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FEATURES OF THE DYNAMIC PROCESS OF THE FORMATION OF SURFACE PARALLEL ON MACHINE KINEMATICS

Key words

Spatial mechanisms, actuators, systems, trajectories, especially oscillatory processes extremes, pulse effects, addition of pulses, the spectrum load.

Summary

This study considers the technological complex process that comprises a drive system space. The complex consists of parallel kinematics machines and a table of 6-coordinate drives. It is shown that in the process of forming surfaces are special trajectories of the relative position of the working body of the machine and table. In certain areas there are oscillating stochastic processes of infinitely small amplitude. The methods are a synthesis and theoretically mathematical description of oscillating processes. Because of the random dynamic loads, the drive system operating in specific areas of the trajectories are defined.

Introduction

Technological equipment, which includes parallel kinematics machines, has rich functionality. Application of mechatronic control systems to this equipment allows for computer-integrated methods of forming high efficiency. Therefore, the study of formation is relevant. The problem in general is to develop multi-mechatronic technology systems with high levels of accuracy. The problem is related to important scientific and practical tasks of highly technological equipment, including equipment for metalworking. Recent studies and publications [1, 2] shows the results of the development and use of technological equipment based on mechatronic drive systems with parallel kinematic constraints. The study presents the characteristics of hardness [3], and features programming equipment [4]. Selected publications devoted to the study of dynamic precision machinery [5] are also addressed.

Results of research activity, due to the peculiarities of trajectories in the shaping of surfaces on parallel kinematic machines in the literature were found.

Through the investigation of unsolved aspects of the study of special problems, related site trajectories in the shaping of surfaces on parallel kinematics machines, including areas where there are abrupt changes in direction (kinks) trajectories are investigated.

The aim of research outlined in this paper is to determine the stochastic dynamic loads that occur at specific sites trajectories. The tasks of the research is a detailed analysis of dynamic processes in specific areas of trajectories and the generalization of dynamic processes on a specially developed technique and to establish statistical regularities of stochastic dynamic loads acting on the executive body of the special occasion plot trajectories in the shaping of surfaces on parallel kinematics machines.

1. The main material research

Research is carried out on a specially designed technology sector. The technologically complex machine is designed for multi-machining within a workspace of 500x500x500 mm. The number of managed coordinates is 12. Six of them are provided with actuators to move tooling. The other six managed coordinates that provide the necessary spatial positioning of the table. The complex system allows the necessary precision machining – 0.05–0.1 mm when using open-loop control circuits and 0.005–0.001 mm using feedback measuring the spatial position of the executive body. The Technologically complex system provides high-performance processing of metal, wood, plastic, stone, various building materials, paper, cardboard, and other materials.

The main component of the complex system is the machine-hexapod [1] of the mechatronic control system (Fig. 1).

Machine-driven hexapod includes the Executive Body 1, which has six degrees of freedom and provides spatial movements. The work piece is mounted on a movable Table 2, which can change its position in space by means of manipulation.

The system is based on the schema manipulation mechanism-hexapod and has six discrete actuators based on 3 actuators. The system is equipped with additional drives micromovements. System manipulation provides installation details in the desired position. Regarding this provision is the executive body of the movement, which establishes a rotating spindle.

This technologically complex system is the most efficient in the processing of hard-core surfaces. Relatively simple linear processing is implemented for surfaces such as hyperbolic parabolic and others. Specificity of the kinematic chain produces processing of various surfaces to 4th order and higher.

Implementation of computer-integrated methods of forming the technology sector has significant differences from traditional forming process equipment. This is due to the peculiarities of spatial kinematics of occasions, the presence of singularities (special) provisions specific algorithmic tools and software control systems.

