SLIDING MODE CONTROL OF A SERVOPNEUMATIC POSITIONING SYSTEM

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ABSTRACT

The most wideliy used controller is stil the PID (proportional, integral, derivative) controller because of its simplicity and ease of implementation. However, with the increasing power of computers and microprocessors, more robust and more powerful controllers are able to be implemented in many systems. This paper discusses how to improve the positioninging precision of a servopneumatic positioning system by using a new sliding mode control strategy. In this work, a sliding mode controller is implemented and described.

1. INTRODUCTION

Increased industrial demands on quality and performance over a wide range of operating regions have led to an increased interest in nonlinear control methods during recent years [Edge 1997]. The so-called sliding mode control (SMC) is a particular type of Variable Structure Control System (VSCS). Sliding mode control is a very robust control algorithm for linear- as well as nonlinear systems against parameters and load variations.

2. THE SERVOPNEUMATIC POSITIONING SYSTEM

As an important driving element, the pneumatic cylinder is widely used in industrial applications for many automation purposes thanks to their variety of advantages, such as: simple, clean, low cost, high speed, high power to weight ratio, easy maintenance, inherent compliance. Due to the substantial nonlinearities, early use of pneumatic actuators were limited to simple applications that required only positioning at the two ends of the stroke.

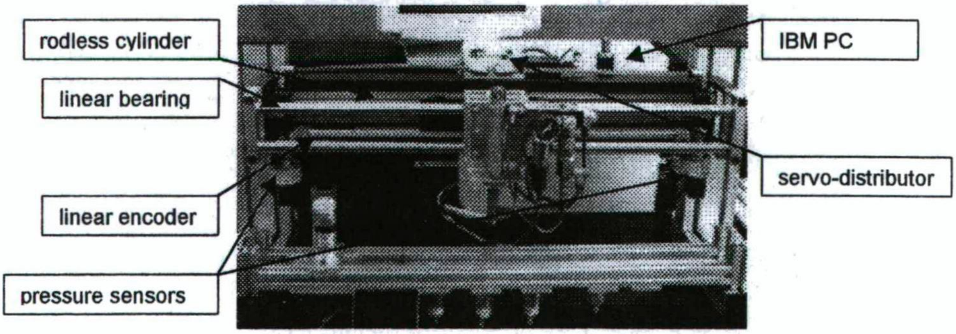


Fig. 1. Photograph of the experimental positioning system

The system under consideration is shown in Fig. 1. It consists of a double-acting pneumatic rodless cylinder (MECMAN 170 typ.) with bore of 32 mm, and a stroke of 500 mm, controlled by a five-way servo-distributor (FESTO MPYE-5-1/8 LF-420B tip.). A linear encoder (LINIMIK MSA 320 tip.) gives the position. Velocity and acceleration are obtained by numerical derivation. Presure sensors are set in each chamber. Their output signals are sent to a PC through a PCL-818 High Performance Data Acquisition Card.

3. THE SLIDING MODE CONTROL

To introduce the idea of Sliding Mode Control we can consider a single-input, single-output second-order nonlinear dynamic system:

$$\ddot{y} + f(y,\ddot{y}) = u + d$$

where u is the control input and d is an input disturbance. $f(y,\ddot{y})$ denote an arbitrary nonlinear function of the two states. Let us defin the „sliding surface” s as a linear combination of the states such that $s=0$ defines the desired system dynamic behaviour:

$$s = \dot{y} + \lambda \cdot y$$

λ is chosen to be positive. If s^2 is a Lyapunov function, then its time derivative needs to be negative, yielding the condition:

$$s\dot{s} < 0$$

We can choose u such that: $u = \delta \cdot sign(s)$

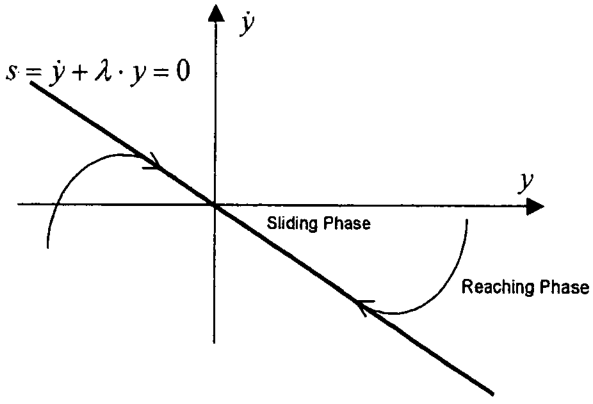
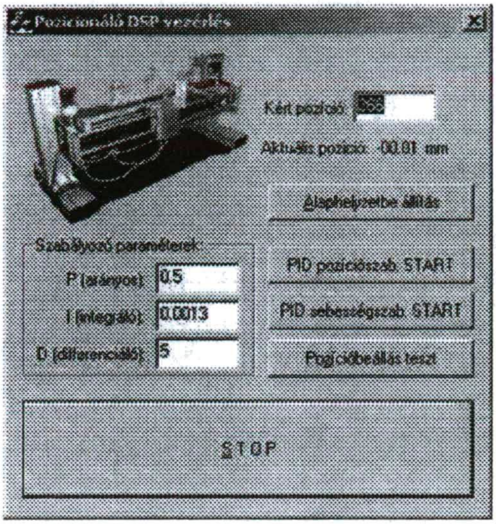


