World Applied Sciences Journal 25 (2): 341-346, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.25.02.7048

Computer-Aided Modeling of Dynamics of Manipulator-Tripod with Six Degree of Freedom

[1]Larisa Alexandrovna Rybak, [1]Elena Vladimirovna Gaponenko, [2]Alexey Valeryevich Chichvarin, [3]Vasiliy Borisovich Strutinsky and [2]Roman Alexandrovich Sidorenko

[1]Belgorod State Technological University named after V.G. Shukhov, Russia, 308012, Belgorod, Kostyukov Street, 46
[2]Stary Oskol Technological Institute named after A.A. Ugarov (branch) NIST "MISiS" Russia, 309512, Stary Oskol, m-d. Makarenko, 42
[3]National Technical University of Ukraine «KPI», Ukraine, 03056, Kyiv, Prospect Peremogy 37

Submitted: Aug 17, 2013; **Accepted:** Sep 26, 2013; **Published:** Oct 1, 2013

Abstract: In this paper we consider the class of machine tools with parallel kinematics, which is based on the use of multi-degree of freedom and multi-threaded rod mechanisms. It is shown that one of their methods to increase accuracy and simplify the management of these mechanisms is the kinematic method of group decoupling of movements. The structure of a manipulator-tripod with six degrees of freedom with a group of kinematic decoupling of movements was offer. For the synthesis and mathematical modeling of the manipulator of parallel kinematics is built 3D- model of the robot arm, tripod in the software package Solidworks, which allows you to obtain the necessary design and technological documentation. With SimMechanics CAD translator model is imported into the software package Matlab. In turn, the program MatLab mathematical simulation of the robot arm. With the model are removed data on the position and speed of change in the lengths rods. The general structure of the control mechanism was offered. The data of the mathematical modeling of the dynamics of the manipulator-tripod. The graphs are changing the position coordinates of the working body of the time and position error bars of the manipulator at a time.

Key words: Hexapod · Tripod · Parallel structure mechanism · Parallel kinematic manipulator-tripod · Movement decoupling · 3D-model · Mathematical model · Positioning error

INTRODUCTION

One of the most important trends in the development and production of innovative machine-tools is the use of mechatronic components that combine in a single form factor means of precision mechanics, electronics, electrical engineering [1-3]. The main result of the use of mechatronic components is the creation of new types of metal-working machinery of modern high technical level. In recent years, a new class of machine tools with "parallel" structure, in which all coordinates are related and any movement in one dimension requires the simultaneous coordinated change of all the other [4]. Equipment with parallel kinematics [5-7] is based on the use of multi-degree of freedom and multi-threaded rod mechanisms that allow one and the same mechanisms to carry out transport operations gripping the work, installation details and transaction processing technology and built-in high-speed high-torque drives and computers can not only manage technological movement of a machine, but also to compensate for its shortcomings.

Paper Body: The mechanisms with parallel structure include tripods, tetrapods, hexapods, etc. Hexapod and tripods are the subject of much research. There are examples of successful designs of machines, benches and other equipment for different purposes on the basis of mechanisms of parallel structure [8-10].

Corresponding Author: Larisa Alexandrovna Rybak, Belgorod State Technological University named after V.G. Shukhov, Russia, 308012, Belgorod, Kostyukov Street, 46

Recently, in design of the parallel kinematic mechanisms to improve accuracy and simplify the control method is applied group kinematic decoupling, i.e. when the translational movement of the moving platform independent of the rotational movement and position of the leading roll orienting mechanism of the working platform relative to the movable body does not depend on the axial displacement drive output shafts.

On Fig. 1 showed kinematic scheme of kinematic decoupled manipulator-tripod with six degree of freedom [11].