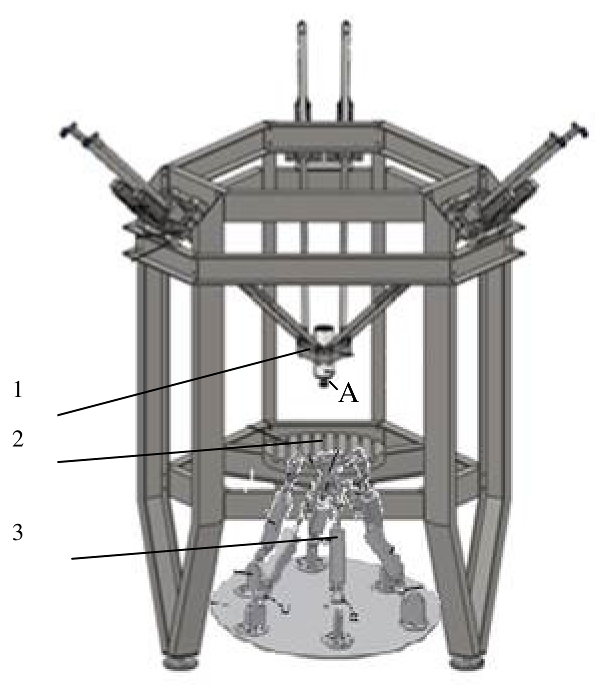

Fig. 1. Technological complex based on the machine-hexapod manipulating the system

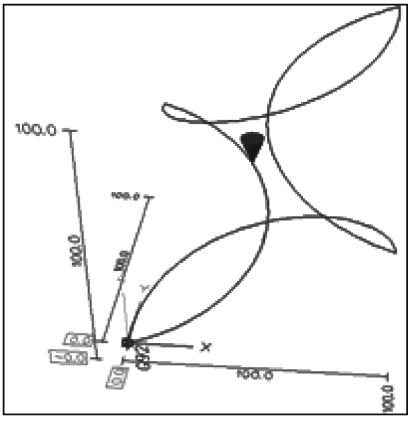

Fig. 2. A typical trajectory of the executive board space system drive that has features as fractures (cone in the figure shows the transverse angular position relative to the executive body of the table)

One feature of computer-integrated methods of forming the technology sector is the presence of complex trajectories of moving the tool relative to the table. Trajectories have features as fractures (Fig. 2).

In sharp changes of direction (turn trajectory) in a dynamic system processing facility having complex dynamic loads. During the study, a detailed analysis was made of processes at the point of fracture trajectories.

Movement of the executive board as a rigid body is described by the translational motion characteristic point (pole) and turn around this point [7]. A characteristic point of the executive body, taken as pole, determines the motion of the executive body in space. The point moves to the corresponding trajectory, which can be complex. Moving the pole is determined by the vectors in natural trihedral (natural 3-hedron) trajectories.

Technologically complex kinematic chains include a drive and transfer with high gain and combine with programming features that lead to specific sections of trajectories of the tool relative to the current position of the table. In specific areas is a sharp change in cross-tool angular position (Point A) (Fig. 3).

To describe the kinematic trajectory parameters, we used natural trihedral (natural 3-hedron) trajectories. In specific locations, the natural trihedrals suddenly change their position. 3-hedron $\vec{\tau}_1 \ \vec{n}_1 \ \vec{b}_1$ changes to 3-hedron $\vec{\tau}_2 \ \vec{n}_2 \ \vec{b}_2$.

The experimental study included the movement of the executive table on specific areas of the trajectory. For measuring the movement of the executive body, the sudden change in direction of motion used highly sensitive noncontact laser triangulation measuring distances Series RF603-10/2. The meter has a working range of 2 mm with precision measuring 0.2 microns. This system used two meters installed in two mutually perpendicular directions at a distance of 11 mm from the reference cylindrical surface of the executive body (Fig. 4).

