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Structure of system position–force control of the drive Stewart platform

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Abstract

The article deals with the device in the form of Stewart platform with adaptive, robust control and fuzzy logic control. It` describes electric rods. The algorithms and systems of position-force control with variable structure are considered. The results of the simulation platform developed by Stewart layout with a crank mechanism are presented.

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Keywords: structure; control; force control; position-force control; structural of mechanisms; electric drive.

1. Introduction

The Analysis of robotic designs of stationary and mobile systems for special purposes showed the feasibility of Stewart platform[1-3]. Control position and orientation of the platform output link by varying the lengths of the legs with the integrated linear electric drive (ED), or using a crank mechanism.

Generally, a pilotless flying machine (PFM) name any flying machine without crew with remote or an off-line control. Starting arrangements (SA), by the form start PFM are divided into installations with vertical and inclined start, on mobility - on stationary, semiportable (folding) and mobile[1-4].

The analysis of designs PAC with various kinds SA and conditions of their operation shows an urgency of creation of devices with vertical start and corresponding robotic stationary or mobile starting complexes. Orientation and stabilization of position of a starting table is provided with application of a platform of Stewart with adaptive control[4].

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Control of position and orientation of a target link of a platform is carried out by change of lengths of legs by means of the built in linear electric drive (ED).

In works[4,5] by means of MATLAB/SimMechanics the problem of computer modelling of change of working space of a mobile link of a platform of Stewart based on the decision of a return kinematic problem, formalization of the communications excluding ambiguity of position of a target link and algorithm developed by authors in Solidworks the program environment dares. Formation of working space is carried out by numerical methods on special computing algorithm.

Separate results of the analysis of working space and positions of a platform of Stewart are shown on Fig. 1.

a) b)

On Fig. 1(a), are shown both positions and orientations of a mobile platform, and section of a working zone by orthogonal planes XOY, XOZ and working zones in space XYZ at following values of corners α, β, γ : $\left(\alpha = 10,\ \beta = 10,\ \gamma = 49\ degrees\right)$.

The combination of some variants of orientations of platforms leads to discontinuity (heterogeneity) of working zones (Fig. 1a,), that shows impossibility of continuous moving of a platform in a working zone.

Generalised structure EP of bars (Fig. 2), allowing to realise depending on a condition of the mechanism with parallel structure (MWPS) various combinations item (PID, robust, fuzzy logic), impedance and independent position-force control (PFC)[4,6].

The interrelation of level and signs on change of operating signals of position S_0 and forces P_0 is reached by representation of blocks of interrelation of channels $A_{SF}(\varepsilon_s)$, $A_{SF}\left(F\right)$ and logic regulators of position $\Phi_S\left(S_0, F\right)$ and forces $\Phi_F(F, \varepsilon_s)$ in a kind[4,7]:

$$\begin{cases} A_{SF}(\varepsilon_s) = \mathrm{sgn}(K_{SF} \cdot \varepsilon_s); \\ A_{FS}(F) = 0; \\ \Phi_S(S_0, F) = 1; \\ \Phi_F(F, \varepsilon_s) = F_0 \cdot A_{SF}(\varepsilon_s). \end{cases} \tag{1}$$

where K_{SF} - factor of strengthening of the block of interrelation of channels of position and force.

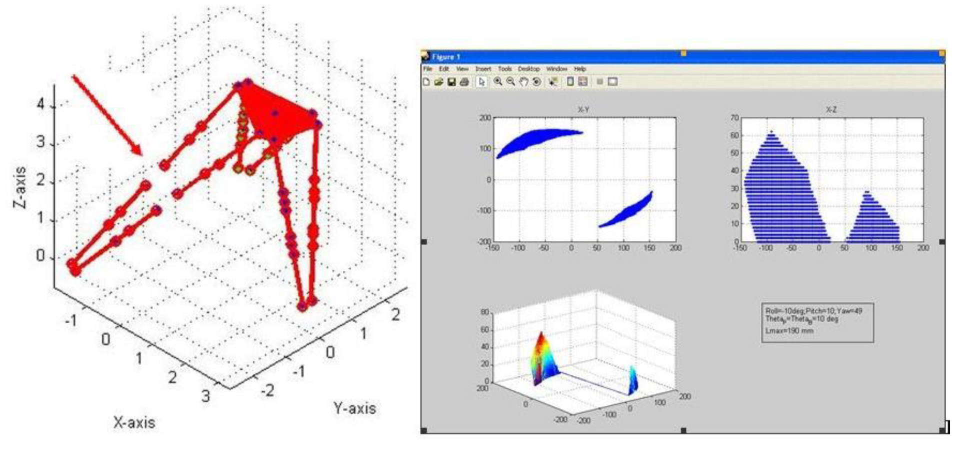

Fig. 1. Results of modelling platform of Stewart: (a) positions and orientations of a mobile platform; (b) sections of a working zone.