Manipulator-tripod with six degree of freedom (Fig. 1) consist of basement with three blocks (1) of actuators translational and rotational motions of input shaft universal joint transmission (2) and translational motion vectors are orthogonal to each other. External axis universal joints (4,7) of each “leg”, as part of the parallelogram (4,5,6,7) are parallel. The output shafts (3) propeller rotation gear pairs associated with the mobile platform (8) and is the leading element mounted on it a spherical mechanism with rotary pairs and working body (9). The axis of rotation of the legs on the mobile platform are orthogonal to each other. In rotation legs mobile platform installed, with the possibility of rotation, drive shafts spherical mechanism, which provides orientation working body. The output shafts are connected by three identical kinematic chains with drive shafts orientation of the working mechanism of the body. End-effector orientation mechanism (8) consist of universal joint (9)? Ft the input is one of the unsupported drive shafts (3) and the output - the output shaft with the end-effector (8). In other unsupported shafts reinforced cranks (10) in two spherical diads, each consisting of a crank and connecting rod (11). Parallelograms (12, 5, 13, 14) provided parallel axes of the output shafts (2) of the drive unit (1) and axle unsupported drive shafts (3) orientation mechanism of the end-effector (8).

For the synthesis and mathematical modeling of the parallel kinematics manipulator was built 3D-model of the manipulator in the software package Solidworks (Fig. 2).

For designing “upwards” modeling method was used, i.e. first created details, then they are inserted into the assembly and match the requirements of the project. This model allows to obtain the necessary design and technological documentation.

The capabilities of the software system allows to import, using SimMechanics CAD translator, built 3D-model of the manipulator in the program package MATLAB. SimMechanics is Simulink library for physical

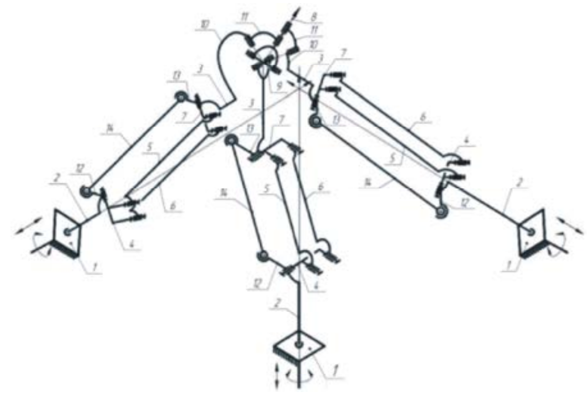

Fig. 1: Manipulator-tripod with six degree of freedom

Fig. 2: 3D-model of parallel kinematics manipulator in software package SolidWorks

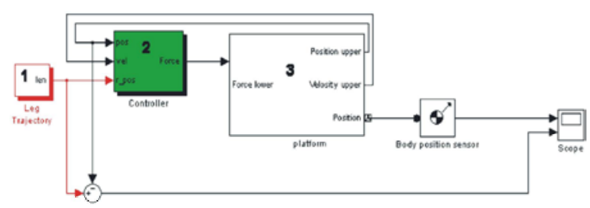

Fig. 3: Model of manipulator-tripod in program package Matlab

modeling of mechanical systems, which allows you to create models of mechanical objects and shared with other MathWorks packages to develop prototypes of real control systems [12].

In turn, the program package MATLAB execute mathematical simulation of the robot arm (Fig. 3). From the model given data on position and velocity changes of the length of the legs.

Blocks 1 are responsible for the conversion of reference obtained in the form of coordinates and angles of the upper platform, changes in length of the legs. Process diagram is shown in Fig. 4.

The rotation angles translated into movement by using Euler's formula. Blocks 2 in this case are the regulators.