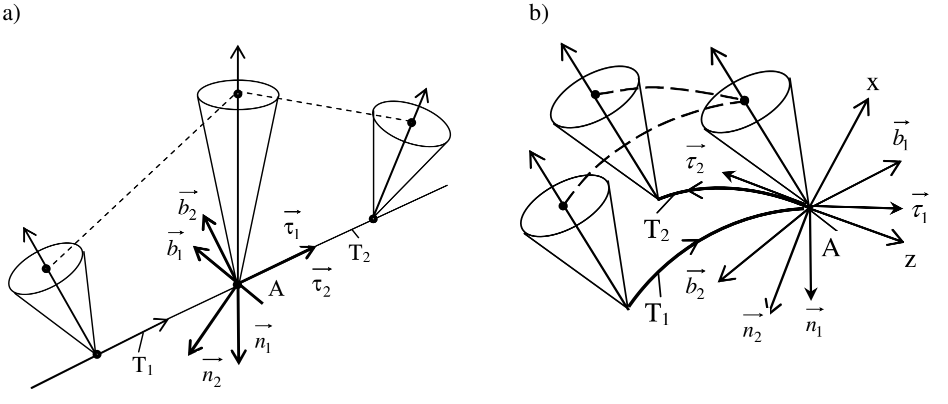

Fig. 3. Paths of specific areas accompanied by a sharp turning tool (a) and a sharp change in direction of the tool (b)

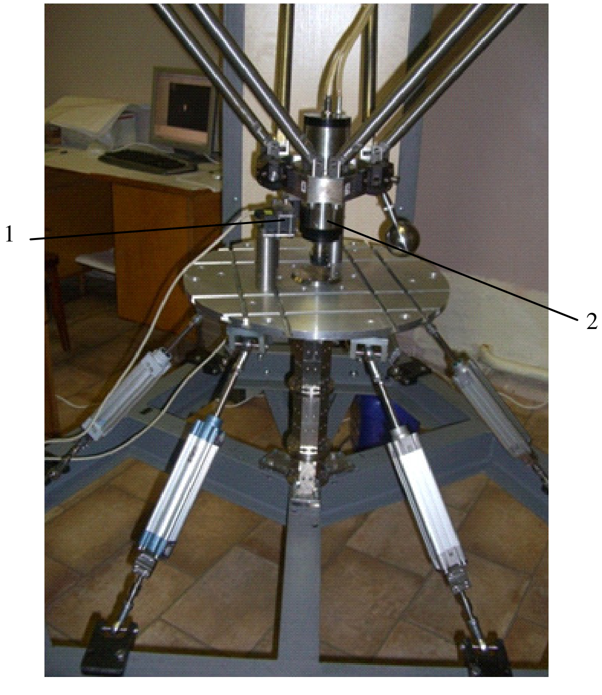

Fig. 4. Set 1 laser meters on a stationary table when measuring the movement of the executive body 2 in a special section corresponding to the direction of motion of 90° or 180°

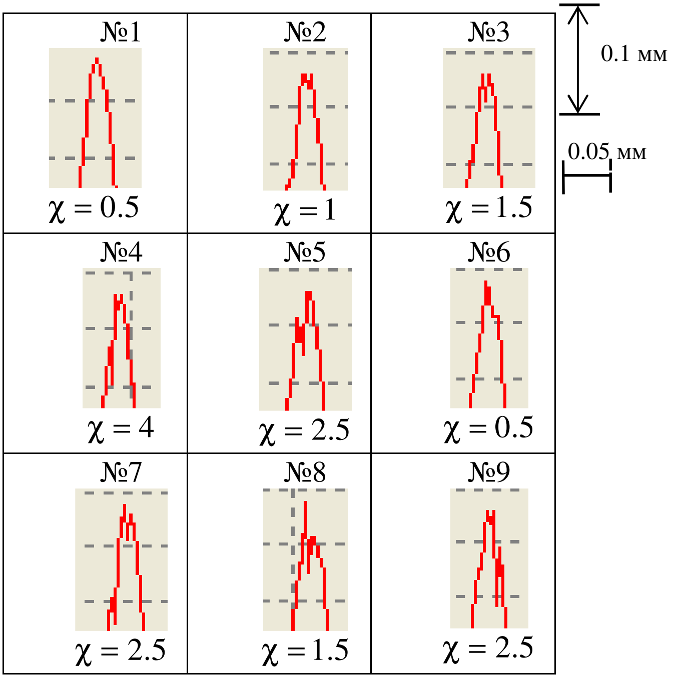

Fig. 5. Measured nine realizations (№ 1–№ 9) oscillatory process the special trajectory (χ – number of complete oscillations executive body)

During the experimental measurements, the defined displacement executive board is at its outlet into position (special section of the trajectory) and then reverse the movement at the turn of 90° or 180°. Carried out consistent enforcement authority to the position corresponding to one vertex of a square given trajectory. Measurements of sequential access to the position of the registration displacement of the executive body for the special section. Obtained experimentally determined set of realizations of the random process of high-frequency oscillatory movement of the executive body of the particular region (Fig. 5).

