23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

ROTARY MOTION SELECTED CONTROL METHODS ANALYSIS FOR PADDLE SORTERS ARMS

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Abstract: *The paper presents the research results of two methods for the paddle sorter rotary motion control used in the sorting process of the objects transported on a conveyor belt. The paddle sorter arm is driven by a set of servo which consists of a servomotor and a servo drive where motion control is carried out using the voltage pulses generated by microcontroller board, designed by the author. In the control of the paddle sorter motion the smallest possible acceleration achievement is important while the assumed trajectory tracking error obtains permissible value. It turned out that open loop motion control method based on IIR filter (Infinite Impulse Response) is a better solution than PLL motion control (Phase Locked Loop) due to the lower extreme acceleration obtainment at the same assumed permissible trajectory error.*

Keywords: High speed paddle sorters, Servo, Motion control, PLL, IIR.

1. Introduction

Contemporary methods of parts separation for assembly lines or parcel deliveries in logistic centres implement entirely automatic stream sorting systems where control reliability subject to high regime.

Sorting process involves sorters as they have a direct impact on safety of units sorted in the context of dynamic overloads. Paddle sorters are well-known and appreciated devices due to their simple constructions and reliability (McGuire P. M., 2009). Paddle sorters can be driven by various types of mechanisms e.g. a four-bar linkage, although today servo drives and motors are more popular due to a possibility to choose from a variety of motion profiles such that mentioned overloads are minimized. Set of servo can include various servomotors such as PMSM (permanent magnet synchronous motors), BLDC motors (brushless direct current motor) or stepper motors. Different position control systems based on feedback loops (Linares-Flores et al., 2015) as well as digital filters damping overload can be implemented in order to control the servo drive (Besset et al., 2016, Chang, Tsu-Chin Tsao, 2014, Biagiotti et. al., 2012). The purpose of this paper is to compare two contemporary motion control solutions with implementation of the PLL (Phase Locked Loop) and the IIR filter (Infinite Impulse Response) for paddle sorter arm. The control method with IIR filter is the variant preferred as it allows smooth out the course of position such that the first derivatives of position – velocity is continuous and finally finite acceleration values.

2. Unit examined

The unit examined has been presented in Fig. 1. Paddle sorters driven by a stepper servomotor have been installed beside the conveyor belt. The unit has been equipped with a set of servo consisting of the (1) ES-DH2306 (servo drive) and (2) ES-MH342200 (servomotor) made by Leadshine with GL80 planetary gearbox. Information about angular position of the paddle sorters is passed to the servo drive with (3) STM32F429 microcontroller by means of (4) EL7202 (MOSFET driver) and two lines in a form of

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pulses, steps and direction with the implementation of timer module hardware and the microcontroller working in PWM mode (Pulse Width Modulation).

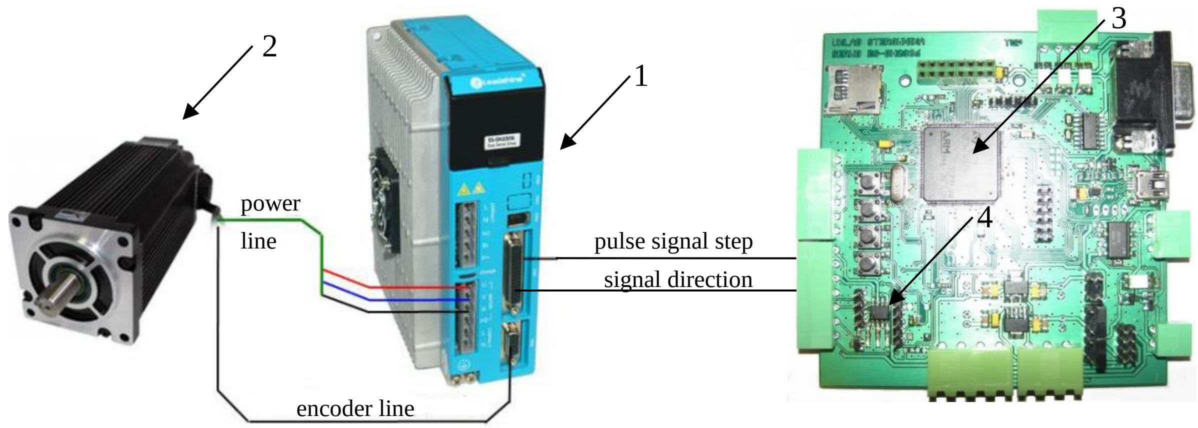

Fig. 1: Scheme of the unit examined: 1 – servo drive, 2 – servomotor, 3 – microcontroller board as a master control unit, 4 – MOSFET driver for step and direction pulses generation.