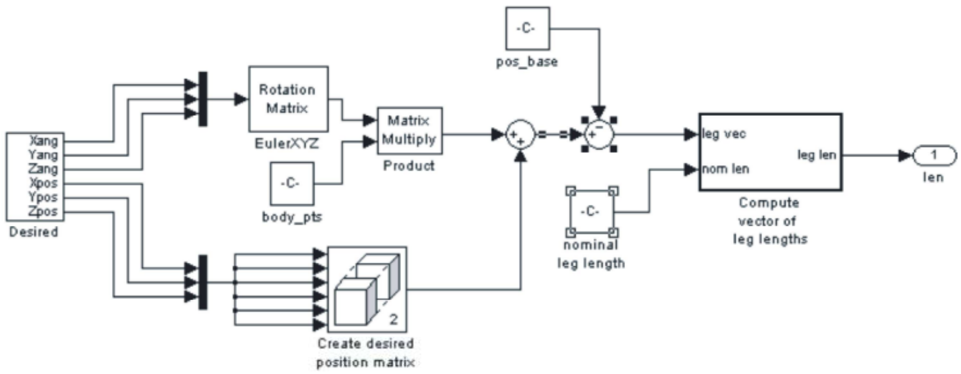

Fig. 4: Scheme of trajectory conversion for leg of manipulator-tripod

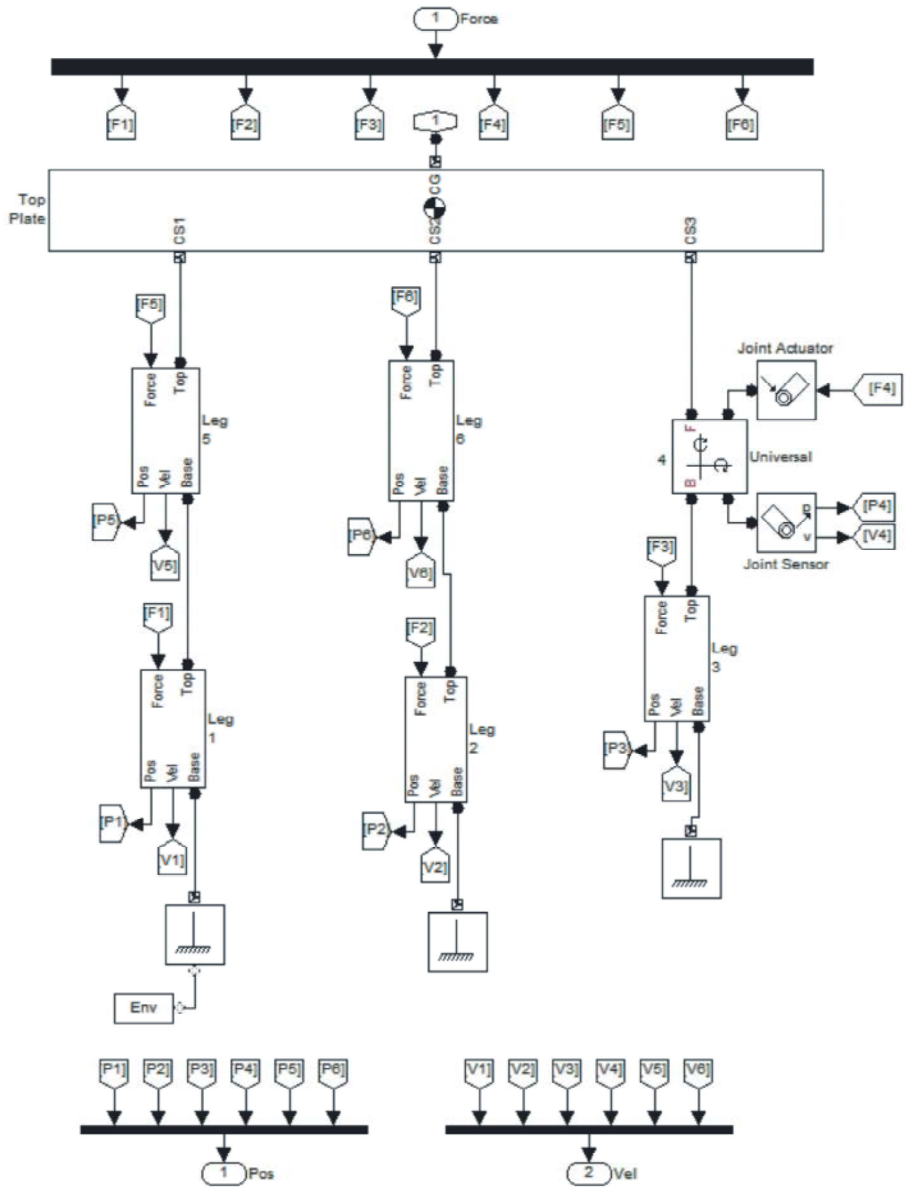

Fig. 5: Model of manipulator legs

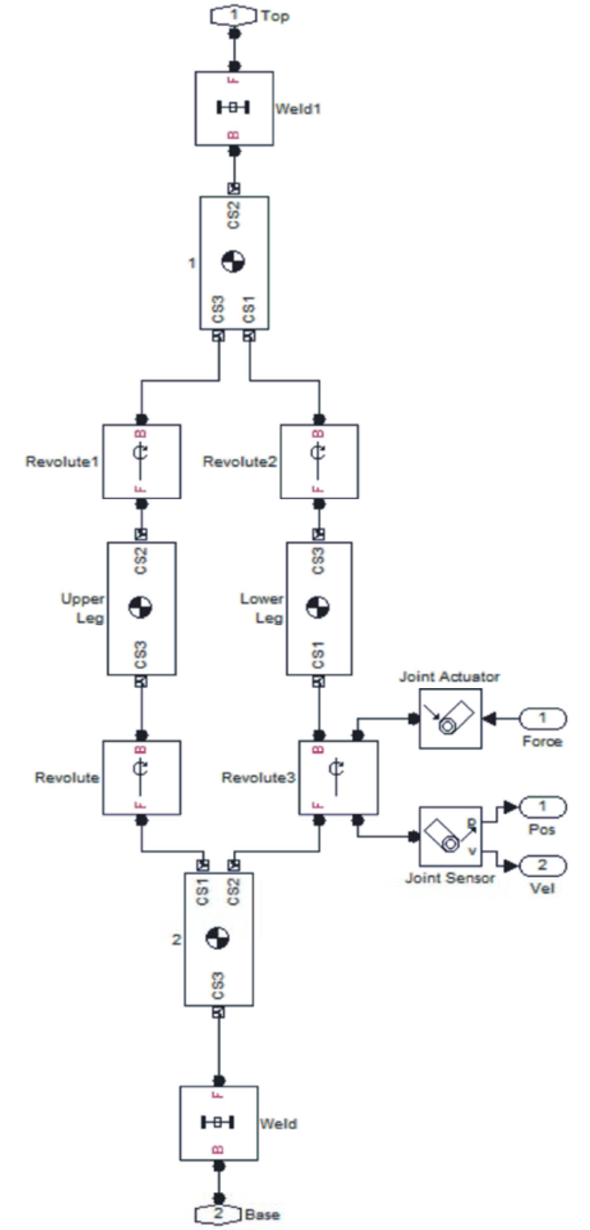

Fig. 6: Translational leg of manipulator-tripod

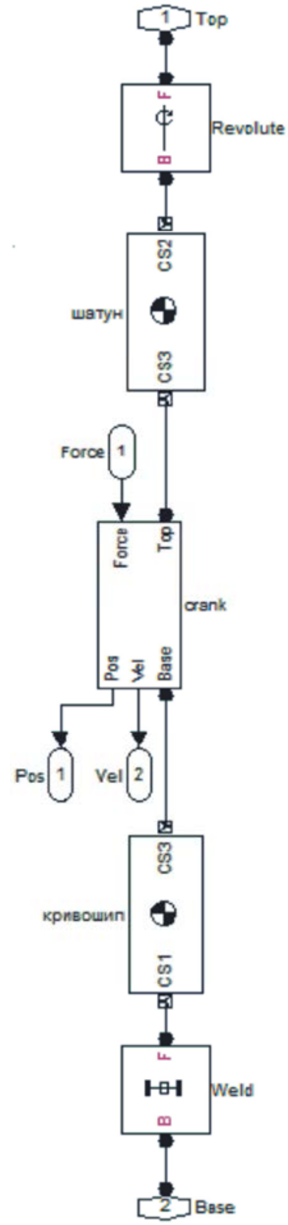

Fig. 7: Rotational leg of manipulator-tripod

Obtained using the Euler formulas movements then added to the displacement matrix. The resulting line translations of the center of mass of the platform are converted into changes of the length of legs in the block "Compute vector of leg length".

Block 3 is the manipulator-tripod mechanical system (Fig. 5). Translational legs "Leg1-3" realize translational moving of end-effector, rotational legs "Leg5-6" and universal joint 4 realize rotational moving of end-effector.

On each leg specified positioning sensors P1-P6 and velocity sensors V1-V6, from which data is read.

Each leg of parallel kinematics manipulator in program package MATLAB presenting be model, shown in Fig. 6, 7.

Showed on Fig. 7 crank block is a crank-and-rod mechanism (Fig. 8).

In modeling the desired value to the length of the leg is compared with the current value and supplied to the control system, generating value supplied to the drive of legs.