Based on experimental measurements revealed that under specific sections of the trajectory there are high-frequency oscillatory movements of the executive body small amplitude random. A typical implementation of the oscillation process the special trajectory includes several small amplitude oscillations (Fig. 6).

Move the executive body of the particular trajectory subject to the laws of random nature and are poorly defined (blurry, Fuzzy) infinitesimal processes [8]. They are sold as a package impulses. The number, amplitude and pulse frequency and shape are determined by the operation of the equipment. Typical pulse packets, consist of 0,5 – 3 oscillations pulse (Fig. 7).

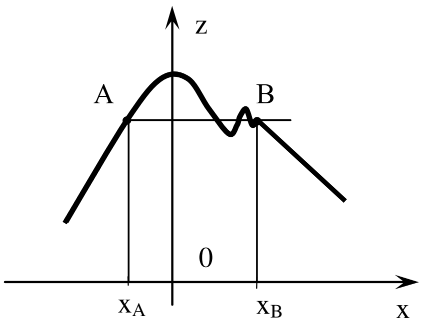

Fig. 6. Typical implementation process at the point of breaking the trajectory, which is half (χ = 1.5) complete oscillation

To study the dynamic processes in specific points of the trajectory matrix and applied stochastic processes of different scale [8]. Random matrix summarizes the set of realizations of the random oscillatory process in the number of extrema. The matrix is formed as a table (Table 1), respectively graphs shown in Fig. 5. Values one component of the matrix corresponds to maximum process, and the value -1 corresponds to minimum process.

The second row of the table corresponds to the conventional image of the process shown in Fig. 7a, and the fifth line corresponds to the process shown in Fig. 7b.

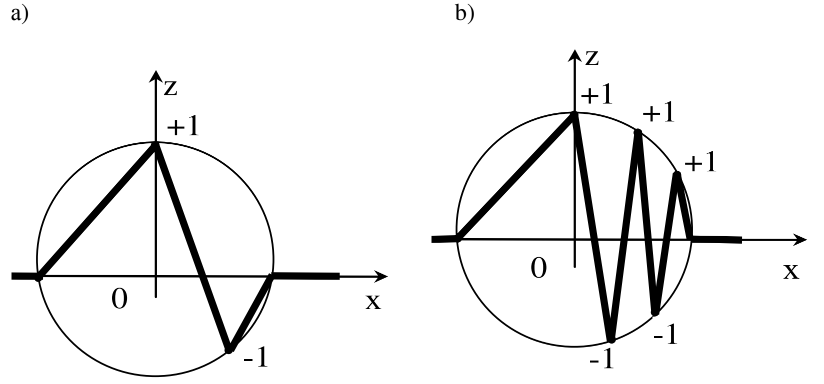

Fig. 7. Typical infinitesimal oscillatory processes of change in the trajectory of a singular point: a – a process corresponding to one complete shake b – a package of pulses containing 2.5 vibrations

Table 1. The presence of extremes in some implementations oscillatory process the particular trajectory

№ implementation process	entrance z_A	The presence of extreme process								out z_B	*Swinging-ness* χ
1	0	+1	0	0	0	0	0	0	0	0	0,5
2	0	+1	-1	0	0	0	0	0	0	0	1,0
3	0	+1	-1	+1	0	0	0	0	0	0	1,5
4	0	+1	-1	+1	-1	+1	-1	+1	-1	0	4
5	0	+1	-1	+1	-1	+1	0	0	0	0	2,5
6	0	+1	0	0	0	0	0	0	0	0	0,5
7	0	+1	-1	+1	-1	+1	0	0	0	0	2,5
8	0	+1	-1	+1	0	0	0	0	0	0	1,5
9	0	+1	-1	+1	-1	+1	0	0	0	0	2,5

Random matrix is the basis of a detailed analysis of the process. As it is defined by the average number of extrema and filtering of information is conducted to determine significant informative process parameters. The analysis carried out separately for each component of six-dimensional vector of coordinates describing the position of the executive body in space.

