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CONTROL OF 2D DELTA ROBOT WITH SIEMENS TECHNOLOGY PLC

Bogdan Gajić, *Roking, Belgrade, bogdan94@hotmail.com*
Miloš Božić, *Vorwerk-autotec, Serbia, Čačak, m.bozic@vorwerk-automotive.rs*
Vojislav Vujičić, *University of Kragujevac, Faculty of technical sciences, Čačak, vojislav.vujicic@ftn.kg.ac.rs*
Miroslav Bjekić, *University of Kragujevac, Faculty of technical sciences, Čačak, miroslav.bjekic@ftn.kg.ac.rs*
Srećko Ćurčić, *University of Kragujevac, Faculty of technical sciences, Čačak, srecko.curcic@ftn.kg.ac.rs*

Abstract

This paper presents the realization of a 2D Delta robot and control using the Siemens technology PLC controller S1511. The 2D Delta robot is powered using synchronous servo motors controlled by the Siemens servo drivers V90. The robot monitoring and control is realized via Siemens HMI panel. All devices communicate over Profinet industrial network. Configuration of robot kinematic and transformation in TIA portal is also presented.

Keywords: Delta robot, kinematic, PLC, servo, Profinet.

INTRODUCTION

With the progress of computer technology and the capabilities of today's processors, modern PLC controllers provide features that once required specialized controllers. One of the examples is the application of PLC controllers in applications with robots. The modern Siemens PLC 1500T PLC technology controllers [1] enables control of various types of robots such as SCARA, Delta robot, etc. Program and management implementation is done according to IEC 61131-3 [2], which enables PLC developers to easily program applications with robots without learning new programming languages and learning new development environments.

This paper presents an educational example of a Delta robot application using a PLC controller. The paper consists of the following sections. The first part is short overview of parallel kinematic robot and its usage. In the second part realization of a delta robot model and control is presented. The third part shows some of the kinematics functions and possibilities for creation of complex movements.

DELTA ROBOT OVERVIEW

Delta robots were created as an engineer response to the industry's need for fast, accurate and repetitive low load operations. Due to such features, they have become an indispensable part of automated systems that handle packaging, sorting and similar operations. They are suitable for working with small electronic components as well as with food. Except for packaging and sorting, these robots are used in medicine as well in 3D printing tasks.

Fig. 1. *ABB delta robot* [3]

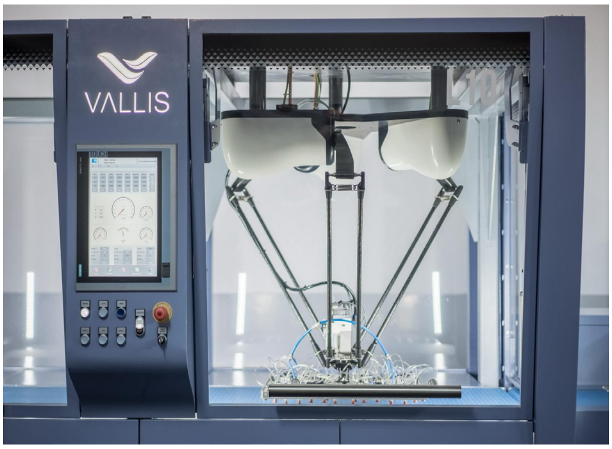

Fig. 2. *Delta robot in high efficiency machine for inmold labels* [4]

Delta robot is a type of parallel manipulator consisting of two or three arms that are attached at one end to the base platform and at the other end to the movable platform on which the gripper is located. There are actuators on the base platform, one for each arm, and the arms consist of two parts, the actuated part and the passive part. A Delta robot with, for example, 3 degrees of freedom may, depending on whether tool has an actuator, have a fourth degree of freedom representing the orientation of the tool. The most common installation of such systems is with the arms hanging from the top.

There are delta robots that use linear actuators. The appearance of such a robot is shown in the figure (Fig.3) for 3D printing tasks.