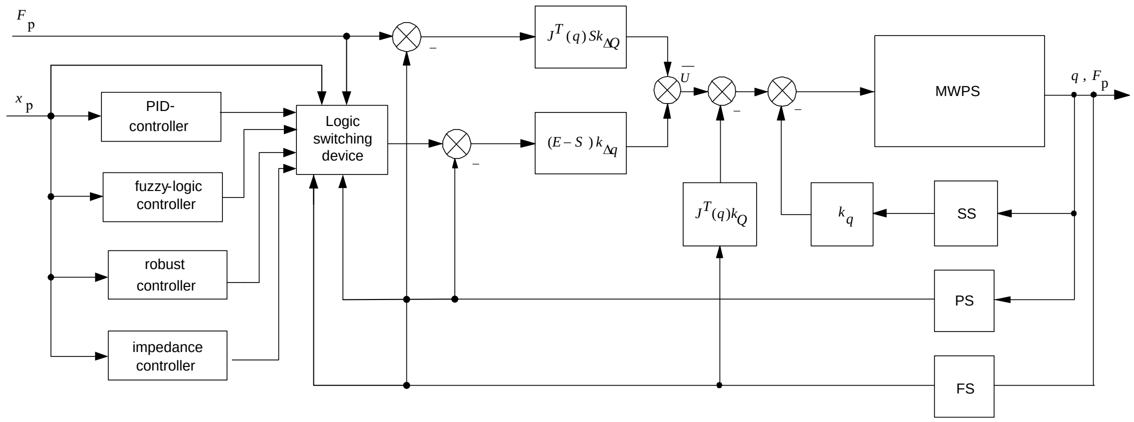

Figure 2. Generalised block diagramme ED of bars MWPS: LSD- the logic switching device

The problem of increase of speed of two-channel system at contact interaction can be solved application of a logic functional regulator of force $\Phi_F(F,\varepsilon_s)$ a following kind:

$$\Phi_F(F,\varepsilon_s)=\begin{cases}K_{F1}\ \forall\ (K_{F2}\cdot F_0-\varepsilon s)>0;\\ 1\quad \forall\ (K_{F2}\cdot F_0-\varepsilon s)\le 0.\end{cases} \tag{2}$$

To exclude shock interactions of target link MWPS with external object at switching of control with force on item it is possible by introduction of a nonlinear functional regulator of position with logic control $\Phi s\ (S_0,\ F)$. In this case regulators $A_{SF}(\varepsilon_s)$, $A_{FS}(F), \Phi s\ (S_0,\ F), \Phi p\ (F,\varepsilon_s)$ will become:

$$\begin{cases}A_{SF}(\varepsilon_s)=\mathrm{sgn}(K_{SF}\cdot\varepsilon_s);\\ A_{FS}(F)=\mathrm{sgn}(K_{FS}\cdot F);\\ \Phi_S(S_0,F)=\begin{cases}K_S\cdot\int_0^\tau(S_0-S_0')\cdot dt\ \ \forall\ A_{FS}(A)=0\wedge S_0<S_0'\\ S_0'\qquad\qquad \forall\ A_{FS}(F)=1\wedge S_0=S_0'\end{cases};\\ \Phi_F(F,\varepsilon_s)=F_0\cdot A_{SF}(\varepsilon_s).\end{cases} \tag{3}$$

where K_S, K_{SP}, K_{PS} - factors of strengthening of corresponding regulators; S'_0 - co-ordinate of a point of a contact.

The structure of the system realising given algorithm[4], is presented on Fig. 3. Drive works as follows: at movement in a bonded area the signal from the gauge of force ДF is absent, the logic switching device (LSD_2) switches system in a short circuit mode by position, and a signal of an error of a mismatch by position through LSD_S, the integrator and the adder actuates an executive office. At a contact of external object the signal with ДF switches LSD_S and LSD_2, the signal of item task S0 is fixed at level S'_0, corresponding to co-ordinate of a point of a contact.