As a result, detailed analysis of the processes of the particular trajectory revealed that every component of the vector position of the executive body of the special section is a package of pulses. Packet pulses presented as a set of distributions of pulse type. Generalized functions correspond to Dirac δ-function fixed, different for each pulse, the integrated rate:

$$\int_{-\varepsilon}^{+\varepsilon} \delta_i(t)dt = S_{oi},$$

where ε – infinitesimal number $(\varepsilon \neq 0)$; S_{oi} – integrated rate corresponding i-th pulse.

If pulses at particular trajectory are in the same plane, have flat pack pulses (Fig. 8a).

The action of two packets of pulses in two mutually perpendicular planes resulting effect depends on the relative position (phase) pulses (Fig. 9).

If the pulses are simultaneously (in phase) are resulting in a load of two-dimensional δ-function (see Fig. 9a).

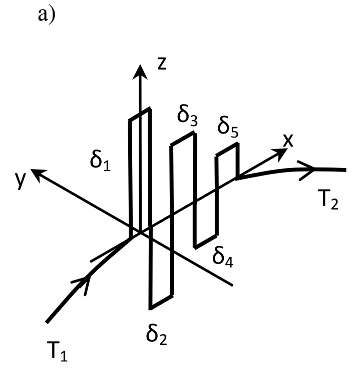

Fig. 8. Oscillatory processes in particular trajectory in the form of packets of pulses: a – package impulses, acting in the same plane, b – two-phase pulse packets that are in two mutually perpendicular planes

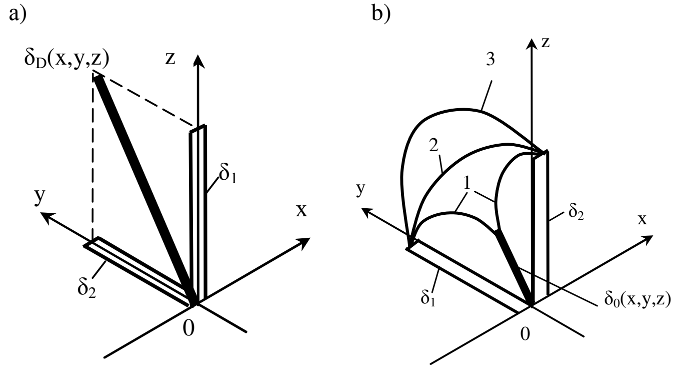

Fig. 9. Effects of two mutually perpendicular pulses: a – matching (in-phase) pulses, b – pulses with different phase shift values

If there is a phase shift pulses (Fig. 9b) resulting momentum changes its magnitude and direction. If the phase of the out put pulses do not match, then the locus of the resulting pulse (curve 1) has a minimum. In case of partial overlap phase pulse travel time is a convex curve (curve 2). By increasing the degree of overlap locus (curve 3) is removed, assuming the limit in the case of complete matching phase pulses.

In simultaneous action of three mutually perpendicular momentum of the load circuit is complicated (Fig. 10).

Effects in phase three mutually-perpendicular pulses (see Fig. 10a) corresponds to the force factor as a three-dimensional δ -function [8]. In the presence of phase difference pulse component is a superposition of actions in mutually perpendicular directions. The presence of a significant phase difference leads to complex spatial pulse pressure on executive body (Fig. 10 b). The resulting impulse process $\delta(x, y, z)$changes its direction in space. Its locus has a complex spatial form of the curve G. Maxima correspond to an integral curve pulse curve process $\delta_1, \delta_2, \delta_3$. Minima correspond to points of the largest components of the phase difference pulses.

