ACTA TECHNICA CORVINIENSIS
– Bulletin of Engineering
Tome IX [2016] , Fascicule 2 [April – June]
ISSN: 2067 – 3809

[1.]Iveta ONDEROVÁ, [2.] Viliam ČAČKO, [3.] Ľudovít KOLLÁTH,
[4.]Juraj ONDRUŠKA, [5.] Ľubomír ŠOOŠ

TESTING PULL-RODOF OF THE PARALLEL KINEMATIC STRUCTURE

[1-5.] Slovak University of Technology in Bratislava, Faculty of Mechanical Engineering, Institute of Manufacturing Systems, Environmental Technology and Quality Management, Bratislava, SLOVAKIA

Abstract: The work describes the kinematic structure of production machinery. I compare the serial and parallel kinematic structures, which are the main carriers of industrial robots and manipulators. I show possibilities, advantages and disadvantages of both structures, the basic distribution and kinematics motion. Parallel mechanisms are characterized by their kinematic structure presented a closed kinematic chain. The end effector mechanism is coupled to the base of more than one arm. This design provides an advantage particularly high rigidity mechanism and other related properties. The disadvantage of such a construction is limited workspace. In terms of positioning and management of this structure because of its complexity rather problematic. It is a structure that allows quick positioning of the tool with three degrees of freedom. Control system with a mechanical part is actually built on the Faculty of Mechanical Engineering. The work focuses on testing the parallel kinematic structure. Finally, the tests are evaluated. Results of experiments to serve in the design of telescoping steering rods and positioning parallel kinematic structure type Tricept in workspace.
Keywords: repeatability and accuracy of the distance position overshoot, paralel kinematic structure, pull-rodof

NOTE

The basic structure of the tricep developed at the SUT (Slovak University of Technology) FME (Faculty of Mechanical Engineering) can be represented by a parallel kinematic structure. The mechanism is based on a tripod structure with an added central shaft and is rigidly attached to the platform. It is connected to the frame by means of a spherical or universal joint.

Therefore, the tricep is constructed from a frame, three linear motors, central shaft, and a platform. Motion of the PKS (Parallel Kinematic Structure) is not a result of simple addition of partial movements, but a more complex calculation since moving members are configured parallel to each other. The goal of this contribution is to measure the unidirectional accuracy and position repeatability as well as the measurement of multidirectional accuracy of the end effectors position.

TRICEP PARAMETERS

The tricep was tested at the institute of manufacturing systems, environmental technology and quality management at the SUT FME in Bratislava. The test parameters are as follows:

- maximum loading: 300N
- maximum telescoping length: 550mm
- maximum angle of rotation of the central shaft: 40°
- motor: Maxon EC 60, power: Pelm=400 [W], freq. Of rotation: n1 = 2900 [min-1],
- digital encoder: HP HEDL 9140
- transmission: Maxon GP 81, ratio: i = 3,7:1

The working area of the PKS does not have a simple path as opposed to mass produced devices. Its motion is given by the distances and position of the axes of rotation of the telescoping shaft. The size of the working area is given by the structures parameters. Its greatest limitation is the length of the telescoping shafts and their corresponding angles of rotation since collisions must be avoided with the fixed platform and main frame.

DESIGN AND IMPLEMENTATION OF THE EXPERIMENT

Measurements were performed utilizing systems from Leica Geosystems. The measuring apparatus consists of a measuring device, probes, PC with software for data acquisition and processing within polyworks software.