3. Hardware and software for microcontroller board

Microcontroller, SD card slot and MOSFET driver are the most important elements of the microcontroller board. Fig. 2 is divided into three blocks: microcontroller software (1), microcontroller hardware (2) and device board hardware (3).

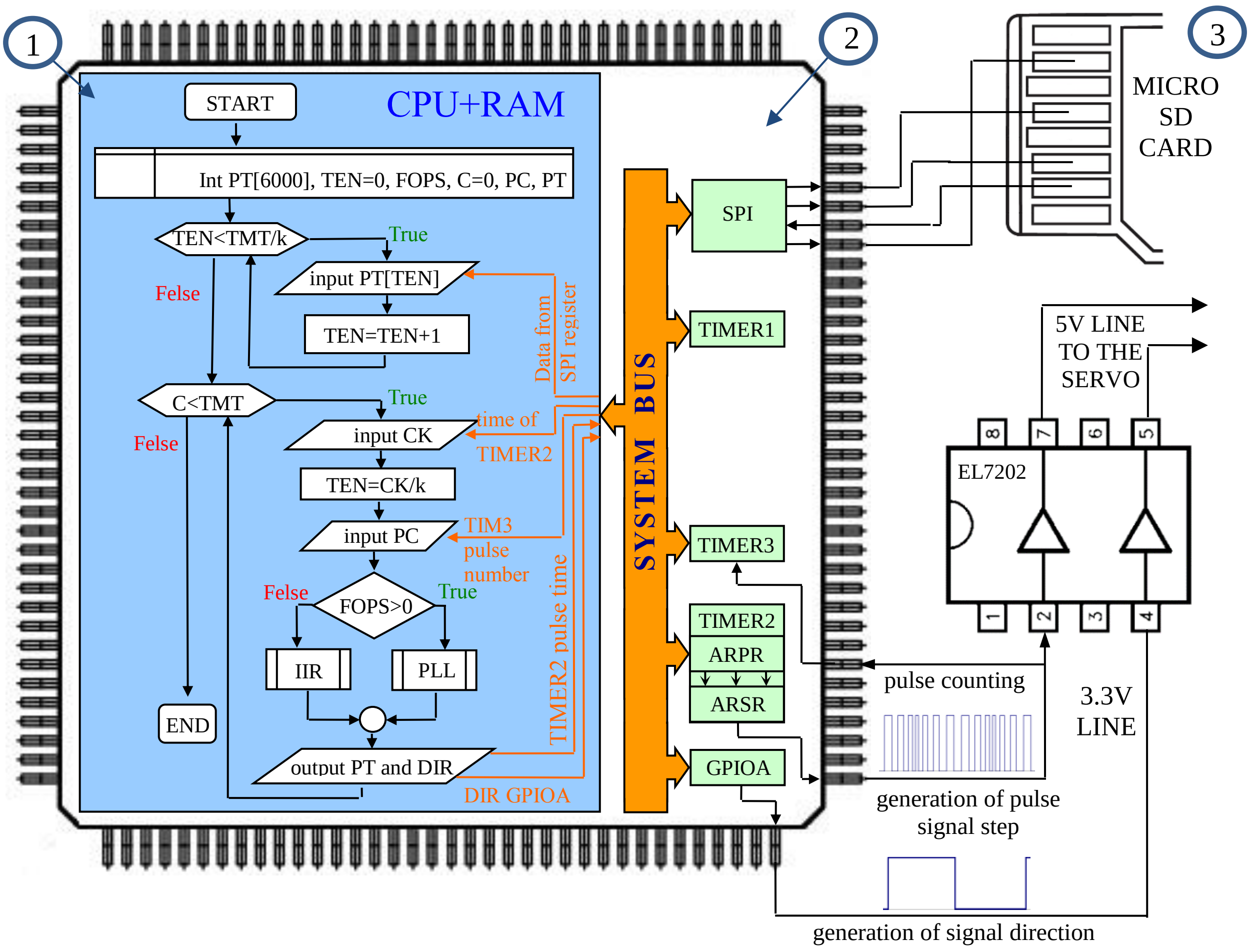

Fig. 2: Program block diagram of microcontroller (flowchart) and connection scheme of main devices of microcontroller board: TEN – table element number, PT – position table, FOPS-FIR or PLL select, CK– clock, TMT – total movement time, PT – pulse time, PC – pulse counter, k – the time interval between successive elements of the array.

