10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

KINEMATIC ANALYSE OF PARALLEL HEXAPODE STRUCTURE

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ABSTRACT
This paper informs about design and construction of mechanism with parallel kinematic structure with six degree of freedom. Kinematic analyse is used in parallel kinematic structures design. Analyse makes possible to determine position, speed and acceleration of mechanism parts. There are two methods for kinematic analyse – direct and inverse. Designed algorithm was used for calculation of the length values of active legs during moving in real time.
Keywords: *Kinematic analyse, parallel kinematic structures, hexapod*

1. INTRODUCTION
Parallel kinematic structure is a closed-loop mechanism in which the end-effector is connected to the base by at least two independent kinematic chains. A fully-parallel manipulator is a closed-loop mechanism with an n degree of freedom end-effector connected to the base by n independent chains which have at most two links and are actuated by a unique prismatic or rotary actuator.
Kinematic analyse is used in parallel kinematic structures (PKS) design. Analyse makes possible to determine important mechanism properties, as are position, speed and acceleration of rotary or linear mechanism parts as well as tool centre point (TCP). There are two methods for kinematic analyse:

- **Direct kinematic analyse**: it goes out from known input values of length or rotation kinematic structure parts and analyse is used for determination of position and orientation of TCP.
- **Inverse kinematic analyse**: there are input values - position and orientation of TCP and accounted are corresponding changes of length and rotation of structure parts. The most important is determination of lengths of mechanism legs. Analyse solution is equations system for mathematical functions definition between continuous changing of position and speed and acceleration of legs. These parameters are used for guarantee of regular action of mechanism drive units.

2. SCHOOL HEXAPOD DESIGN AND KINEMATIC ANALYSE
The school hexapod is developed in University of Žilina (Slovakia) at Department of Machining and Automation. Kinematic structures: to fully describe the position and orientation of the 6 degree of freedom (DOF) platform of the hexapod manipulator, six co-ordinates are needed. Three of them are positional displacements that define the position of a reference point for the platform with respect to a fixed co-ordinate frame. The other three co-ordinates are angular displacements that define the orientation of the distal platform. We define generalised Cartesian space co-ordinates **p**, whose elements are the six variables chosen to describe the position and orientation of the platform, as **p** = f $(x, y, z, \varphi, \theta, \psi)$.

Mechanism has following parts: fixed base, moving platform, six legs with six drive unit, six cardan joints for junction of legs and fixed base, six cardan joints for junction of legs and moving platform.