Fig.2. Sliding motion in the state space

The process of sliding mode control can be divided into two phases, that is, the approching phase with $s \neq 0$ and the sliding phase with $s = 0$.

The pneumatic servosystem is a very nonlinear time-variant control system because of the compressibility of air, the friction force between the piston and the cylinder, air mass flow rate through the servovalve, etc. The sliding mode control theory was used to solve the model imprecision problem and also widely applied in nonlinear control. Sliding mode control (SMC) has received great interest over the past decade. Compared to traditional control methods, the most advantageous feature of SMC is that it can result in very robust control.The main defect of SMC is the chattering phenomenon. In recent years, techniques to eliminate chattering phenomena have been presented. The basic principle is the introduction of a boundary layer around the switching surface.



Kért pozíció: [illegible]

Aktuális pozíció: -00.01 mm

Szabályozó paraméterek:

P (arányos): 0.5

I (integráló): 0.0013

D (differenciáló): 5

Fig.3. The Controller Operating Window

4. EXPERIMENTAL RESULTS

Int he following experimental result, the system pressure is set to be 5 bar and the sampling time is 2 ms. The tracking performance of the sliding controller depends highly upon the value of the sliding line slope. A large value for the sliding line slope ensures good tracking performance but too large slope can cause instability. The basic feature of this design is that high speed and high positioning accuracy can be met despite of the fact that the controlled process suffers from friction and mechanical flexibility. Friction effects are usually reduced by introducing a compensator based on an identified friction model. However, an accurate friction model is usually difficult to obtain because of its characteristics of timevariation during changing environmental parameters. SMC is able to compensate unknown friction in positioning systems, despite of the complicated characteristics of friction. In this paper, the PID-sliding surface controller is applied to the position control of a proportional-valve-controlled pneumatic rodless cylinder. A sliding mode controller sends the system states onto the sliding surface and keeps them there. This scheme can solve the chattering problem without loss of robustness and control accuracy. This paper introduces a modified sliding mode control strategy to reduce the chattering problem and uses it in a positioning system.