Fig. 3. *3D printer with parallel kinematics and linear actuators*

ROBOT REALIZATION

In this paper, a 2D delta robot was implemented because of its simplicity and ease of implementation on an existing platform with servo motors. The configuration of the 2 deegree delta robot is shown in the following figure.

Fig. 4. *Realized 2D delta robot*

As can be seen from the figure above, this configuration allows the movement of the actuator in two axes and thus has two degrees of freedom, the third degree of freedom can be achieved by controlling the orientation of the tool.

The following figure (Fig.5) gives a graphical representation of the front view of such an assembly together with the indicated essential parameters and coordinate systems.

Based on kinematics zero point, all geometric parameters of the kinematics object are defined.

Flange Coordinate System - the coordinate system of a tool whose z axis always points in the negative direction to the z axis of the kinematic coordinate system.

The zero position of the kinematics is indicated with solid line, while the displacement of the kinematic system for the given angles α_1 and α_2 is indicated by a dashed line. A_1 and A_2 represent the rotary axes of the actuator.

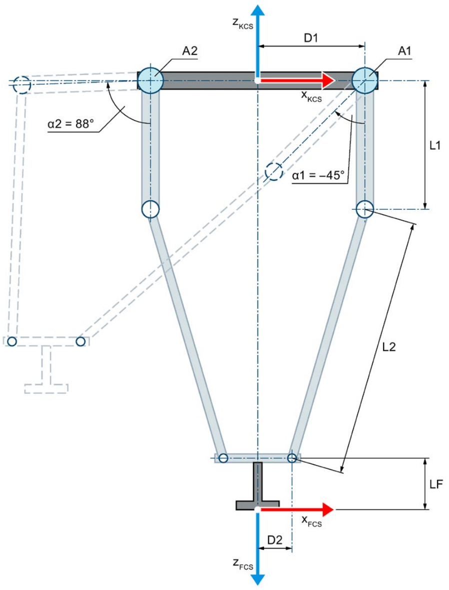

Fig. 5. *2D delta robots with highlighted important parameters* [4]

Geometric distances:

• D_1 denotes the distance from the center of the axis A_1 to the center of the base platform (radius of the base platform)

• D_2 indicates the distance from the engagement of the lower arm to the center of the mobile platform (radius of the mobile platform)

• L_1 indicates the length of the upper arm

• L_2 indicates the length of the lower arm

• LF denotes the distance of the origin of the tool coordinate system from the moving platform expressed in the z axis of the kinematic coordinate system

• D_1 and D_2, L_1 and L_2 are identical for both arms of the robot

In the zero position of the A_1 and A_2 axes, the upper arms show in the negative direction the z axis of the kinematic coordinate system.

The following figure shows the allowed and not permitted joint positions.

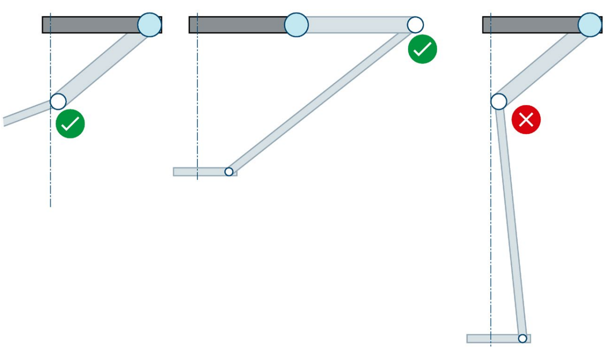

Fig. 6. *Allowed joint positions of 2D delta robots* [4]

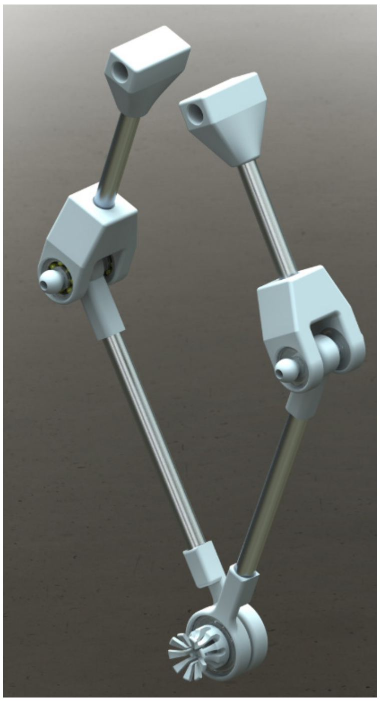

Fig. 7. *3D model or robot assembly*

CONTROL SYSTEM

The following figure shows the control system used to control the delta robot.

