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Maciej GNIADEK*

INTERACTION OF INPUT SHAPING AND CASCADE CONTROLLER FOR DC DRIVE CONTROL

Various mechanical systems demand precise positioning control strategies. Cascade control of DC motor driving unit is still one of the most popular structures of automatic positioning. One of the main problems of this structures are the oscillations of the current, speed and position. All of these oscillations negatively effect on the electronics and mechanics live time. The method of input shaping (or in general signal shaping) is used to reduce this problem. The signal shaping was implemented for reference torque, reference speed and reference position signal. The common work of multiple input shapers is also presented. The results were compared with control without of signal shaping. The robustness for parameters change was tested. The research was conducted in MATLAB/Simulink environment.

KEYWORDS: Input shaping, command generation, signal shaping, cascade control, DC drives

1. INTRODUCTION

Many practical mechanical systems demand precise positioning. One of the most classical approach to this problem is the cascade control. This method is one of the simplest in implementation. One of the main problem of the method is the oscillation in current, speed and position control loops. The paper shows the implementation of input shaping algorithm in propose to reduce its occurrence.

2. INPUT SHAPING

2.1. The input shaping theory

Input shaping is one of the simplest and most effective method of oscillations reduction. The main idea of the method is a convolution of reference signal and a series of impulses. The moments of application and amplitudes of impulses are the key thing in oscillations reduction. If those parameters are chosen properly the oscillations of response are antiphase and reduce each other. This situation is presented in Figures 1 [5] and 2 [1].

* Poznan University of Technology.

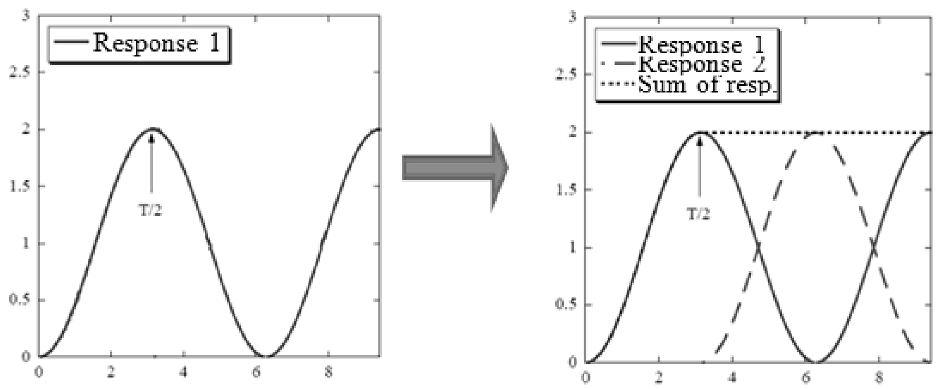

Fig. 1. Input shaping basis – object response

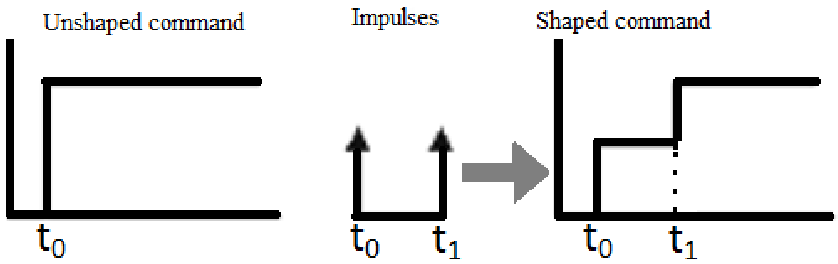

Fig. 2. Input shaping basis – signal convolution

The moments of application are connected with the object natural frequencies and its damping. Proper parameters for the simplest algorithm can be calculated from the equation (1) [2]:

$$\begin{bmatrix} A_i \\ t_i \end{bmatrix} = \begin{bmatrix} \frac{1}{1+K} & \frac{K}{1+K} \\ 0 & 0.5T_d \end{bmatrix} \tag{1}$$

where

$$K = e^{\left(\frac{-\varsigma\pi}{\sqrt{1-\varsigma^2}}\right)} \tag{2}$$

T_d is the period of object natural frequency and ς is the damping coefficient of this frequency. All the information can be extracted directly from the object transfer function [3]. As the “object” for input shaping the whole control loop with controller can be considered.

3. CASCADE CONTROLLER

Usage of single control loop (with single controller) can be sometimes insufficient for control quality or may lead to large complexity of the controller. In this case cascade control should be considered. The simple regulators are connected in series and created master-slave structure [4].

3.1. Cascade control of DC drive

In the task of positioning tree loops are usually used. The most common structure is presented in Figure 3 [6].