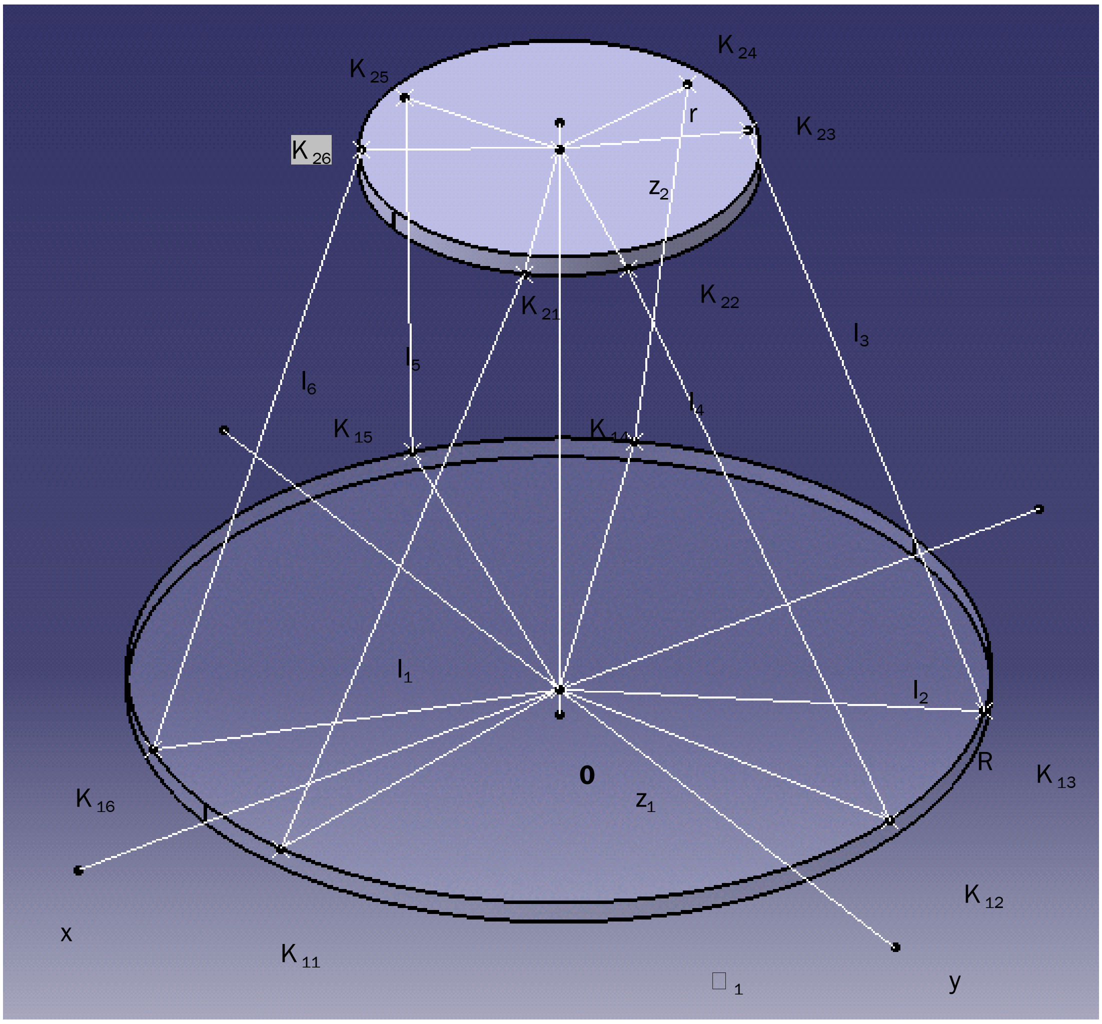

Figure 1. Schema of school hexapod design

In figure 1 is schema of school hexapod design. Points of intersection of two rotary axes of cardan joints at base are marked K_{1i}. They are in plane π_1 in level z_1, symmetrical on circle with radius R. Points of intersection of two rotary axes of cardan joints at platform are marked K_{2i}. They are in plane π_2 in level z_2, symmetrical on circle with radius r. Points K_{1i} and K_{2i} are joined with lines l_i . There is starting position of liner power units. Jacobi's matrix of hexapod mechanism:

$$J = \begin{vmatrix} L_1 & L_2 & L_3 & L_4 & L_5 & L_6 \\ M_1 & M_2 & M_3 & M_4 & M_5 & M_6 \\ N_1 & N_2 & N_3 & N_4 & N_5 & N_6 \\ P_1 & P_2 & P_3 & P_4 & P_5 & P_6 \\ Q_1 & Q_2 & Q_3 & Q_4 & Q_5 & Q_6 \\ R_1 & R_2 & R_3 & R_4 & R_5 & R_6 \end{vmatrix}$$

There are (for i = 1, 2, 3, 4, 5, 6):

$$L_i = \frac{K_{2i}(x) - K_{1i}(x)}{l_i} \qquad P_i = N_i K_i(x) - M_i K_i(z)$$

$$M_i = \frac{K_{2i}(y) - K_{1i}(y)}{l_i} \qquad Q_i = L_i K_i(z) - N_i K_i(x)$$

$$N_i = \frac{K_{2i}(z) - K_{1i}(z)}{l_i} \qquad\qquad R_i = M_i K_i(x) - L_i K_i(y)$$