Peripheral modules in a microcontroller such as timer modules or SPI (Serial Peripheral Interface) are available for CPU through the bus system. Blue field shows the flowchart of program executed by CPU microcontroller. At first the array of integers from the SD card is transferred to the RAM memory which represents course of reference position. As soon as this operation is completed the program moves to the execution of the main loop control.

The following parameters are provided: time counted from the start of motion with TIMER2, the number of pulses from TIMER3 and the value of the array element for the reference position which number is proportional to time. On the basis of the data collected calculations for control variable with PLL or FIR method due to selected control mode are implemented. The control value in a form of pulse period is transferred to the ARPR register (Auto Reload Preload Register) in TIMER2 which after the completion of the previous pulse is transferred to ARSR (Auto Reload Shadow Register).

4. Control algorithm

Flowchart of the control program presented in Fig. 2 allows to select one of the two control variants using the buttons on the microcontroller board: in the closed loop with the implementation phase locked loop (PLL predefined process flowchart in Fig. 2) or the open loop with the implementation of infinite pulse response (IIR predefined process flowchart in Fig. 2).

By introducing marking specified in Fig. 2 for the PLL block:

$$T = \frac{KP}{PT[TEN] - PC} \tag{1}$$

where:

T – pulse period (calculated as a integer), *KP* – proportional coefficient of the PID controller, $PT[TEN]$ – element of the array of course of reference position requested with number TEN proportional to *CK* time in TIMER1, *PC* – number of pulses counted by TIMER3 (Fig. 2), which have been provided in *CK* time to the servo drive.

For IIR block:

$$PT_{\mathrm{smoothed}}[TEN] = \sum_{i=0}^{i=TEN} \frac{PT[i] \cdot a^{-(TEN-i)}}{a^{-(TEN-i)}} \tag{2}$$

$$T = \frac{f_{\mathrm{TIM2}} \cdot k}{PT_{\mathrm{smoothed}}[TEN] - PT_{\mathrm{smoothed}}[TEN-1]} \tag{3}$$

where:

a – coefficient for the filter taking values from 0 to 1, f_{TIM2} – TIMER2 clock speed [MHz], *k* – the time interval between successive elements of the array, *TMT* – total motion time for the arm [μs], $PT_{\mathrm{smoothed}}[TEN]$ – output value which is a floating point number, TEN – element of the array for the filtration element provided.

5. Results and discussion

The key element during the paddle sorters motion time history is tracking the reference motion profile with small track errors for the angular position and small values of accelerations.

The reference course angular position is based on the sinusoid function presented in Figs. 3a and 4b.The time of working cycle of the paddle sorter arm amounts to 0.76 s., The time for single control iteration amounted to 350 μs. The course of motion of the arm for both control modes has been carried out so that the maximum error of tracking the angular position amounted to 0.33 º (angle in degrees).

IIR method regulation (Fig. 3b) allows to achieve over 20 times smaller extreme accelerations (revolution per second squared) in relation to PLL method regulation (Fig. 4b).