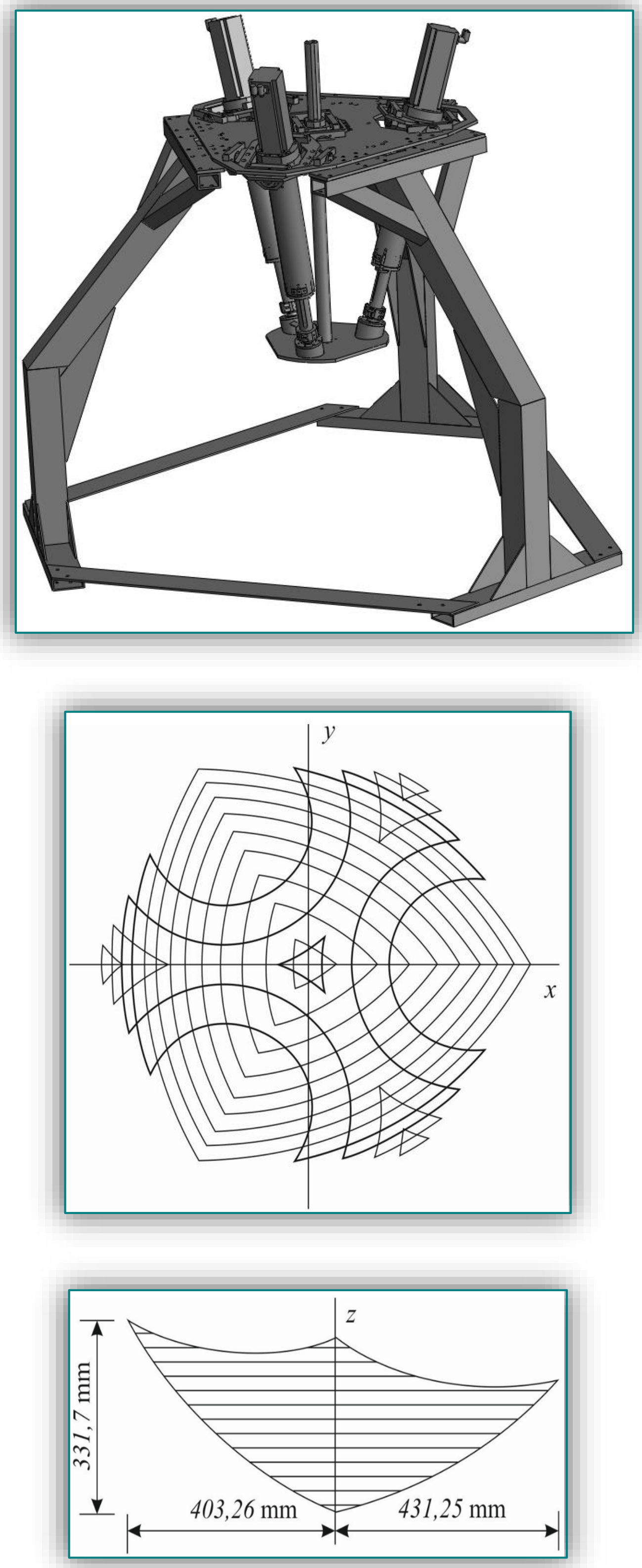

Figure 1. Design of the PKS and the working area of the PKS

MEASURING APPARATUS

Utilizing the laser tracker (Leica Absolut Tracker AT 901 – Basic) actual position of the mechanism end effector is recorded as it moved to the predefined "programmed" position. Technical documentation for the device is given in table 1.

Table 1: Leica parameters

Directing the beam	Pohyblivé zrkadlo
Source beam	pevný
Method of measurement	IFM+ADM+uhol
Range	160m
Rotate	360°
Maximum acceleration	360°/s^2
The maximum speed	180°/s
The accuracy of the lines (IFM)	±0,4 μm
Angle accuracy	±15 μm

The laser tracker also allows for non-contact measurements but requires a probe which accurately reflects the emitted beam from the laser (Figure 2).

Figure 2. The laser tracker

EXPERIMENTAL PROCEADURE

The experiment was divided into two parts. In the first part, the unidirectional positional accuracy is measured. The second part measured the positional accuracy of multidirectional movement. For the sake of the experiment, it was necessary to include an imaginary cube within the working area of the mechanism. Its corners were defined by C_1 to C_8 and was positioned in order to fulfil the following conditions:

- Placed in a zone were most work was assumed to occur,
- Represents the largest permissible volume, where the edges are parallel to the general axis of the system.