Jacobi's matrix after hexapod parameters substitution has form:

$$J = \begin{vmatrix} -0,359 & 0,213 & 0,145 & 0,145 & 0,213 & -0,359 \\ 0,039 & -0,291 & 0,329 & 0,329 & 0,291 & -0,039 \\ 0,934 & 0,934 & 0,934 & 0,934 & 0,934 & 0,934 \\ 249,29 & 92,44 & -156,96 & -156,96 & -92,45 & 255,92 \\ -283,12 & -49,6 & 220,19 & 220,19 & 49,6 & -283,12 \\ 36,56 & 36,51 & -36,43 & -36,43 & 36,52 & 36,56 \end{vmatrix}$$

3. HEXAPOD KINETIC UNIT MOVEMENT CALCULATION

Movement of tool centre point is realised by changing of length and space orientation of all mechanism legs. Realisation most simply movements needs coordinate cooperation all six legs too. Calculated length values of mechanism legs are operated in control system and are sent to power unit in periodical time interval.

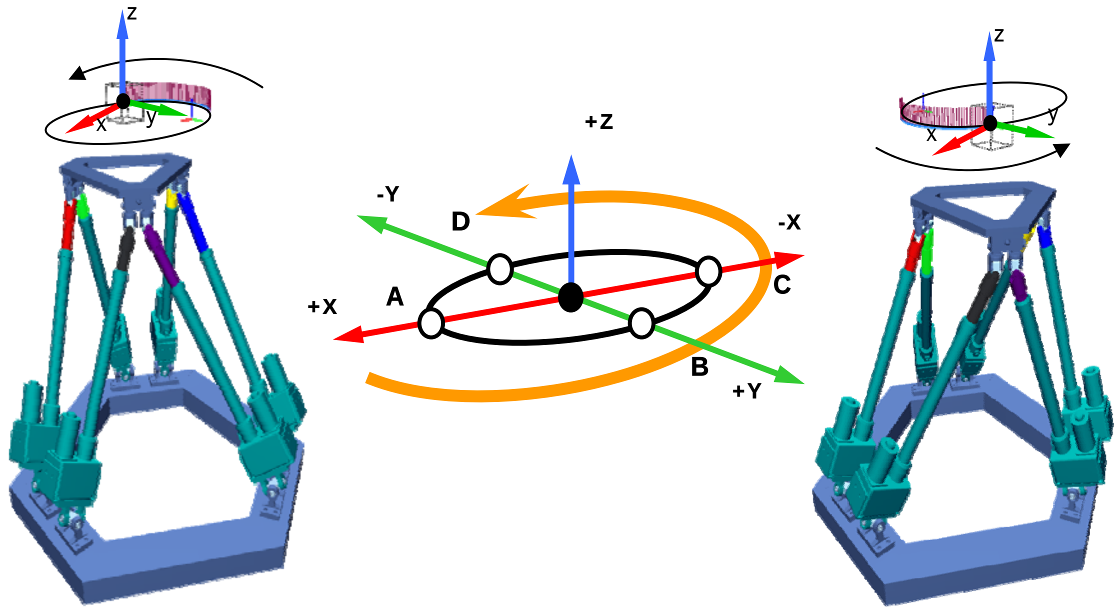

Figure 2. Circle interpolation in plane XY through points A, B, C, D

Calculated length values of mechanism legs for circle interpolation (figure 2) are presented in figure 3.