Fig. 8. *Delta robot control equipment*

The components used for 2D delta robot are:

1) Human machine interface (SIMATIC HMI-KTP400 BASIC / 6AV2123-2DB03-0AX0)
2) Power module (PM 190W 120/230 VAC / 6EP1333-4BA00)
3) Programable logic controller (SIMATIC S7-1500T / CPU 1511T-1 PN, 6ES7511-1TK01-0AB0)
4) Servo drivers (SINAMICS V90 PN / 6SL3210-5FB10-1UF0)
5) Servo motors (SIMOTICS S-1FL6 / 1FL6022-2AF21-1AA1)

Siemens kinematics are user-programmable mechanical systems in which multiple mechanically coupled axes produce the motion of a working point. The S7-1500T technology CPUs provide functions for controlling kinematics systems, e.g. for handling tasks, with the kinematics technology object. Typical applications include pick & place, installation and palletizing. The kinematics control panel and extensive online and diagnostic functions support commissioning of kinematics systems. The kinematics technology object is integrated in the system diagnostics of the S7-1500 CPU. The kinematics technology object calculates motion setpoints for the tool center point (TCP) of the kinematics considering the dynamic settings. The kinematics technology object calculates the motion setpoints for the individual axes of the kinematics and vice versa from the current values of the axes using the kinematics transformation. The kinematics technology object outputs the axis-specific motion setpoints to the interconnected positioning axes.

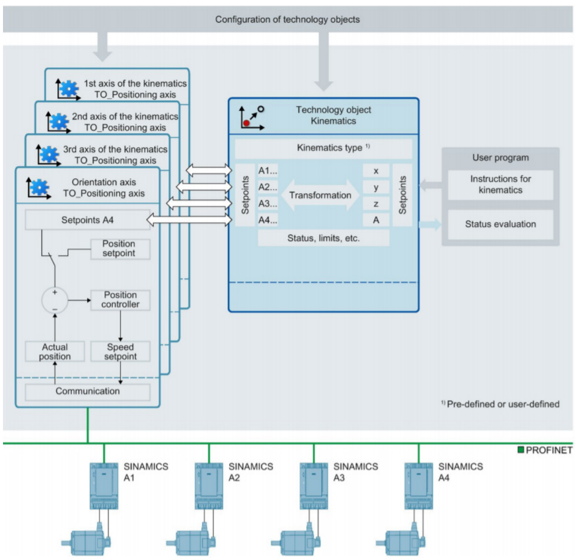

Fig. 9. Configuration of technology object

The kinematics technology object provides the kinematics transformation for the predefined kinematics types on the system level. If the user defined kinematics systems, user also must provide the user transformation in a separate program.
User must create the individual axes of the kinematics in the TIA Portal as *Positioning axis* or *Synchronous axis* technology objects. When the configuration of the kinematics technology object is finished, relation of axes is in accordance with the configured kinematics type.

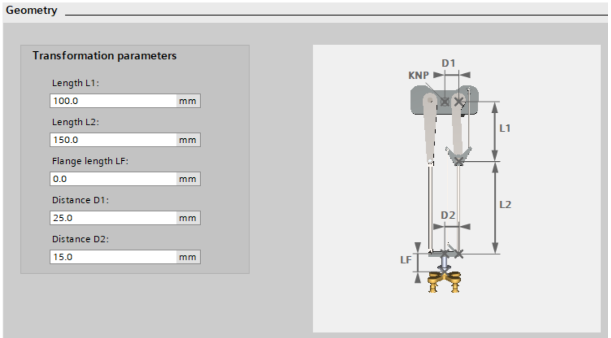

***Fig. 10.** Configuration of the Delta robot segments dimension*

After adjusting the geometry of the robot, it is necessary to define the dynamic characteristics of the robot. The following figure shows a window that defines the speed, acceleration and jerk of the robot axis.