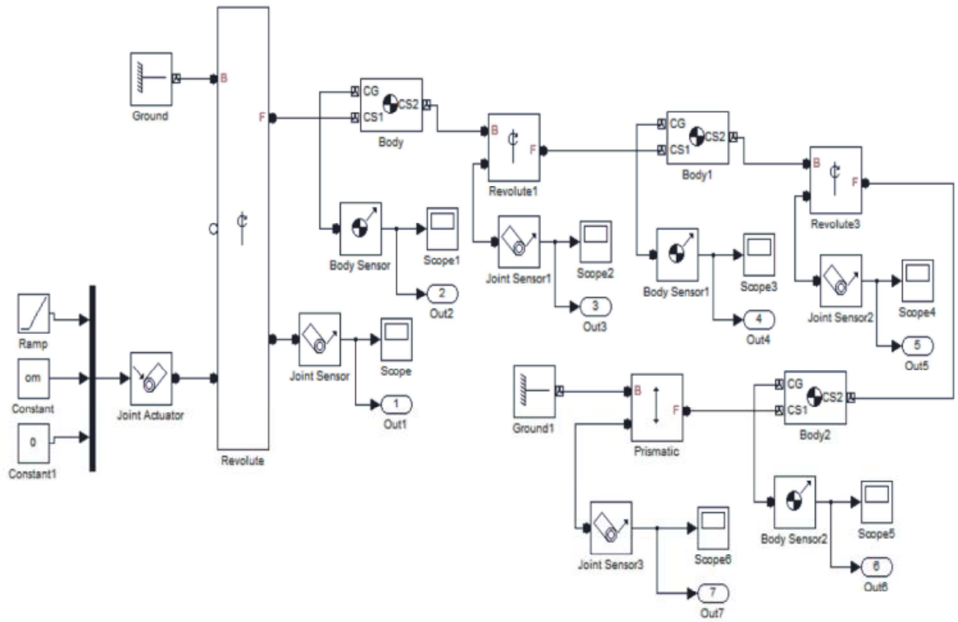

Fig. 8: Crank-and-rod mechanism

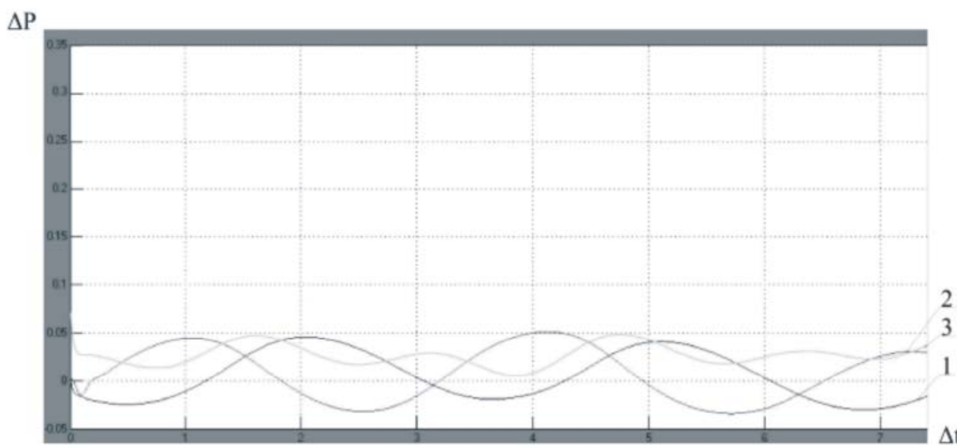

Fig. 9: Graphs of position of moving platform center

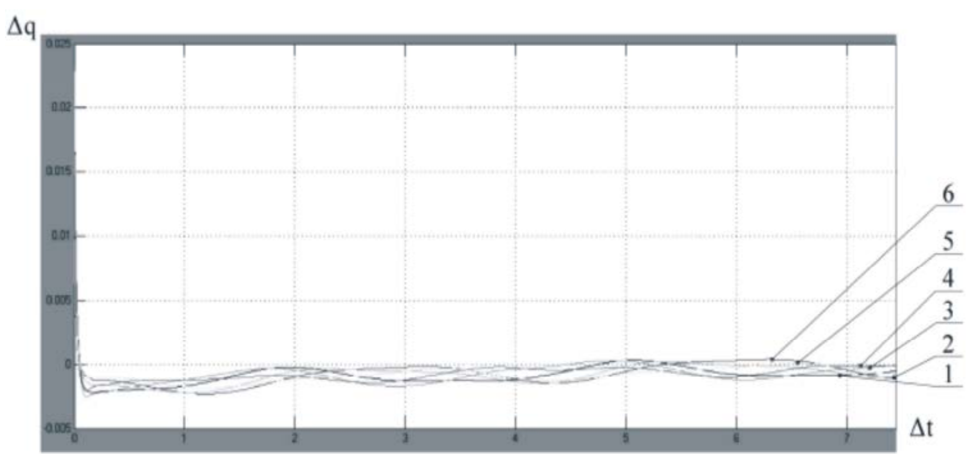

Fig. 10: Positioning errors of manipulator legs

In the result of modeling of the parallel kinematics manipulator can be obtained various dependencies. In this paper, we present some of them. In Fig. 9 shown graphs of position coordinates of the center of the platform from time. Numbers 1, 2, 3, marked variation curves of the center of the platform to the coordinates x, y, z respectively. In Fig. 10 shown the position error of parallel kinematic manipulator legs. Curves 1-6 denote positioning errors of each leg in a certain period of time.

CONCLUSION

In this study was proposed structure of the manipulaotor-tripod with six degrees of freedom with a group kinematic decoupling of movements and built its 3D-model in the software package Solidworks. With SimMechanics CAD translator model is imported into the software package Matlab. In turn, in the program MatLab mathematical simulation of the manipulator was performed. The simulation of the manipulator-tripod constructed graphs of position coordinates of the working body of the time and the position error of the manipulator rod at a time.

The Dependences Obtained the Following Conclusions:

- In arbitrary end-effector trajectory of manipulator-tripod maximal variance of end-effector location is 0.05.
- In measurement process maximal positioning error is 0.025 mm on the six rod of manipulator-tripod.

ACKNOWLEDGEMENT

Work performed as part of the Strategic Development Program of BSTU named after V.G. Shoukhov on 2012-2016 years (No 2011-ПР-146).

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