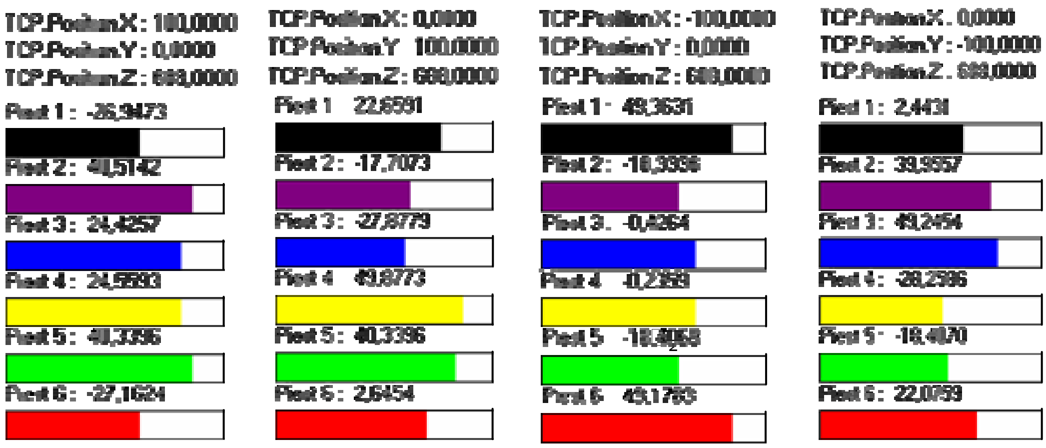

Figure 3. Lengths changing of six hexapod legs (Piest 1 - 6) in points A, B, C, D

Demonstration of expected operation space is shown in fig. 4 (green colour). There is space for all possible position of TCP and for all legs extensions.

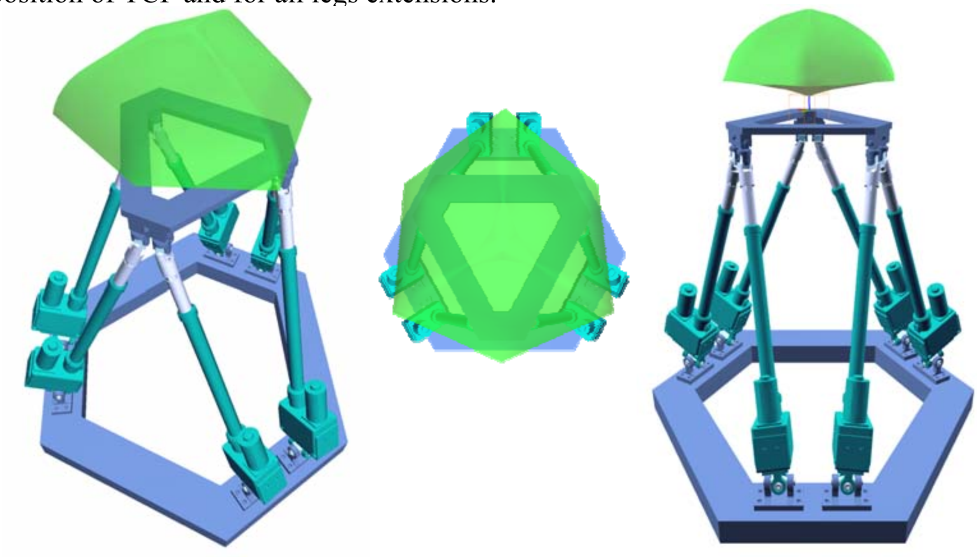

Figure 4. Hexapod expected operation space

4. CONCLUSIONS

Development and research of parallel structure machines and robots began app. twenty years ago. In comparison with classical kinematics of machines we can consider that the development in this field is very intensive. Nowadays, problem of kinematic analysis is handled at high level, mostly solution of inverse task for location and velocity by using differential kinematics. A lot of publications were issued for PÚK solutions of location, but there are still some unanswered questions [1, 8]. Similarly it is also with analysis of work place accuracy determination, calibration, path planning, singleness analysis and kinematic synthesis. By means of Jakobi‘s matrix were obtained perfect results of solutions of static analysis. More and more authors are dealing also with transmission quality (performance mapping depending on location in work place). Dynamic analysis and synthesis are less studied. Single chapter is made up by controlling that is still improving due to development of IT technologies.

Basic problems which obstructed PKS practical application were solved. It is possible to mention, that PKS development and research is pointed at PKS application into practice. It is mostly about calibration (accuracy), control (velocity, acceleration), design (kinematic and dynamic synthesis) and component development.

PKS development is short – run compared with long – run machinery development with serial kinematic structure. Whereupon it is possible to expect, that in the future will arise more and more projects supporting PKS research.

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