In order to measure position, measurements had to be performed with respect to the planes in figure. 3.

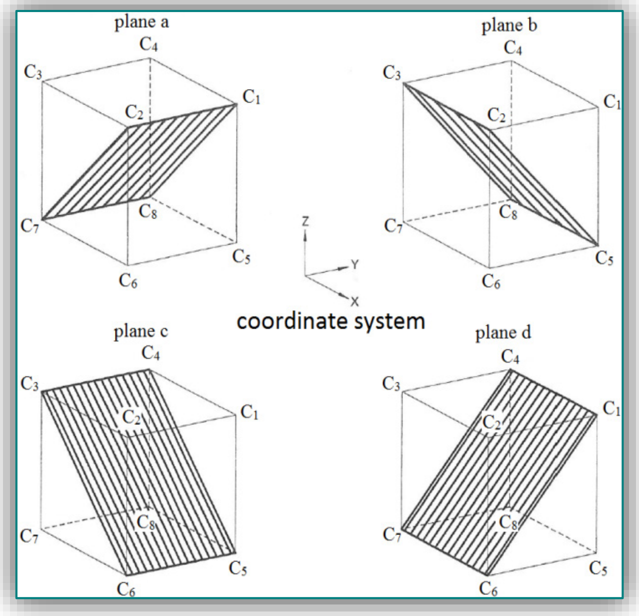

Figure 3. The positional accuracy of unidirectional movement

The positional accuracy of unidirectional movement was calculated as follows:

$$AP = \sqrt{(\overline{x} - xc)2 + (\overline{y} - yc)2 + (\overline{z} - Zc)2} \quad (1)$$

where:

$\overline{x}$, $\overline{y}, \overline{z}$ - average values of the coordinates after repeated movement to the same point

x_c, y_c, z_c - are the coordinates for the given position.

Unidirectional positional repeatability was calculated by the following method:

$$RP = \overline{l} + 3S_l \quad (2)$$

$$\overline{l} = \frac{1}{n} \sum_{j=1}^{n} lj \quad (3)$$

where

$$lj = \sqrt{(xj - \overline{x})2 + (yj - \overline{y})2 + (zj - \overline{z})2}$$

$$Sl = \sqrt{\frac{\sum_{j=1}^{n}(lj - \overline{l})2}{n-1}} \quad (4)$$

$\overline{x}$, $\overline{y}, \overline{z}$ - average values of the coordinates after repeated movement to the same point

x_j, y_j, z_j - are the coordinates for the given position

Measurement of the positional accuracy of multidirectional motion required at least three measurement points. Distance and motion paths were also necessary to determine (Figure 4).

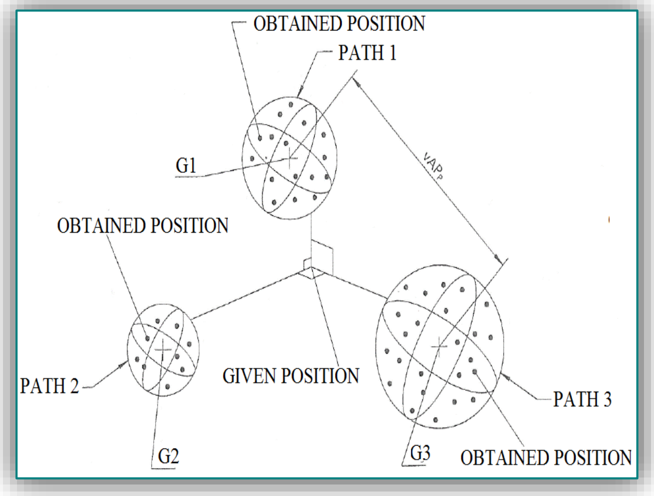

Figure 4. Measurement of the positional accuracy of multidirectional motion

The maximum deviation between the centres of cluster points, obtained at the end of individual paths, represents the multidirectional accuracy of the position (MAP), and was calculated as follows:

$$vAP_P = \max\sqrt{(xh - \overline{xk})2 + (yh - \overline{yk})2 + (zh - \overline{z}k)2} \quad (5)$$

h, k = 1,2,3

vAP_P defines the distance between point cluster centres (G1 and G3) measured for each axis individually. For each point, 3 MAP values were calculated

- distance between G1 and G2
- distance between G2 and G3
- distance between G1 and G3

From these values, the worst result is taken and is considered the maximum deviation for a specific point.

