Proceedings Book of
9th ICEEE – 2018 International Conference on
"*Climatic Change and Environmental (Bio) Engineering*"
22nd - 24th of November, 2018
Budapest, Hungary

ISBN 978-963-449-105-7 Publisher: ICEEE, RKK Óbuda University

TYPES OF SERVO AXES SYNCHRONIZATION FOR USE IN AUTOMOTIVE RECYCLING INDUSTRY

Miloš BOŽIĆ[1], Vojislav VUJIČIĆ[1], Srećko ĆURČIĆ[1], Milan PAVLOVIĆ[2]

[1]University of Kragujevac, Faculty of technical sciences Čačak, Serbia
[2]University Business Academy, Novi Sad, Serbia

Abstract

To optimize the recycling process in automotive industry, it is necessary to constantly innovates machines where recycling processes take place. In recycling processes, we have selection and cutting of various materials such as: metal, glass, plastic, wood, leather, etc. Various electric drives are used for all these processes. In the past the drives were only mechanically coupled. Mechanical couplings such as gears, couplings, sprockets and other mechanical power transmissions are reliable solutions but not flexible. Changing the gear ratio between the two axes of motion would require a change in the ratio of the mechanical gears or the use of a gearbox. With the development of electronics, the gearing of the axis was moved from domain of mechanics into the domain of electronics. Thanks to the fast regulation structures inside servo drives it is possible to couple two or more axes of movement without mechanical connections, only based on the reading from the position sensor. By introducing electronic coupling, the change in the gear ratio in the software itself is possible without any changes to the mechanics during the work. The paper provides an overview of the basic concepts and parameters for synchronization of two axes in motion. Also, the necessary parameters and settings are explained for synchronizing two axes. Finally, a comparative analysis of three synchronization types was performed: Reverse motion, Synchronizing and Symmetrical, with its advantages and disadvantages on Siemens S1500T platform.

Keywords: *recycling, drives, axes of movement, electronic gearing.*

1. INTRODUCTION

In the process of recycling, it is necessary to cut the time of recycling, use less energy and to protect people from work in dangerous environment. To do this, it is necessary to use modern technologies as robotic separators and cutters. Modern automatic selection lines, known as sortex lines has cameras for classification of different types of materials. After detection of different types of material, it is necessary to put those different materials in appropriate containers. To optimize further these processes, it is necessary to make synchronization between conveyers and robots. Also, in the process of cutting various materials to obtain desired shapes and dimensions, axis synchronization is required. Synchronization of different axes is in the most cases coupled mechanically. Mechanical couplings for power transmission are reliable solutions but not flexible. To increase the productivity, quality and flexibility of modern recycling systems, it is necessary to drive it electronically and make it flexible [10,11].

Electronically coupled servo-driven axes will be presented for the case of two independent axes of movement. First axis will be the master axis, and second one will be slave axis. The leading axis -master gives the value that represents the reference for the slave axis, while the slave axis follows this value according to the defined requirements. Requirements can be in terms of: gear ratio, scaling or different functions between the master and the slave axis.

From the standpoint of mechanics, the synchronized movement of the two axes implies a pair of gears in a relationship. For complicated non-linear relations, curves were used. Curves allows the motion in a non-linear relation. Electronically coupled drives introduces the possibility of defining different curves of motion without complex machine elements and a simple change in the relationship of complex motion by changing the function that defines the connection between the two axes. In the following figure, you can see a block diagram of master and slave axes electronically coupled.

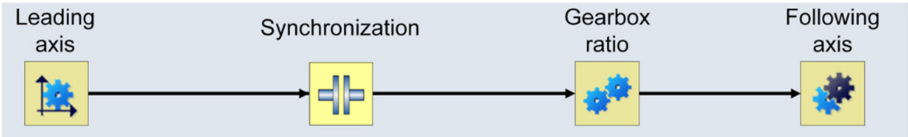

Figure 9: Block diagram of electronic gearing of axes

The setup for demonstration of the principles of electronic gearing is shown in Figure 2 [1, 2].

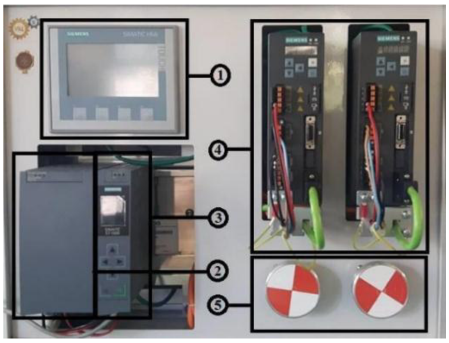

Figure 10: The setup for axes synchronization demonstration 1) SIMATIC HMI-KTP400 BASIC (6AV2123-2DB03-0AX0) operator panel, 2) Power module PM 190W 120/230 VAC (6EP1333-4BA00), 3) PLC SIMATIC S7-CPU 1511T -1 PN (6ES7511-1TK01-0AB0), 4) Servo drivers SINAMICS V90 PN (6SL3210-5FB10-1UF0) and servo motors SIMOTICS S-1FL6 (1FL6022-2AF21-1AA1) [1,2]