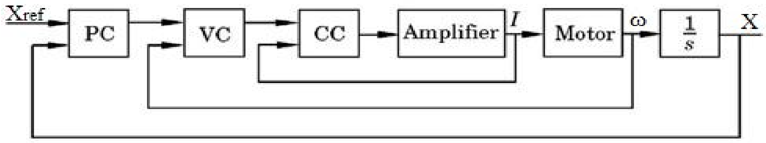

Fig. 3. Cascade controller for DC motor positioning

The Figure 3 contains 3 loops. The internal loop with CC (Current Controller) controls the current and has to be the fastest. The central loop with VC (Velocity Controller) controls the angular speed of the motor ω. The outer loop contains the PC (Position Controller), controls the motor position X, and is the slowest. The output from the outer loop is the reference signal for the internal loop. Each reference signal can be shaped in propose to omit the oscillations.

The structure presented in Figure 3 can be simplified according to selected task. Exemplary if only the speed is controlled, the outer loop should be omitted. This situation will be described in parts 4.1 and 5.1.

The DC motor in the simulation process was executed on the motor with parameters: Rotor Resistance 11.2 Ω, Rotor Inductance 121.5 mH, Moment of inertia 0.02215 kg/m^3, k_e coefficient 1.28 Nm/A.

4. REFERENCE CURRENT SHAPING

The first considered structure contains only one shaper, used to shape the reference current structure.

4.1. Current control

The first considered structure contains only one shaper, used to shape the reference current structure. In the first test cascade control is reduced only to one loop – current control. The CC parameters were tuned to achieve high-speed control. The results are presented in Figure 4.

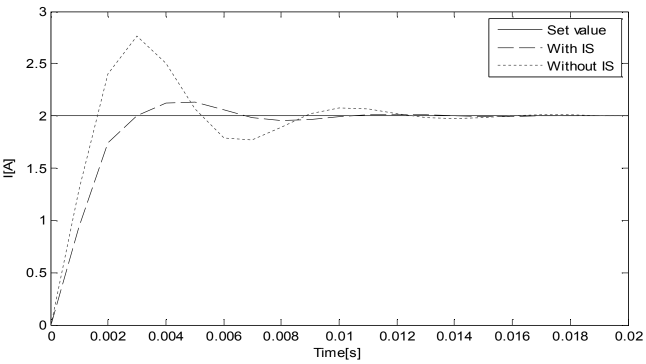

Fig. 4. Current shaping results

The figure (4) presents that the control with shaping is smooth, the overshoot is minimized, the dynamics is slightly lower. Lower oscillations of current are beneficial for the electronics in the system.

4.2. Positioning

The second test presents the influence of current reference signal shaping for positioning. The results are presented in Figure 5.

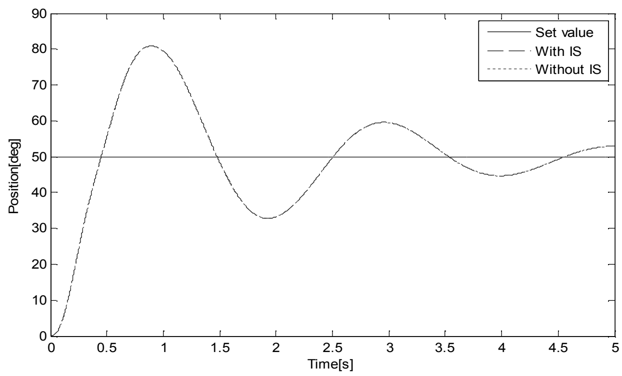

Fig. 5. Influence of current shaping for positioning

The Figure 5 shows that current shaping has any general influence on the positioning. The courses of position with shaping and without of shaping are nearly same - the differences are visible only in small details. The usage of current shaping should be considered because doesn't effect on the positioning and has positive influence on current shape.

5. REFERENCE SPEED SHAPING

The second structure contains single shaper on the velocity reference signal. The tests are respective to point 4.

5.1. Speed control

In the first test two loops were built and used – the current control loop and velocity loop. The results of the test are presented in Figure 6.

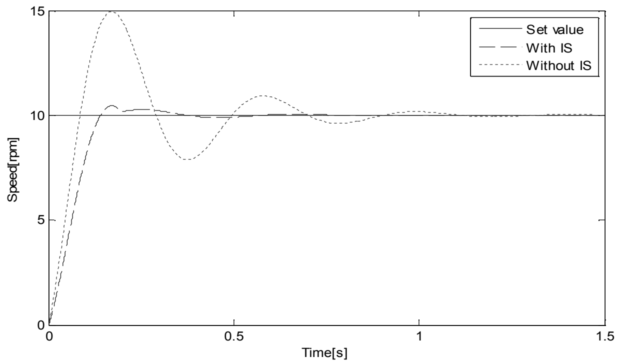

Fig. 6. Influence of speed shaping for speed

The Figure 6 shows that the speed shaping has positive influence on the speed oscillations, that are strongly reduced. The dynamics is strongly limited.