Standards do not specify any further procedures for the evaluation of the results. Therefore MAP results were obtained for points P1, P2, P3, and P4. The experiment can be repeated with different loads and speeds.

IMPLENENTATION OF EXPERIMENT

Three types of measurement cycles were used (linear, pendulum, and wandering). Measurements were compensated for temperature changes in environment by a compensating apparatus. The program receives data about the thermal expansion of the guide screw material.

Process of the linear cycle:

Initial position > Measurement point 1 (negative direction),
> Measurement point 2 (negative direction),
> Measurement point n (negative direction),
> Measurement point 10 (negative direction),
> End position,
> Measurement point 10 (positive direction),
> Measurment point 9 (positive direction),
> Measurment point n (positive direction),
> Measurement point 1 (positive direction),

The horizontal axis (Figure 5) shows values of set coordinate points. The vertical axis shows the deviation from the set position. The zero line represents an imaginary value of the maximum allowable deviation, determined before measurements. The blue line represent connected points which were detected by the laser tracker in the negative direction (from absolute zero to highest value). The green line represents connected points in the positive direction. The red line represents the average measurement values in the negative and positive directions. From the curves of the graphed results it can be seen that an anomaly occurs between values obtained at the mid and end position values. At the time, this anomaly was not completely determined, therefore a further measurement was performed.

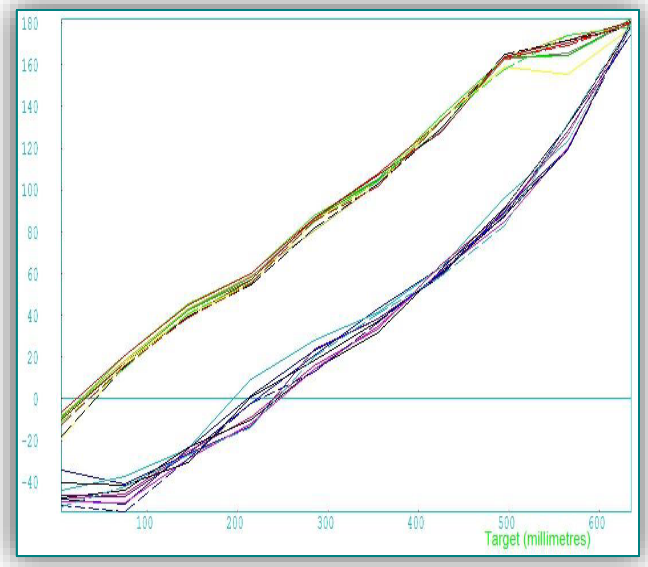

Figure 5. Process of the linear cycle

The measurement to determine the anomaly (fir. 6) was performed throughout the complete motion. In order to quickly diagnose, only one linear cycle was used. From the results it was found that there was not a direct correlation between the initial (absolute zero) and end points as can be seen in the graph. It was determined to perform another linear cycle with software correction at 50 μm which defines an imaginary clearance in the screw.

