

$$(\varphi_{Ri} - \varphi T)^2 + (\theta_{Ri} - \theta T)^2 \leq \Delta^2,$$

where Δ is some small angular size ($\Delta=0,02..0,05$).

The nearest direction is by surplus of stochastic matrices of coordinates. Logical procedure of next kind is used for this purpose

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IT ← 0
ITR := for i ∈ 1..10000
      ITR ← i if  $(MR\phi_{e_i} - \phi T)^2 + 1 \cdot (MR\Theta_{e_i} - \Theta T)^2 \leq 0.001$ 

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As a result of calculations on this chart the row of points which are the nearest to the set values ϕT and is determined ϕT and ΘT . The last point ($i=ITR$) is accepted as most near to the set co-ordinates.

The got index of point of ITR is determined by the column of spatial matrix of loadings and proper him column of spatial matrix which determines the projections of vector of moving (fig.9).

F, H		E, mkm
-1,205	→	0,22
-1,848		0,335
-17,822		0,916

Fig. 9. Example of calculations of column of spatial matrix of vector of moving of sphere of E on a vector to the column of spatial matrix of vector of loadings of F in a spherical hinge

The developed procedure is realized in an algorithm and program for COMPUTER. It allows to find power descriptions of the managed spherical support in all of possible range of angular positions of mobile sphere.

CONCLUSIONS

1. The developed aerostatics supporting knot is intended for perception of loading to 1 kN and adjustings of position of sphere within the limits of diametral gap which makes 100 mkm. The change of position of sphere is carried out the special stream system of adjusting of reactions of separate aerostatics supports of spherical hinge.

2. Complex description of inflexibility of spherical hinge practically does not depend on angular position of sphere in the range of corners $\pm 20^\circ$ and described polinomial dependence, near to linear in the range of loadings $\pm 350N$.

3. For description of dependence of moving of sphere from an actual load it is expedient to utilize a discrete model as a set of stochastic spatial matrices which establish a synonymous connection of vectors of loading and vectors of moving of sphere mutually.

As it is recommended to take into account direction of subsequent researches presence of casual changes of parameters of spherical hinge and their influence on exactness and inflexibility of hinge.

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