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AN OVERVIEW OF ROBOTS WITH PARALLEL KINEMATIC STRUCTURE

Michal BARTOŠ[1], Ivan KURIC[2], Martin BOHUŠÍK[1], Vladimír STENCHLÁK[1]. Supervisor: Vladimír BULEJ[1]

[1]Faculty of Mechanical Engineering, Department of Automation and Production Systems, University of Žilina, Univerzitná 1, 010 26, Žilina, SR,
michal.bartos@fstroj.uniza.sk, martin.bohusik@fstroj.uniza.sk, vladimir.stenchlak@fstroj.uniza.sk, vladimir.bulej@fstroj.uniza.sk
[2]University of Bielsko-Biala, Faculty of Mechanical Engineering and Computer Science, Department of Industrial Engineering: kuric.ivan@gmail.com

The article is focused at current state of knowledge of robots with a parallel kinematic structure. Article describes robots with a parallel kinematic structure. The comparison between robots with a serial kinematic structure is made and the advantages of individual structures are described. The analysis of the construction and the division of parallel mechanisms is performed. The article describes the most well-known and unused constructions of robots with a parallel kinematic structure.

Robots with parallel kinematic structure

There are several definitions of the mechanism with parallel kinematic structure, the basic definition says: **"A general parallel manipulator is a mechanism with a closed kinematic chain, the end effector or platform of which is connected to the base by several (at least two) independent kinematic chains."[**4]

Parallel mechanisms are interesting due to some of their properties:

- at least two chains allow us to distribute the load evenly throughout the chain;
- minimum number of controls;
- the minimum number of sensors needed to control the mechanism in a closed loop;
- when the actuators are locked, the manipulator and its effector remain in position; this is an important security aspect for certain applications, such as medical robotics.

Parameter	Serial kinematic structure	Parallel kinematic structure
Mechanical architecture	+ simple architecture	- More complex architecture
Payload	- Higher weight, worse dynamic properties, higher flexibility	+ Lower weight, better dynamic properties, higher rigidity of the robot
Accuracy, repeatability	- Loss of accuracy and repeatability	+ Easier to achieve greater accuracy and repeatability
Actuator placement	- Worse dynamic properties - Greater robustness of the manipulator - The need to run cabling throughout the mechanical structure	+ Better dynamic properties + Lighter construction + Possibility to spatially separate the actuator
Workspace size	+ relatively large workspace	- The workspace is more complicated due to the more complex mechanical construction
Kinematics	direct - simple inverse - complex	inverse - simple direct - complex
Axle load	- high - each axis carries the same weight	+ low - weight division
Weight	- high	+ low
Load capacity	- average	+ high - weight division

Table 1. Comparison of properties of robots with serial and parallel kinematics structure[5]

2. Construction of a robotic device with a parallel kinematic structure

In the case of parallel robots, the endpoint is the so-called mobile platform (hereinafter referred to as the platform). The platform usually serves to support the attached end effector and is connected to the base by several parallel arranged arms (guide chains).

The whole structure contains at least one closed kinematic chain with at least two branches. Shifts in the legs cause the platform to shift, as shown in Fig. 1. Platform movements are defined by trigonometric functions of the direct and inverse kinematics tasks depending on the geometry of the mechanism, the type of joints, the number of arms, and their kinematic arrangement.

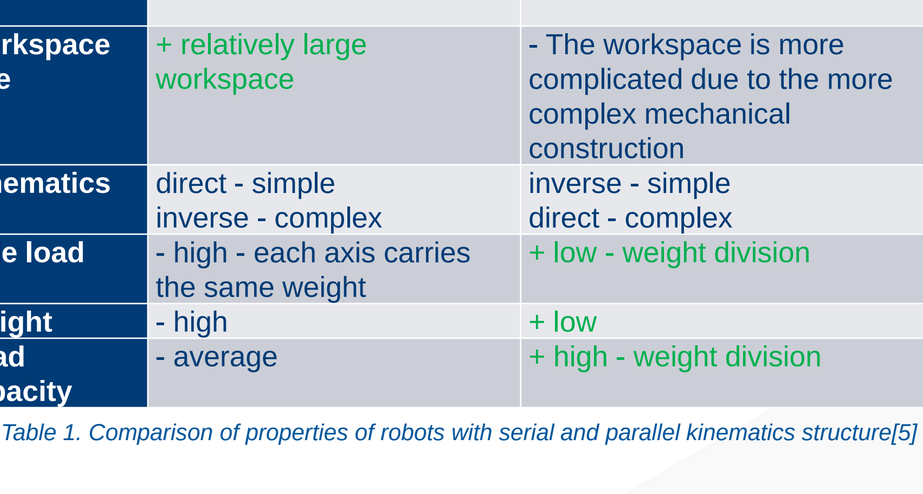

Figure 1 – Basic structure of robot with parallel kinematic structure

Parallel robots can also be divided according to the number of degrees of freedom, as follows:

- **Universal robot** - a robot that has all six degrees of freedom, is able to achieve any position and orientation in space.
- **Redundant robot -** has more than six degrees of freedom.
- **Deficient robot** - has less than six degrees of freedom. [8][9]

Parallel robots can be divided according to the shape of the workspace in which the effector or end platform moves into:

- **Plane -** its movement is allowed only within one plane, it has a maximum of three degrees of freedom (2T-1R).
- **Spatial -** moves in 3D space, so the robot can have up to 6 degrees of freedom (3T-3R). Guide chains of various types.
- **Spherical -** can only perform a spherical motion relative to its base.
- **Symmetric -** a manipulator that has the number of guide chains equal to the number of degrees of freedom [10]

Parallel robots can also be divided according to the number of guide chains (arms) into groups they have (some types of parallel robots are shown in the pictures below):

- **Six guide chains:** - hexapod/linapod
- **Five guide chains:** - pentapod
- **Three guide chains**: - tripod/tricept/trivariant/exechon
  - delta robot/triglid
- **Two guide chains:** - bipod

3. Areas of application and usage of parallel robots

The industrial sphere is probably the most important in terms of the use of parallel kinematic structures. Of course, parallel kinematic robots did not push serial kinematic robots out of the industrial robot market, but thanks to its advantages such as **rigidity** and **very good dynamics**, they found their application. Many variants of the construction of parallel structures also offer a wide range of applications. The main areas of application of parallel kinematics include:

- Machining
- Forming machines
- Test equipment
- Rehabilitation aids
- Handling operations
- Measuring machines
- Simulation devices
- Pharmaceutical and medical facilities

According to the purpose, industrial robots and manipulators can be divided into several groups, namely performing robots[17]:

Technological operations:

- spot welding (Fanuc Robotic - F200i)
- laser welding (Neos Robotic- Tricept 805),
- water jet machining (Fooke - Triomaxx)
- deburring of castings (MutiCraft - MultiCraft 560),
- wood processing (Reichenbacher - Pegasus)

Handling operations:

- manipulator (SMT Tricept - TM 805, TR 600),
- positioning of samples under microscopes (Hexel - Hexabot;
- positioning of the workpiece (TAS Hexapod),
- positioning of optical elements (Laval University - Agle Eye),
- positioning of simulator platforms (CAE-Flight simulators - AH-I)

Assembly operations (Festo - Delta robot; SMT Tricept - TR 600).[18]

Conclusion

The article deals with an overview of parallel kinematics robots their architecture and usage in the industry. Also, kinematics and their parts are described. A comparison with serial robots is made. In the future is expected that parallel robots will be increasingly implemented in industry. These robots can replace serial kinematics robots in certain applications. But the development is still

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