2. MOTION CONTROL EXAMPLE OF ON THE FLY MATERIAL SELECTION

In accordance with the Open Motion standard [3], there are functional blocks that are standardized and customized for use in industrial applications which include and motion applications. In addition to the general blocks used to turn the servo axis on, homing, resetting errors, etc. There are several special functional blocks that allow synchronization of the movement which are shown in the Table 1.

Table 1: Special functional blocks for synchronization

MC_GearIn	Runs relative synchronization.
MC_GearInPos	Runs absolute synchronization.
MC_PhasingRelative	Relative positioning using MC_GearIn and MC_GearInPos.
MC_PhasingAbsolute	Absolute positioning using MC_GearIn and MC_GearInPos.
MC_Camin	Runs coupling with CAM profiles.

Electronic coupling can be relative and absolute. Relative coupling is the coupling without definition of the phase between the axes in movement. Gearing is executed right after the synchronization request is received, and in accordance with the dynamic capabilities of the process itself. Absolute coupling is the coupling where the phase between the axes in movement is defined. The coupling is performed according to the requirements for the position between the axes or according to the dynamic parameters of the system [4, 5].

The following figure shows the principle of the selection process of different types of recycled materials on the fly, without stopping conveyor by using synchronization. The selection line system has two axes. Conveyor as master axis brings recycled parts. Servo drive with spindle moves carts which is equipped with robotic griper [6 - 9]. This concept can be applied to modern recycling systems [11].

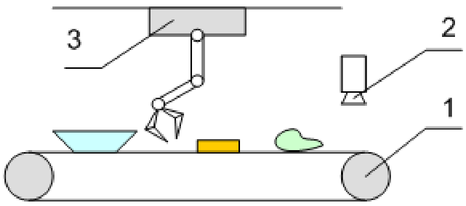

Figure 3: System for on the fly recycling 1) conveyor as master axes, 2) high speed camera for position detection of different types of materials, 3) servo axis with robotic griper as slave axis

The cart is defined as a linear axis with software and hardware limit switches. The process of selection on the fly has four phases:

1. Synchronization of the carts by speed and/or position
2. Synchronization movement of servo axis with conveyor when the taking operation is performed
3. Go to the appropriate container position
4. Go to waiting position or in the new cycle

This type of application can be realized by using absolute synchronization, i.e. using the functional block MC_GearInPos. Table 2. shows the appearance of the functional block and gives the meaning of the input parameters. Using the MC_GearInPos functional block, the synchronization is performed in relation to the leading position and the following axis. There are two types of synchronization using this block. SyncProfileReference = 0 - represents a synchronization type 0 using dynamic system parameters and SyncProfileReference = 1 - represents the type 1 of synchronization using the distance axis value.

Table2. Inputs of functional block for position synchronization

Master	Leading axis
Slave	Following axis
Execute	Signal for execution of function block
Ratio Numerator	Gear ratio on the master side
Ratio Denominator	Gear ratio on the slave side
Master Sync Position	Master axis synchronization position
Slave Sync Position	Slave axis synchronization position
Sync Profile Reference	The type of synchronization mode
Master Start Distance	Master axis traveled path during synchronization
Velocity, Acceleration, Deceleration, Jerk	Motion parameters
Sync Direction	Direction of motion for synchronization

Master distance (synchronization type 1) - By applying this type of synchronization, it is necessary to define the position of synchronization as well as the path traveled during synchronization. The start and end positions of the synchronization are clearly defined. Dynamic parameters are in the second plan. The processor performs a calculation based on the position of the slave axis and master axis. Depending on the values of the initial and final position parameters, three different cases can be observed. 1. Reverse motion, 2. Synchronizing and 3. Symmetrical.