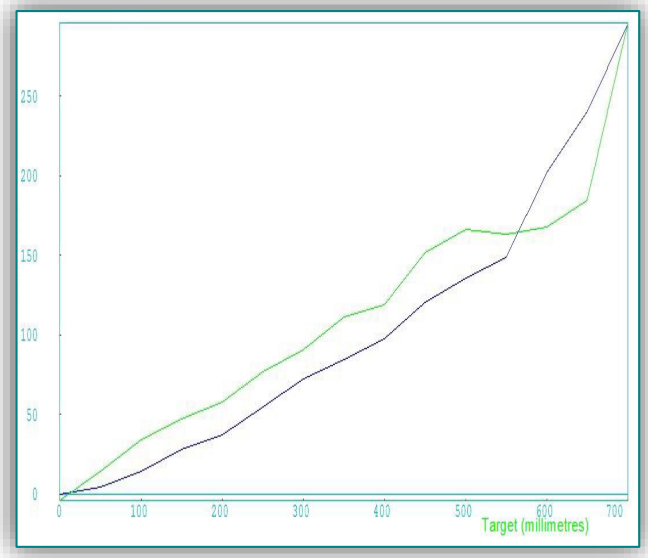

Figure 6. The measurement to determine the anomaly

From the resulting graph it was concluded that the measuring apparatus was not at fault, nor was the measurement procedure to blame for the anomaly, but rather the tolerances in the mechanism itself.

Process of the pendulum cycle: cycle was performed such that the initial "first" point from the negative and positive directions was measured 10 times. Afterward measurements of points 2, 3,..., n were performed.

Initial position > Measurement point 1 (negative direction)> +5mm
-5mm > Measurement point 1 (positive direction)> -5mm
+5mm > Measurement point 1 (negative direction) > +5mm
-5mm > Measurement point 1 (positive direction) > -5mm …
+5mm > Measurement point 1 (negative direction) > + hodnota kroku
+5mm > Measurement point 2 (negative direction) > +5mm
-5mm > Measurement point 2 (positive direction) > -5mm
+5mm > Measurement point 2 (negative direction) > +5mm …
-5mm > Measurement point n (positive direction) > -5mm

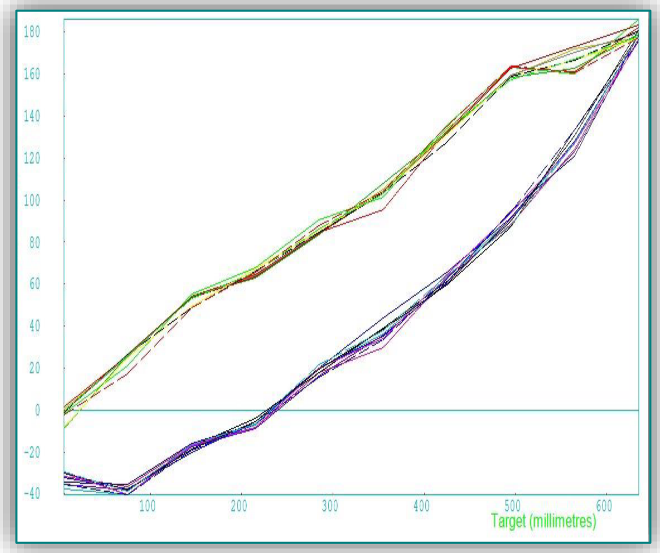

Figure 7. Process of the pendulum cycle

Process of the wandering cycle: performed such that the first point is measured 10 times in the negative direction. Then point 2 is measured in the negative direction while point 1 is measured 10 times in the positive direction, followed by point 3 in the negative direction and point 2 in the positive direction repeated up to point 10.

Initial position > Measurement point 1 (negative direction) > Initial position > Measurement point 1 (negative direction) > Initial position …

> Measurement point 1 (negative direction) > + step value (70mm)

> Measurement point 2 (negative direction) >

> Measurement point 1 (positive direction) >

> Measurement point 2 (negative direction) > …

> Measurement point 1 (positive direction) > + 140mm (step value x2)