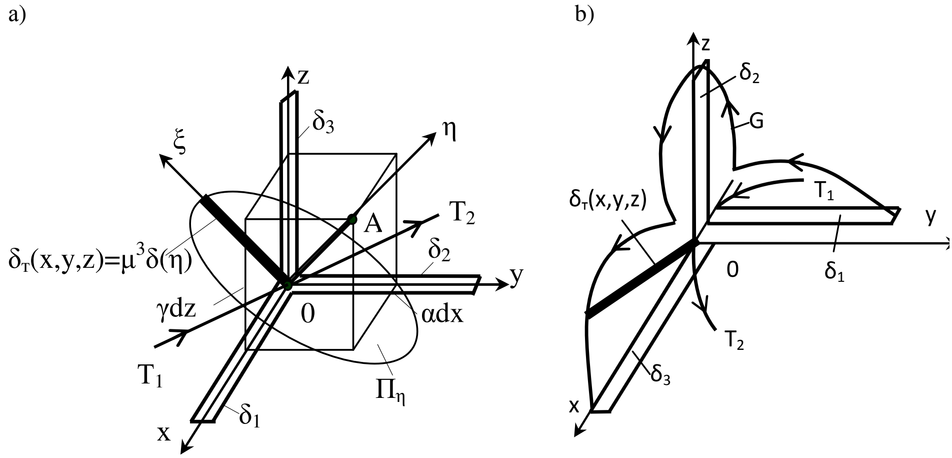

Fig. 10. Interaction processes as a set of three pulses acting on a special trajectory: a – action-phase pulse and summarize current pulses in phase-three-dimensional-function, b – action shifted in phase three pulses

As a result, processing of stochastic matrices revealed that oscillatory process the special section has a frequency spectrum that ranges from a constant value independent of frequency for a single pulse to the load spectrum that approximates the δ -function for sufficiently large chysli impulsiv in the packet. Pursuant to describe random process changes the trajectory suggested to use a stochastic process with a limited range [9] implementation of which presented as a series:

$$z(t) = \sum_{k=-\infty}^{+\infty} z(t_k) \frac{\sin[2\pi f(t - t_k)]}{2\pi f(t - t_k)},$$

where f – base value of cyclic frequency.

The sample time value t_k^* and process $z_k(t_k)$set by random generator with a uniform distribution law. In this case, the particular trajectory emerging spatial $F(t)$ load executive body (Fig. 11a). A typical implementation of a load variable amplitude and period. The basic process of the frequency fluctuations observed in groups (see Fig. 11 b).

Random load force in a short period of time. They occur on specific areas of trajectory (indicated by arrows in Fig. 12).

Random load acting in the tangent plane natural trihedral around specific areas of the trajectory toward the bisector of the angle between the tangent to the trajectory of the right and left of the point of breaking.

With the implementation of methods for forming parallel kinematics machine to restrict dynamic pressure. This is achieved by software system by changing restrictions on natural trihedral trajectories on specific areas.

