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TESTING OF PARALLEL ROBOTS

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Abstract: The advanced techniques of measurement statistic methods are presented in this work. Nowadays more and more producers use parallel kinematic structures as a manipulators, machining machines or measurement instruments. This structures main disadvantage, when compare to serial kinematic structures, is its limited workspace. The workspace is even smaller because of the existence of singularities. For this reason one of the tasks of our research is to maximize space for measurement requirements. Classic model of the cube within the working space for testing robots according to the ISO 9283 is not suitable for special workspaces which parallel kinematic structures robots are because it covers only a little part of workspace. This paper consider the workspace of Tricept which is a parallel kinematic structure type robot designed at Slovak university of technology in Bratislava. Relatively small dimensions of the workspace of Tricept is the main disadvantage as well as others parallel kinematic structures. This paper describes the other ways to choose measured positions used for testing this type of robot. This article also briefly describes the design of experiments of Tricept to determine the impact of various factors on one of important indicator of quality which is the position of end effector of robot. As a main design of experiment was chosen Central composite design. The presented paper gives certain overview on adapting the estimates of measurement uncertainty in position error compensation and analyse sources contributing to the overall difference between desired and real position. The measurement uncertainty is based on various influences, such as measurement environment, temperature during operation, used materials and others known or unknown factors. Positioning accuracy is one of the most crucial aspects which affects the quality of product, although it is often claimed that parallel kinematic structures are more accurate than serial one it is still highly demand increasing quality.
Keywords: parallel robot testing, tricept, measurement uncertainty, design of experiment

INTRODUCTION

The whole process testing of robots used for manufacturing of the product can be divided into three parts. First one is the process of planning the design of experiments. The design of experiments tells how the measures will be done. In this step we can do simulations for reduction of factors with lower influence on measured parameters. The second is measuring the desired parameters to evaluate the quality of robot. Measurement results includes measurement uncertainty. Measurement uncertainty is an important parameter to express measurement results. Most factors affecting the outcome of the measurement can be quantified and evaluated. The last one is assessment the measured data.

PARALLEL KINEMATIC INDUSTRIAL ROBOTS

Types of parallel kinematic industrial robots

The definition of industrial robot is according to ISO 8373 that it is automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. This robots use sensors to control the move on the path of travel of the end effector (device at the end of an arm or rod of robot designed to interact with the work environment, where the tools are attached). There are serial or parallel kinematic structure robots (Figure 1). The difference between them is that serial robots consist from links connected via actuated joints in series and a parallel robots are those who have at least two rods/legs connected to the end effector and the base via actuated or passive joints. There are for example tripod, octopod, hexapod and others robots with multi-axis serial, parallel and hybrid kinematic. The name of these robots is usually according of a number of rods. This robots are used for high-speed picking, packing, assembly, manufacturing or measuring. They can be used in all kinds of industry. We have also other kinds such as tricept. Difference between tricept and tripod is that tricept has a one helping central rod.[1]

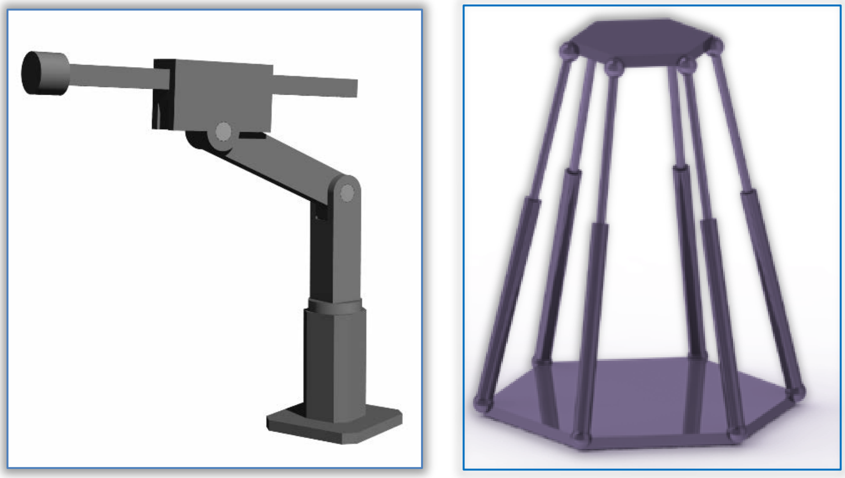


Figure 1 – Serial structure versus parallel structure robot type

Parallel kinematic type tricept

Parallel kinematic structure type tricept was designed and built at STU (Figure 2). It consists of static and movable platforms. Static platform lies on construction of tricept and it is attached by primary joints with three telescopic rods and one central rod. The movable platform is mounted with the telescopic rods by the secondary joints. The telescopic rods are actuators driven by autonomous servomotors with adjustable length. Ejecting is performed by ball screws. The end effector joined to movable platform can be for example milling machine, drill, manipulator etc.