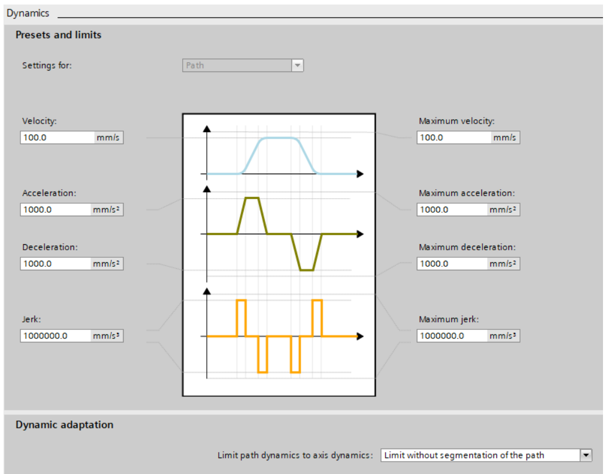

***Fig. 11.** Configuration of the dynamic of Delta robot*

FUNCTIONS OF THE KINEMATICS TECHNOLOGY OBJECT

Functions of the kinematics technology object is executing by using the motion control instructions. The following table shows some of the functions that are supported by the technology object.

***Table 1** – Kinematic functions for interpolation*

MC_MoveLinearAbsolute
MC_MoveLinearRelative
MC_MoveCircularAbsolute
MC_MoveCircularRelative

MC_MoveLinearAbsolute/Relative

With the Motion Control instruction MC_MoveLinearAbsolute, a kinematics is move with a linear motion to an absolute/relative position. Cartesian orientation is also used absolute/relative. Dynamic behavior during movement is defined with the parameters *Velocity*, *Acceleration*, *Deceleration* and *Jerk*.

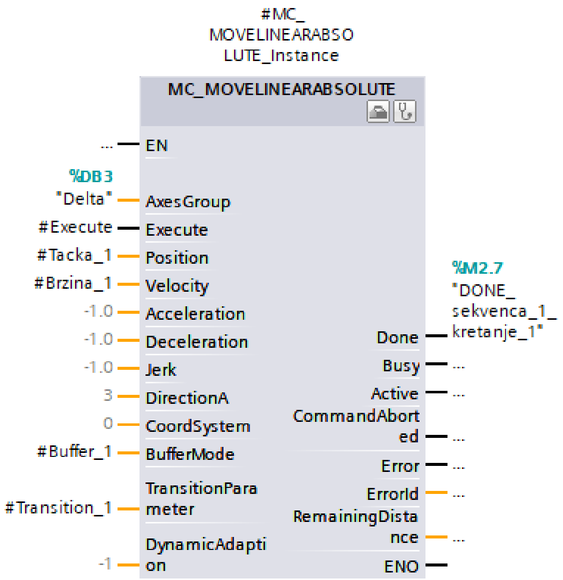

Fig. 12. Function block for absolute linear motion

MC_MoveCircularAbsolute/Relative

With the Motion Control instruction MC_MoveCircularAbsolute, a kinematics is moved with a circular motion to an absolute/relative position. Cartesian orientation is also used absolute/relative. Dynamic behavior during movement is defined with the parameters *Velocity*, *Acceleration*, *Deceleration* and *Jerk*.