> Measurement point 3 (negative direction)>

> Measurement point 2 (positive direction) > …

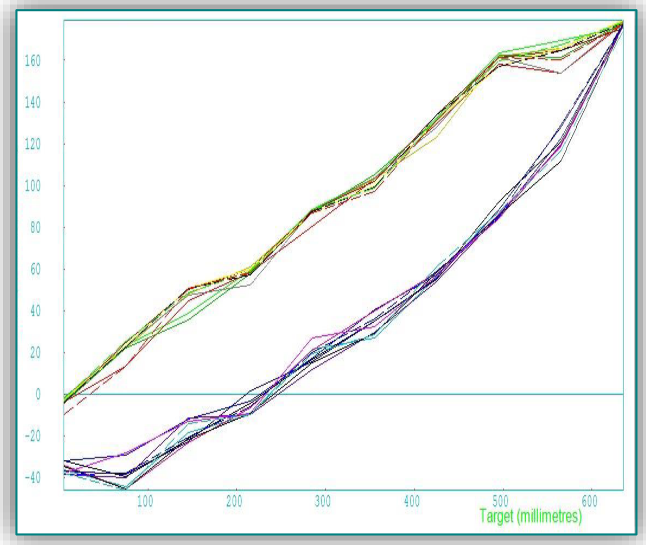

Figure 8. Process of the wandering cycle

CONCLUSION

Afore mentioned parameters (Table 2) were evaluated in RENISHAW software according to standard ISO 2302-2. From the curves on the graph, the pendulum cycle shows lowest values in terms of deviation or repeatability.

Table 2. The aforementioned parameters

	linear cycle [μm]	pendulum cycle [μm]	wandering cycle [μm]
AP	247,315	233,342	239,671
RP (forward)	45,445	25,550	38,752
RP (reverse)	34,815	28,561	32,127
νAPp	91,552	88,002	94,229

When defining the highest deviation, it was appropriate to utilize the linear cycle. However, the character for repeatability are not yet completely describable, therefore more cycle types are necessary to implement into the measurements.

Acknowledgment

The research presented in this paper is an outcome of the project No. APVV-0857-12 "Tools durability research of progressive compacting machine design and development of adaptive control for compaction process" funded by the Slovak Research and Development Agency.

Note

This paper is based on the paper presented at The 9th International Conference for Young Researchers and PhD Students - ERIN 2015, May 4-6, 2015, Monínec, Czech Republic, referred here as[4].

References

[1.] KOLLÁTH, Ľudovít, ONDEROVÁ, Iveta, KUREKOVÁ, Eva. Príspevok k výskumu kinematických štruktúr výrobnej techniky. In Automatizácia a riadenie v teórii a praxi. ARTEP 2013 [elektronický zdroj] : workshop odborníkov z univerzít, vysokých škôl a praxe v oblasti automatizácie a riadenia. Stará Lesná, SR, 20.-22.2. 2013. Košice : Technická univerzita v Košiciach, 2013, s.USB kľúč, s.44-1/44-9. ISBN 978-80-553-1330-6.

[2.] ONDEROVÁ, Iveta, KUREKOVÁ, Eva, KOLLÁTH, Ľudovít, PLOSKUŇÁKOVÁ, Lucia, Experimentálna verifikácia technologických parametrov v rezacích strojov s nekonvenčnou kinematikou. In Instruments and Control 2013 : 37. seminar ASR. Ostrava, ČR, 26.4. 2013. Ostrava : VŠB - Technická univerzita Ostrava, 2013, s.53-61. ISBN 978-80-248-2967-8.

[3.] ONDEROVÁ, Iveta, KOLLÁTH, Ľudovít, Testing and verification of selected technological parameters of the PKS. In Proceedings of the 15th International Carpathian Control Conference [elektronický zdroj] : ICCC 2014; Velké Karlovice, Czech Republic, May 28-30, 2014. [s.l.] : IEEE-Czechoslovakia Section of IEEE, 2014, S. 398-402, CD-ROM. ISBN 978-1-4799-3527-7.

[4.] ONDEROVÁ, Iveta, ČAČKO, Viliam, KOLLÁTH, Ľudovít, ONDRUŠKA, Juraj, ŠOOŠ, Ľubomír, Testing pull-rodof of the parallel kinematic structure, The 9th International Conference for Young Researchers and PhD Students - ERIN 2015, May 4-6, 2015, Monínec, Czech Republic

ISSN:2067-3809