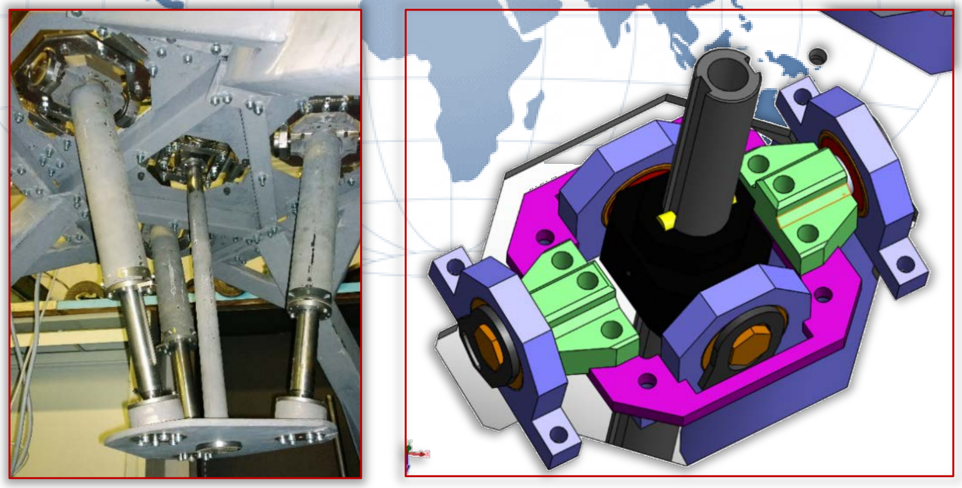


Figure 2 – Parallel structure type tricept

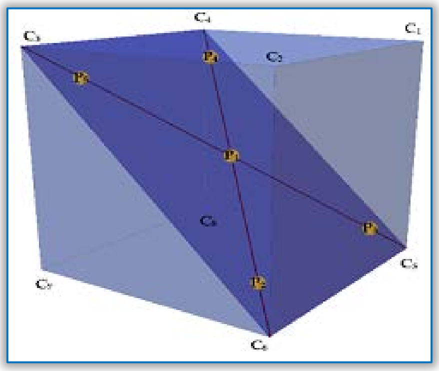
TESTING OF TRICEPT

The testing method of parallel kinematic structure triceptit based on the standard STN EN ISO 9283:2001. At first it is required to create a co-ordinate system of the tricept. Whereas that the static part of the tricept in situated on top of the effector, the origin of the coordinate system should be situated on the top of the static platform. For the simplification, we decided to put the origin of the co-ordinate system in the centre of the endpoint of the end effector during the maximal ejection of all rods.[3]

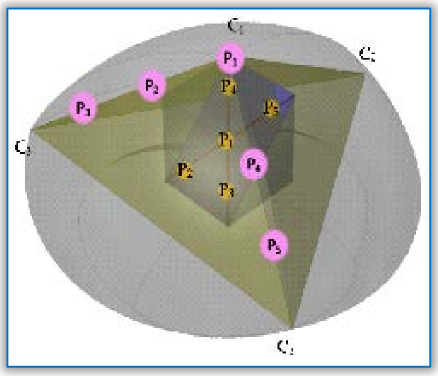
The next step is design of a covering spatial component, in which we define planes, in which are testing points. According to the standard ISO 9283 the measured position (P_1, P_2, P_3, P_4, P_5) are situated on a plane in a cube, which is determined by the edges of the cube (C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8). An example of such a cube with the testing plane $C_3 – C_4 – C_5 – C_6$ is in the Figure 3a.

The cube must be situated in the workspace of the tricept. Given the fact that the workspace has a typical form, the methodology of testing proposes to use the covering spatial component as an object adjusted on the basic workspace of the tricept (Figure 3 b). For better interpretation of the covering spatial component we inserted directly into the workspace different universal form - pyramid. A comparison of the size of these components in the workspace of tricept is in Figure 4.

The main reason why new methodology doesn't use a cube as recommended by standards, is covering the greatest possible volume of workspace of tricept. Another point of interest during measuring process is existence of singularities, thus places in the work field where it's not defined what values are measured.



a)



b)

Figure 3 a) Testing cubes with testing points P_1, P_2, P_3 and P_4 at $C_3 – C_4 – C_5 – C_6$, plane,
b) Covering solid feature for testing the tricept in contrast with a cube under STN EN ISO 9283:2001 standards.