There are three types of movement to achieve the same target point:

- Via an intermediate point and the end point
- Via the circle center and angle in a main plane
- Via the circle radius and the end point in a main plane

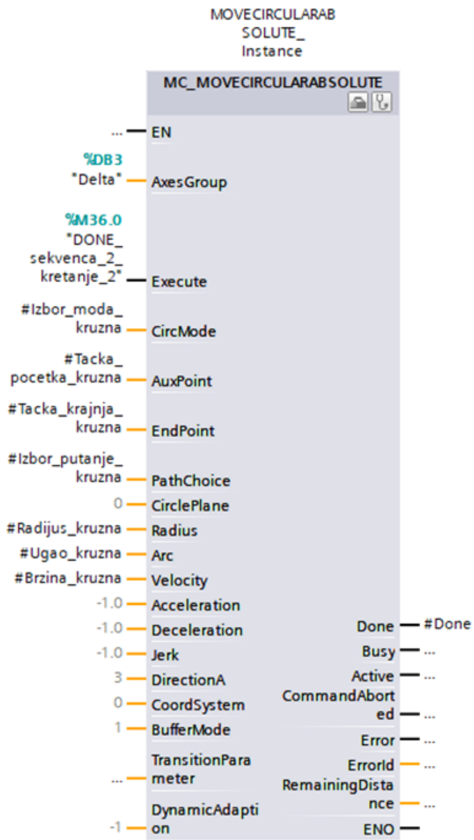

Fig. 13. Function block for absolute circular motion

COMPLEX MOVEMENTS

Linear and circular movements can be joined. The robot, for example, moves linearly on a section of the path, then performs a circular motion. When going from one path to the next, it is possible to choose the proximity of the passage near the target point, as it is case with standard industrial manipulators.

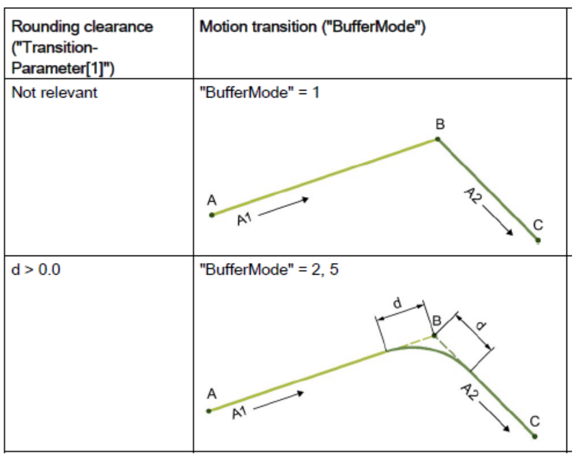

Fig. 14. Two linear movements connected [4]

It is possible to record the programmed and traveled path within the TIA portal. The following figure shows the layout of the robot window and model of Delta robot during operation. One can notice the red path that the robot has pass.

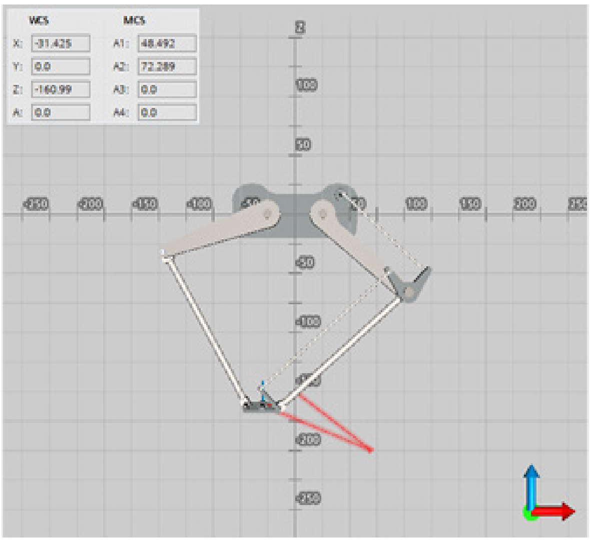

Fig. 15. *Path recording*

CONCLUSION

In this paper is presented one realized 2 axis Delta robot. The Delta robot is controlled by the application of a PLC controller and standard motion function blocks. Using only two servo motors and simple mechanical parts, the mode of operation of a two-axis delta robot can be displayed. This model is very suitable for education because is based on a simple model. It is very easy to show the basics of kinematics, transformation matrices and demonstrate all this on this simple robot based on industrial equipment.

ACKNOWLEDGEMENTS

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