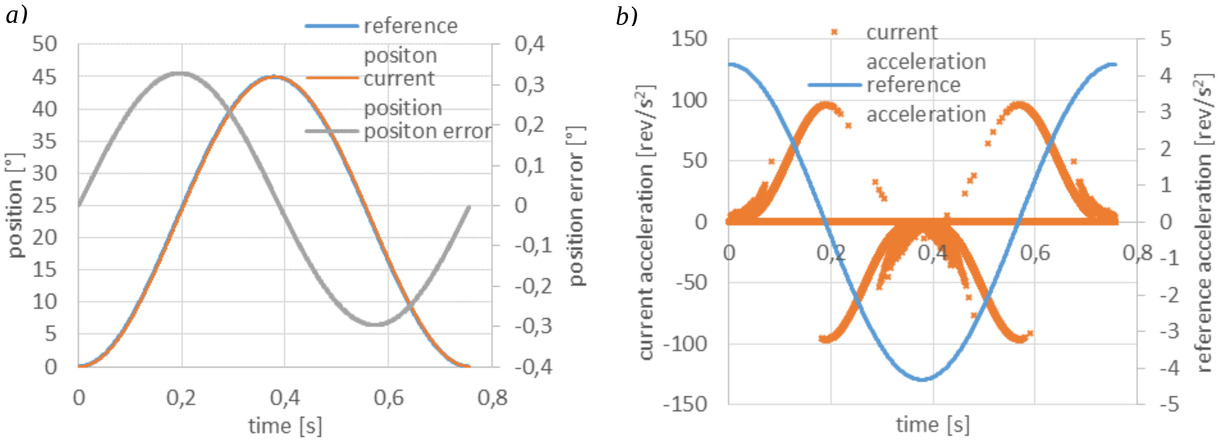

Fig. 3: Course of position and acceleration for motion control of paddle sorter arm with IIR filter.

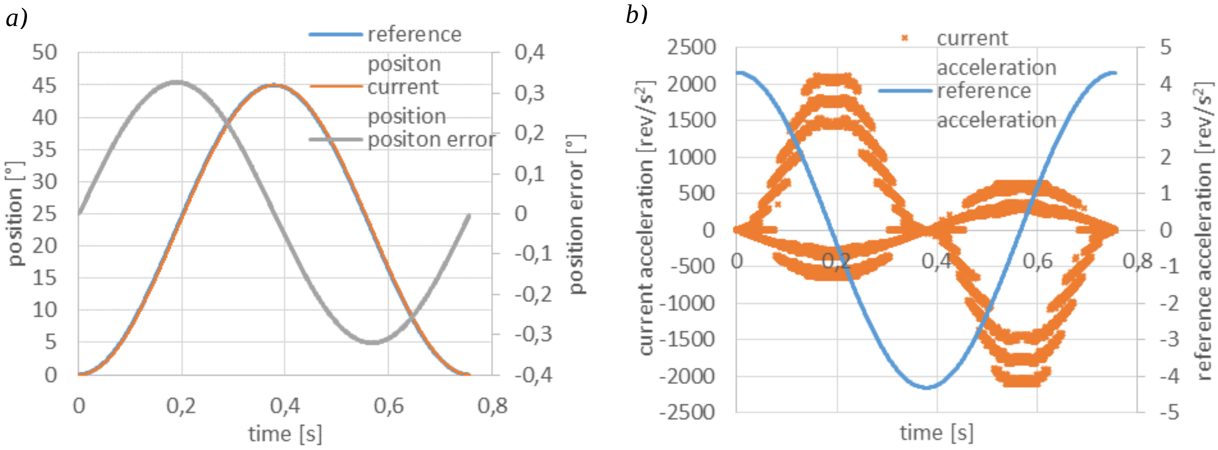

Fig. 4: Course of position and acceleration for PLL motion control of paddle sorter arm.

6. Conclusions

The use of the PLL method provides position error compensation, due to the presence of a closed loop system, so that a significant deviation between current course and reference course position is impossible. However, this method for rotational motion control causes large acceleration values in relation to the IIR control method. In case of rotational motion control of the paddle sorter arm, the reference position profile is well known while tuning. Therefore it is easy to verify if there is a small position error between current position course and assumed reference position before we start the sorting process. Due to this reason, the IIR method of the motion control of the paddle sorter arm should be used and resign from it, only when the arm does not follow the reference position profile during the preliminary tuning.

References

McGuire, P.M. (2009) Conveyors: Application, Selection, and Integration. Taylor and Francis Group.

Linares-Flores, J., García-Rodríguez, C., Sira-Ramírez, H. and Ramírez-Cárdenas, O.D. (2015) Robust Backstepping Tracking Controller for Low-Speed PMSM Positioning System: Design, Analysis, and Implementation, IEEE Transactions on Industrial Informatics, Vol. 11, No. 5.

Besset, P., Bearee.R., Gibaru O. (2016) FIR Filter-Based Online Jerk-Controlled Trajectory Generation, 2016 IEEE International Conference on Industrial Technology (ICIT).

Chang, H.L. and Tsao, T.-Ch. (2014) High-Sampling Rate Dynamic Inversion-Filter Realization and Applications in Digital Control, IEEE/ASME Transactions on Mechatronics, Vol. 19, No. 1.

Biagiotti, L. and Melchiorri, C. (2014) FIR filters for online trajectory planning with time- and frequency-domain specifications, Control Engineering Practice 20 (2012), 1385-1399.