5.2. Positioning

Respectively to point 4.2 the influence of speed shaping on positioning was tested. The results are presented in Figure 7.

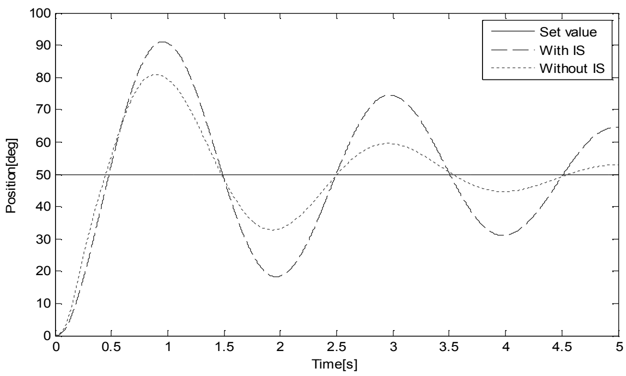

Fig. 7. Influence of speed shaping for positioning

The Figure 7 shows that the high limitation of dynamics has affected negatively on the position courses. The position oscillation has higher amplitudes. This might be result of the limitation of the reference speed signal.

6. REFERENCE POSITION SHAPING

The last simulation was testing the influence of reference position shaping on the position course. The results are presented in Figure 8.

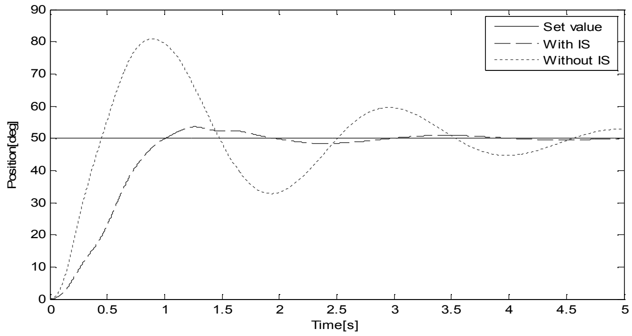

Fig. 8. Influence of reference position shaping for positioning

The Figure 8 shows that position shaping has positive influence on the oscillations of position. The overshoot is strongly reduced, the control time is much shorter. The dynamics is limited.

7. CONCLUSION

The usage of multiple input shapers was also tested. Most of results are not presented. According to previous points, the position and current shapers gave positive results to the control task. Their common work is presented in Figures 9 and 10.

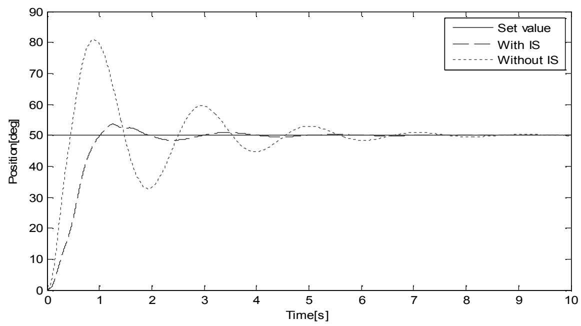

Fig. 9. Influence of reference current and position shaping for positioning

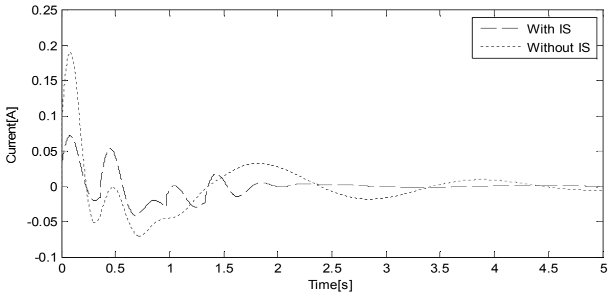

Fig. 10. Influence of reference current and position shaping for current

Figures 9 and 10 confirms the thesis that common work of two shapers will positively influence the current and positioning. The results are achieved with synergy according to chapters 4-6. The current is strongly limited in values and does not change the direction. The positon courses are also improved.

8. CONCLUSION

The application of signal shapers in the cascade control was tested. Three simple shapers were tuned and designed. Basic experiments were conducted.

The usage of signal shapers has positively influenced on the cascade control. System's dynamics is slightly limited but the oscillations and control time are highly improved. The usage of speed shaping did not give many positive results. The limitation of internal control loop dynamics had bad influence on the system. Usage of multiple signal shapers is considerable if the dynamics of internal loops is not highly limited by the shapers. For the system usage of multiple shapers should be generally positive. The limitation of signals amplitudes and dynamics usually may extend the life time of the system. Exemplary if the oscillations of the speed are not reduced the clutches and gears are worn out much faster.

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