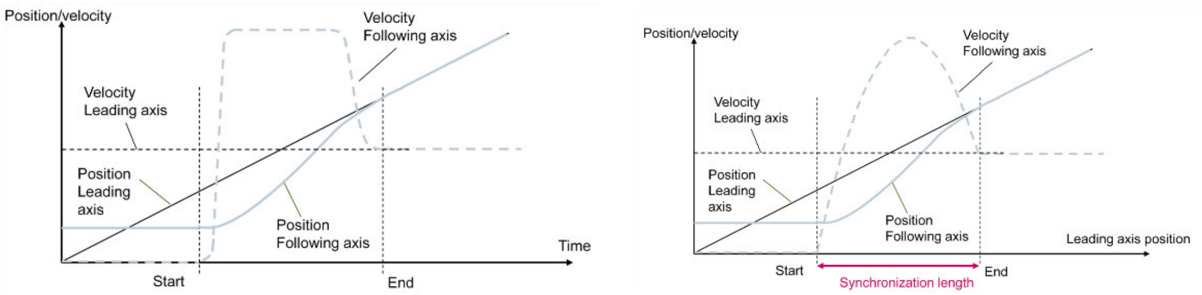

Figure 4. Synchronization Type 0 and Type 1

3. RESULTS AND DISCUSSION

3.1 Revers motion

The first case of synchronization is given in Figure 5. From the diagram there is a movement of the slave axis backwards to achieve synchronization. When recording this diagram, the values of the parameters were as follows:

Master Sync Position = Slave Sync Position = Sync Position = 0mm

Master Start Distance = 100 mm

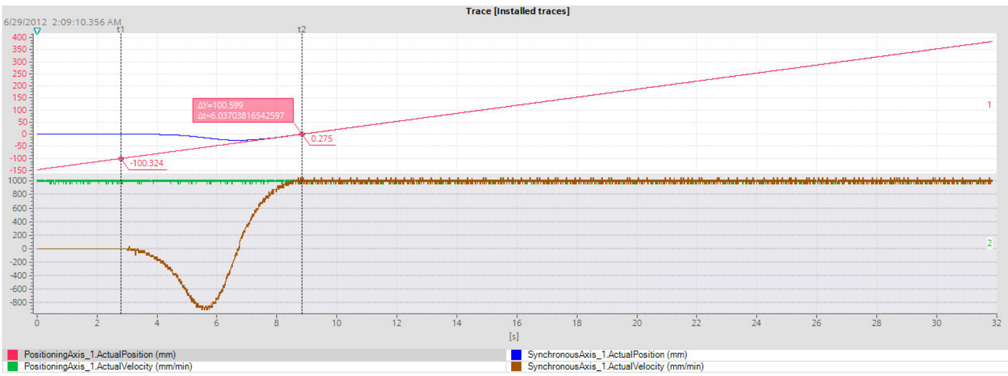

Figure 5. Diagrams of speeds and positions in the synchronization of Revers motion

As can be seen on the diagram, the master axis is moving at a constant speed. Slave axis isn't moving until the master axis achieves the position for the synchronization start.

Start Sync = Sync Position – Master Start Distance

In this case, the start of the synchronization is in the -100 mm position, because:

Sync Position – Master Start Distance = -100mm

Typical for this type of the synchronization is that the slave axis moves in both directions during the synchronization phase. In some applications, this can be a problem, and this kind of synchronization mode is avoided.

3.2 Synchronizing synchronization

The second type of synchronization is the synchronization of the two servo axes in the manner shown in Figure 6. The diagram shows values for this type of synchronization.

Master Sync Position = Slave Sync Position = Sync Position=500 mm

Master Start Distance = 200 mm

As can be seen on the diagram, the master axis is moving at a constant speed. Slave axis isn't moving until the master axis achieves the position for the synchronization start

Start Sync = Sync Position – Master Start Distance

In this case, the synchronization start is in the 300 mm position, because:

Sync Position – Master Start Distance = 200 mm

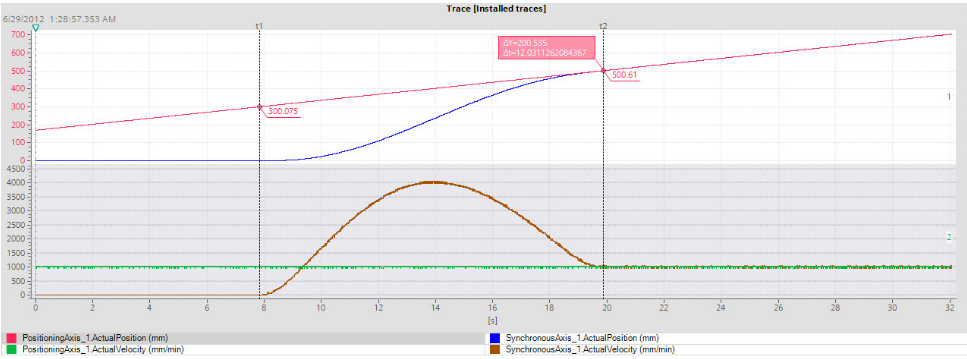

Figure 6. Diagram of speeds and positions during synchronization

3.3 Symmetrical (Optimal) synchronization

Figure 7 shows the appearance of the speed and position diagram during this type of synchronization. For recording these diagrams, the following values are set:

Master Sync Position = Slave Sync Position = Sync Position = 500 mm

***Master Start Distance* = 200 mm**

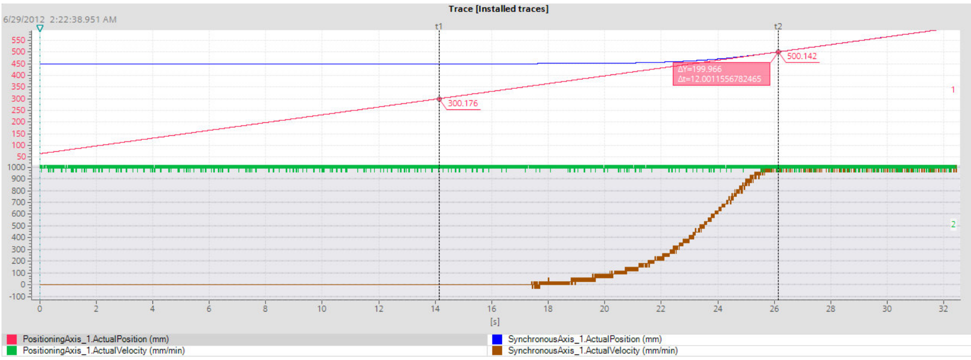

Figure 7. Symmetrical synchronization and speed and position diagrams

As can be seen on the diagrams, the master axis is moving at a constant speed. Slave axis isn't moving until the master axis achieves the position for the synchronization start.

Start Synchronization = Sync Position – Master Start Distance

Sync Position – Master Start Distance = 300mm

Typical for this type of synchronization is that the slave axis is moving only in forward direction during synchronization and the speed is not higher than the speed of the master axis. This synchronization method has the longest synchronization path. However, the advantage of this kind of synchronization is reflected in the fact that the slave axis does not reach the speed greater than the master axis, as well as the movement is only in one direction during synchronization. In the literature, the name optimal synchronization can often be found for this type of synchronization.

Conclusion

An analysis of the development of world experiences in the field of material flow management in the recycling of vehicles show constant progress. The most important is constant improvement of existing processing systems and its response to new challenges. To improve the performance of recycling systems, it is necessary to implement the latest technologies. In this work three types of synchronization which can be implemented in real industrial applications for automotive recycling were presented. By using this concept, given in this paper, the performance of automotive recycling systems can be significantly improved.

Acknowledgment

This work is the result of work on the projects of title: Sustainable development of technology and equipment for motor vehicles recycling No. TR 35033 (2011-2014 (2018)). Which financed by the Ministry Science and Technological Development of Republic of Serbia. Research presented in this paper was supported by Ministry of Science and Technological Development of Republic of Serbia, Grant TR 35033.

References

[1] Miloš Srejić, Example of application of CAM profile using PLC CPU 1511T-1 PN and servo driver SINAMICS V90, bachelor thesis, University of Kragujevac, Faculty of technical sciences Čačak, 2018
[2] Igor Joksimovic, Application of Flying Scissors by applying PLC CPU 1511T PN and SINAMICS V90 Servo Driver , bachelor thesis, University of Kragujevac, Faculty of technical sciences Čačak, 2018
[3] TC2 – Motion Control, Open motion standard [internet] 2018, Available from: http://www.plcopen.org/pages/tc2_motion_control/
[4] Siemens Motion Control [internet]. 2018. Available from: https://w3.siemens.com/mcms/mc-solutions/en/motion-control/pages/motioncontrol.aspx
[5] Industrial protocols [internet]. 2018. Available from: http://www.keep.ftn.uns.ac.rs/predmeti/ee2_3g_indsys_protokoli/
[6] SIMATIC S7-1500 CPU 1511-1 PN manual [internet]. 2018. Available from: https://support.industry.siemens.com
[7] Servo drive V90 manual [internet]. 2018. Available from: https://support.industry.siemens.com
[8] Siemens simatic hmi panels manual [internet]. 2018. Available from: https://support.industry.siemens.com
[9] Marko Petrović, Education board PLC-M258, frequency converter Altivar 32, servo driver Lexium32M, example application Flying saw, master thesis, University of Kragujevac, Faculty of technical sciences Čačak, 2016.
[10] Pavlovic M., Curcic S., Tomovic A., Milunovic S. National economy resource capability for production recycling equipment for motor vehicles, 7th International Quality Conference, Proceedings ISBN:978-86-86663-94-8, May 24th 2013 Center for Quality, Faculty of Engineering, University of Kragujevac, pp 559-565.
[11] Curcic S., Milunovic S. Reengineering prefabricated systems in function flexibility and productivity, International conference UNITECH 2007, 23-24. November 2007, Gabrovo.

Corresponding author:
Miloš Božić, asistent
Department of mechatronics
Faculty of technical sciences Čačak
University of Kragujevac
Svetog Save 65, 32000, Čačak, Serbia
phone: +381648525361

E-mail: milos.bozic@ftn.kg.ac.rs