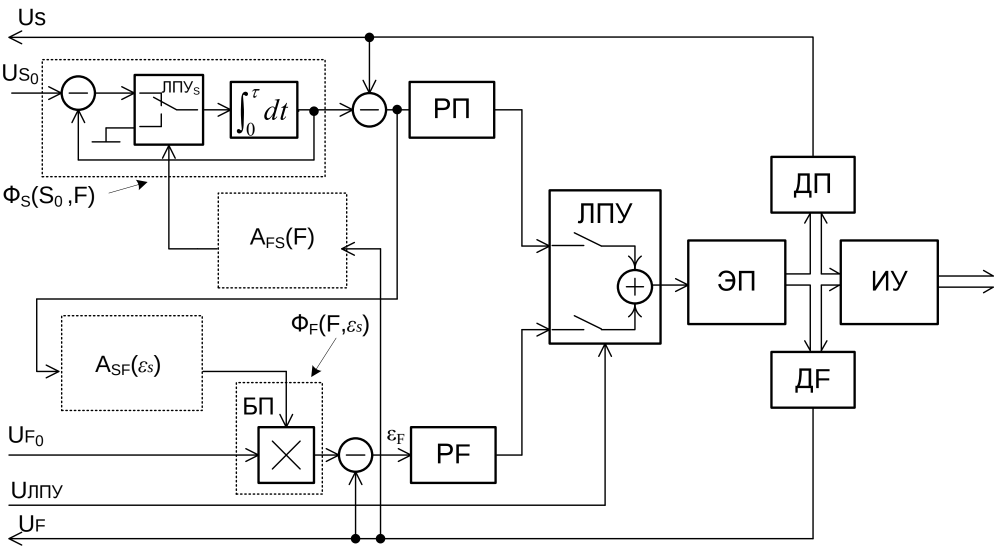

Figure 3. Two-channel system of coherent positional-force control with a nonlinear functional regulator of position with logic control

At working off of operating algorithms by drives of other bars MWPS during any moment of time the signal with ДF becomes equal to zero, LSD_2 is switched to management of position, but the signal of the task switched LSD_S, starts to increase with level $\dot{S}_0$ that provides smoothness of moving at transition from contact to object to work in a bonded area. Achievement of signal $\dot{S}_0$ of size of a signal of the task by position S0 is provided with presence of the individual negative feedback covering the integrator.

For the analysis of EP and CSP algorithms structures established model of Stewart platform (Fig. 4), controlled by a personal computer via the USB interface and IR remote - control panel. The linear actuators are used as the usual hobby servos for the transmission of motion. Control legs electric platform with force feedback by using adaptive fuzzy controller implemented Arduino board.

It was built 3D-model platform software package Solidworks and using imported SimMechanics CAD translator program MatLab. The program MatLab considered platform is depicted in Scheme Plant as a unit, from which removed position and velocity changes in length legs. The input unit is supplied leg Trajectory job being received in the form of coordinates and angles of the top center of the platform $x_0, y_0, z_0, \phi_0, \psi_0, X_0$ where x_0, y_0, z_0 - translational displacement along $X, Y, Z, \phi_0, \psi_0, x_0$ - the angles of rotation about the axes. The angles hexapod platform rotation are translated into movement by means of the Euler formulas.

The obtained by moving the Euler formulas are then combined with the movement of the matrix leg Trajectory, and the resulting linear movement of the center of mass of the platform are converted to change the lengths of the rods in the Controller unit. Then the changed values of the lengths of the legs $l_1', l_2', l_3', l_4', l_5', l_6'$ are converted into the coordinate values and the center of the platform angles $x_0', y_0', z_0', \phi_0', \psi_0', X_0'$. This gives rise to positioning errors between the specified coordinates and angles of the platform and the center of the simulation results. As a result of simulation obtained graphs of the platform coordinates of the center position and then, rods positioning errors hexapod and efforts supplied to each post hexapod. For control with the least errors made optimizing PID controller, which is represented in the model Matlab Controller unit for optimizing PID controller is tuned proportional coefficients (Kp), integral (Ki) and differential (Kd) components. The value of the coefficients Ki, Kp, KD ranged from 0 to 10, and performed an analysis of the resulting errors.

Fig. 4. Platform model on six crank mechanism

The presents the waveform change platform coordinates of the center position and then, legs positioning errors hexapod and efforts supplied to each post hexapod in a certain period of time under optimal PID coefficients ($Kp = 10,\ Ki = 7.5,\ Kd = 8$).

The graphs variables marked $x_0^{'}, y_0^{'}, z_0^{'}$ curves of the position of the center on the platform coordinates $x,\ y,\ z,$ respectively. The curves $\Delta x, \Delta y, \Delta z, \Delta\phi, \Delta\psi, \Delta X$ show the error between the target pixel x_0, y_0, z_0 and the center of the platform angles ϕ_0, ψ_0, X_0 and obtained coordinate values $x_0^{'}, y_0^{'}, z_0^{'}, \phi_0^{'}, \psi_0^{'}, X_0^{'}$. Curves $F1,\ F2,\ F3,\ F4,\ F5,\ F6$ are graphs effort applied to each leg in the hexapod interval of $0...10$.

The conducted numerical modeling and experimental studies confirmed the efficiency and high quality of the developed mechatronic devices.

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