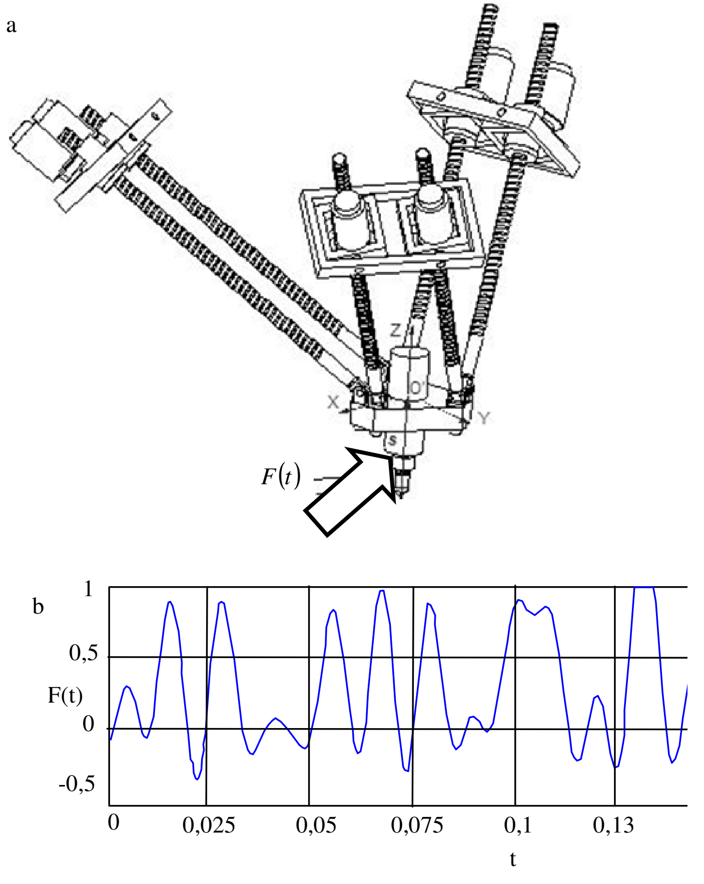

Fig. 11. The load on the executive body of the particular trajectory (a) and a typical implementation of the random module load (b)

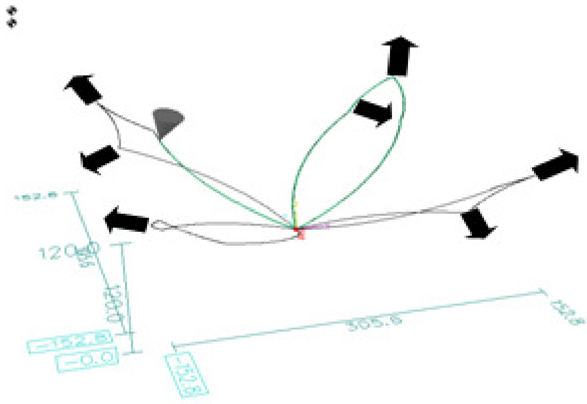

Fig. 12. A typical trajectory of movement of the tool relative to a fixed position table (arrow shows the dynamic loads that occur on specific parts of the trajectory

Conclusions

1. It is shown that the trajectories of moving parallel kinematics machine tool spindle with special areas as fractures, where there are abrupt changes in natural trihedral (natural 3-hedron) trajectory.
2. As a result of experimental measurements revealed that the particular trajectory is a random process of oscillatory nature. The implementation process should 0.5–4 complete oscillations with a frequency of 20 .. 25 Hz and an amplitude not exceeding 20 microns.
3. In particular trajectory impulsive components of acting in mutually perpendicular directions are stored implementing complex spatial switching process that varies from one-dimensional functions to two-or three-dimensional features in-phase component of the process.
4. In particular trajectory plots having broadband random load on the executive body of the direction which corresponds to the bisector of the angle between the tangent to the trajectory of the right and left of the point of breaking, and module load corresponding random process with a limited range.
5. As a direction for further research is recommended to establish reasonable ranges of natural tryedra trajectories on specific areas that correspond to the regulated range of variation of the random module loads on the executive body.

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Analiza właściwości dynamicznych maszyny o kinematyce równoległej

Słowa kluczowe

Mechanizmy przestrzenne, układ wykonawczy, system, tajketoria, ekstrema procesu harmonicznego, efekt impulsowy dodawania impulsów, spektrum obciążenia.

Streszczenie

Artkuł poświęcony jest złożonemu układowi technologicznemu, zawierającemu mechanizm przestrzenny. Układ składa się z maszyny o kinematyce równoległej i platformy z sześcioma napędami. Wykazano, że w procesie ustalania położenia występują specjalne trajektorie odpowiadające pozycji części ruchomych maszyny i platformy. W określonym obszarze zachodzi stochastyczny proces oscylacyjny o nieskończenie małej amplitudzie. Przestawiono metody syntezy i matematycznego opisu teoretycznego procesów oscylacji.

Z powodu losowości obciążeń dynamicznych działanie napędu jest definiowane dla okreęślonego obszaru.