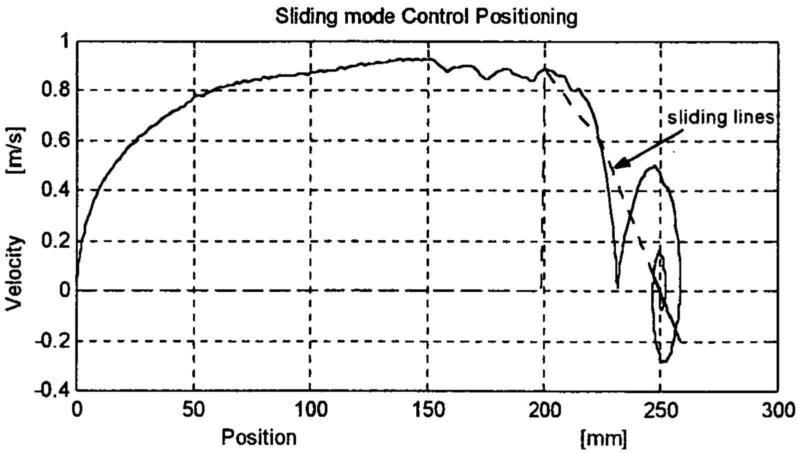


Fig. 4. Phase plane trajectories

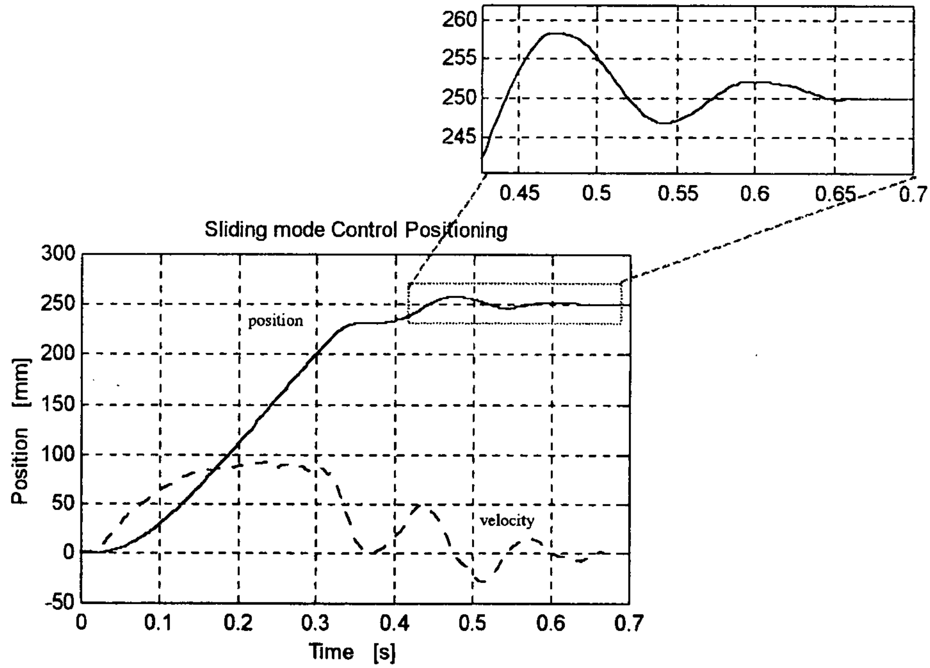


Fig.5. Experimental positioning results

The experimental results(Fig.4.,Fig.5.) show that the system has high robustness and global stability, and has high positioning precision. The positioning accuracy of the pneumatic cylinder is always under 0.01 mm. We can realised the utility of SMC for mechanical systems with Coulomb friction, where standard PID control may not provide adequate closed-loop behavior.

5. FUTURE WORK

We can make the conclusion, that the sliding mode controller is sutable and effective for the position control. Furthermore we interested in simulating and trying out all methods on "real world" systems. So we have created a pneumatic test stand, as shown in Fig. 1. and we will compare the simulation results to experimental results.

REFERENCES

1. Ludvig Gy.: Gépek dinamikája *MK. Budapest, 1983.*
2. Dányi D. Telkes Z.: Szabályozó berendezések *Tankönyvkiadó, Bp. 1972.*
3. Elek I.: Az ipari pneumatika alapjai *Budapest, 1997.*
4. Jeges Z.: Irányítástechnika *Műszaki Főiskola Szabadka, 2000.*
5. Csordás Z.: Pneumatikus irányítástechnika *MK. Budapest, 1966.*
6. Gy.Mester:Neuro-Fuzzy-Genetic TrackingControl of Flexible Joint robots. *Proc.I.Intern.Conf. on Adv. Robotics & Intelligent Aut.pp.93-98,Athens,Greece,1995.*
7. Mester Gy.: Intelligens rendszerek *Szeged. 2001.*
8. Gy.Mester: Neuro-Fuzzy-Genetic Controller Design for Robot Manipulators. *Proc.IECON'95,IEEE,Orlando,Florida, USA, Vol.1.pp.87-92,1995.*
9. Leitch,D.D.: A New Genetic Algorythm for the Evolution of Fuzzy Systems, *University of Oxford,1995.*
10. Fullér,R.: Neural Fuzzy Systems, *Abo Akademi University,1995.*
11. Simulink Dynamic System Simulation for MATLAB *The Math Works Inc.*
12. Real-Time Workshop For Use with SIMULINK User's Guide (MATLAB) *The Math Works Inc.*
13. PCL-818 High Performance Data Acquisition Card with Programmable Gain. *User's Manual Advantech Co.Ltd.*
14. Nouri, B. Modelling and Control of Pneumatic Servo Positioning Systems, *Leuven, 2001*
15. Hanz Richter Hyperplane Design in Observed-Based Discrete-Time Sliding Mode Control, *Oklahoma State University, 1997*
16. Song, J. and Ishida, Y., A Robust Sliding Mode Control for Pneumatic Servo System *Int.J.Engng.Sci. Vol.35,No.8.pp.711-723.1997*
17. Korondi, P., A csúszómód-szabályozás bemutatása az egyenáramú motorok fordulatszám- és pozíciószabályozásán keresztül