Testing points (P_3 a P_5 according to Figure 3 b) are situated in a distance of at least 14% to the side of the pyramid (on which the testing points are situated) from the peaks of the base of the pyramid. For example if in the Figure 3 b) this side of the pyramid has a length of C_3C_1, then the distance of testing position P_3 must be at a minimum length of $0.14 \times C_3C_1$ compared to point C_3.[3,5]

During the testing of the covering spatial component, we will submit with requirements of the standard STN EN ISO 9283:2001 unless otherwise mentioned above. For example the positioning accuracy according to this standard is calculated as follows [3]:

$$\begin{aligned} AP_P &= \sqrt{(\overline{x}-x_c)^2+(\overline{y}-y_c)^2+(\overline{z}-z_c)^2} \\ AP_x &= (\overline{x}-x_c) \\ AP_y &= (\overline{y}-y_c) \\ AP_z &= (\overline{z}-z_c) \end{aligned} \qquad (0.1)$$

where $\overline{x}, \overline{y}$ and $\overline{z}$ are the coordinates of the barycentre of the cluster of points obtained after repeating the same pose n times, x_c, y_c and z_c are the coordinates of the command pose and x_j, y_j and z_j are the coordinates of the the j-th attained pose[3].

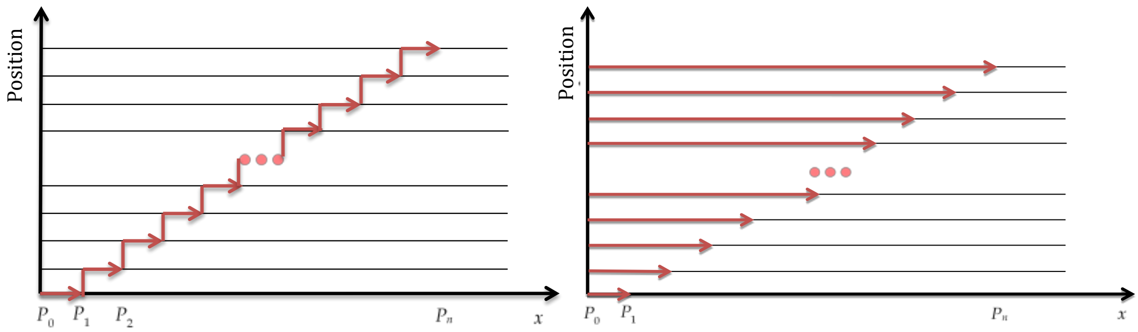


Figure 4. Illustration of possible cycles

Testing methodology of parallel kinematic type robot includes modelling using a CAD program. We had used Inventor® Professional 2016. Via integrated module LiveLink we had imported the model into numerical modelling software ComsolMultiphysics (Figure 4). Both programs Inventor® Professional 2016 and ComsolMultiphysics divide the model is into a finite number of elements using for example tetrahedral elements for creating a so-called tetrahedral network. The network was compressed in cultivated places where it was possible to expect a formation of edge stresses. In this way, the composite elements can be easily mathematically described. The biggest advantage of these programs is that they have a databases of the most commonly used modes. This programs can help to reduce number of considered factors and we use it for economical and time saving reasons.[5]

CONCLUSION

The paper presents in a nutshell new methodology intended to establish testing points for testing position accuracy. This method of testing parallel kinematic structure Tricept is based on the standard STN EN ISO 9283:2001. For better interpretation of the covering spatial component universal form - pyramid was inserted directly into the workspace. The comparison of the size of these components is presented in this paper where is shown the greater volume of workspace which is the advantage of new covering spatial component designed to testing kinematic structures with special workspace forms.

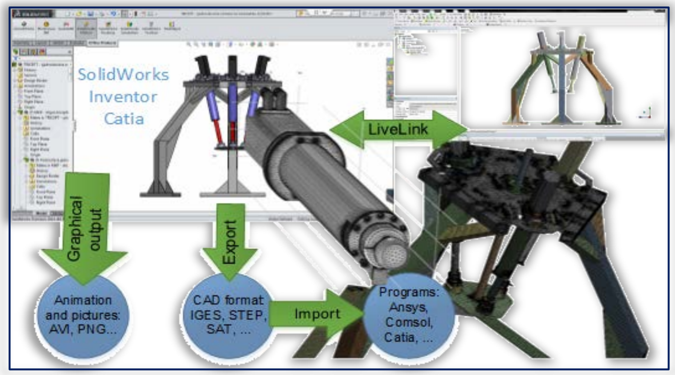


Figure 4. Advantages of creating geometric shapes in Autodesk Inventor [5]

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Note

This paper is based on the paper presented at The 10th International Conference for Young Researchers and PhD Students – ERIN 2016, organized by University of Zilina, Faculty of Mechanical Engineering, in Liptovský Ján, SLOVAKIA, May 10–12, 2016, referred here as [6].

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