Synchronization between Dual Servo Motor using Sliding Mode Control: Cross-coupled sliding mode control technique

Bharat R Vala, Prof. Manisha C Patel

***Abstract*- This paper concern development of sliding mode control technique for motion synchronization for dual encoder servo motor. The main focusing of velocity tracking of dual motor using 1st order sliding mode algorithm. The variable control scheme applied for motion synchronization. However it's very hard to synchronize motion between dual servo motor, but sliding mode control gives satisfactory result. Cross-coupled sliding mode will reduce chattering phenomena in control design.**

Index term—motion syncronization, dual servo motor, sliding mode control, cross coupled control rechnique.

I. Introduction

In order to attain higher manufacturing efficiency, "dual (two) servo systems" are widely used in advanced Computer Numerical Controlled (CNC) machine tools. A well-known example is the linear motor driven gantry type of micro machine tools, double side milling job where dual servos are employed to drive the heavier gantry axis. [1]

Recently, dual servos are also used in spindle systems. "Double sided milling" is an example where two spindles are required to cooperatively remove material on both sides of a work piece. Synchronization of dual servo systems is crucial for achieving the desired manufacturing accuracy. Now a day's P-I controller widely used in control of servo systems but, P-I controller has some disadvantages such as: the high starting overshoot, sensitivity to controller gains and sluggish response due to sudden disturbance. So, the relatively new sliding mode control algorithm can be implemented to overcome to disadvantage of P-I controller. [1][2][6]

In this paper proposed Sliding Mode controllers for the dual servo drive system, to get high performances, we have to control the input variable in uncertainties and disturbance. Two cases are discussed for each control scheme. Normal case, parameter variation case, and disturbance case are considered. When PI Controller is implemented in the system, its gives better performance compared to other controllers, [2] but results are ineffective for disturbance case. Sliding mode control is then implemented. It is observed that system performance increases when compared to PI for parameter variation case and for disturbance case which shows the robustness of SMC. So sliding mode control is superior when compared to other controller in terms of controlPerformance. The sliding mode control is robust to plant uncertainties and insensitive to external disturbances. It is widely used to obtain good dynamic performance of controlled systems.

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There are two main advantages of sliding mode control. First is that the dynamic behavior of the system may be tailored by the particular choice of the sliding function. Secondly, the closed loop response becomes totally insensitive to some particular uncertainties. [2][3][4]

II. Sliding Mode Control Design for Dual Servo system

Consider a servo system and given plant below,

$$J\ddot{\theta}+B\ddot{\theta}=u-d \qquad (1)$$

$$J_n\ddot{\theta}_n+B_n\ddot{\theta}_n=\mu \qquad (2)$$

The first model for real plant and another one for nominal plant, where J is the moment of inertia, B is damping coefficient, u is the control input and d is disturbance. Same taken as nominal plant inputs where μ is nominal control input.

III. Structure of Control Systrm

As show in figure 1 control constist two controllers, sliding mode controller with respect to system (1) and $\theta \rightarrow \theta_n$ is obtained. For mode (2) sliding mode controller is designed to obtain $\theta_n \rightarrow \theta_d$, and $\theta \rightarrow \theta_d$, where θ_d is desire angel and θ_n is nominal angel.

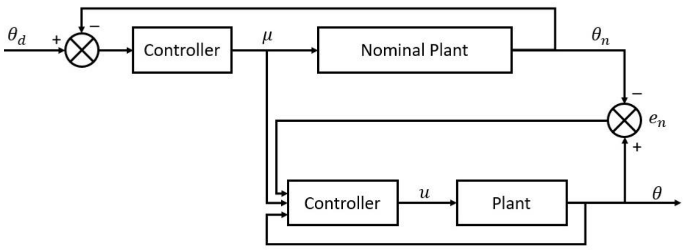

Figure 1 control system

IV. Finding of Feedback Factor H, H_1 and H_2

The design trajectory is θ_d and the nominal-model tracking error denoted as,

$$e=\theta_n-\theta_d \qquad (3)$$

Therefore,

$$\dot{\theta}_n=\dot{e}+\dot{e}_d \qquad (4)$$

And,

$$\ddot{\theta}_n=\ddot{e}+\ddot{e}_d \qquad (5)$$

So we can write that,

$$J_n\left(\ddot{e}+\ddot{\theta}_d\right)+B_n\left(\dot{e}+\dot{\theta}_d\right)=\mu \qquad (6)$$

To modified the equation (6) it can explain as,

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$$\ddot{e}+\ddot{\theta}_d=-\frac{B_n}{J_n}\left(\dot{e}+\dot{\theta}_d\right)+\frac{1}{J_n}\mu \qquad (7)$$

Now designing of controller for nominal model,

$$\mu=J_n\left(-h_1e-h_2\dot{e}+\frac{B_n}{J_n}\dot{\theta}_d+\ddot{\theta}_d\right) \qquad (8)$$

Form equation (7) and (8), we can determine close loop system as

$$\ddot{e}+\ddot{\theta}_d=-\frac{B_n}{J_n}\left(\dot{e}+\dot{\theta}_d\right)+\left(-h_1e-h_2e+\frac{B_n}{J_n}\dot{\theta}_d+\ddot{\theta}_d\right) \qquad (9)$$

And we get,

$$\ddot{e}+\left(h_2+\frac{B_n}{J_n}\right)\dot{e}+h_1e=0 \qquad (10)$$

A. Stability analysis

To make system stable,

$$s^2+\left(h_2+\frac{B_n}{J_n}\right)s+h_1 \text{ Must be Hurwitz.}$$

From $(s+k)^2=0$, we have $s^2+2ks+k^2=0$, therefore,
To compare both equation we find that,

$$h_1=k^2 \qquad (11)$$

$$h_2=k-\frac{B_n}{J_n} \qquad (12)$$

And we get final control feedback factor as h_1 and h_2, The h_1 and h_2 are depends on the *k*, moment of inertia J_n and damping factor B_n of the nominal plant.

According to equation (11) and (12), the designing of control system depends on moment of inertia and damping factor, both equations used as finding feedback factor.

Data of nominal plant will use to find feedback factor *h* for actual plant, explanation of finding of *h* is given below,
In actual plant moment of inertial, *J* and damping ration *B* change continuously with respect to load and distribution of load so the value of *J* and *B* changes between maximum value and minimum value of each other's,

$$J_m\le J\le J_M,\, B_m\le B\le B_M,\, |d|\le d_M \qquad (13)$$

Where J_m *and* J_M are minimum and maximum value of *J*, B_m and B_M are minimum and maximum value of *B*,
Now,

$$e_n=\theta-\theta_n \qquad (14)$$

And sliding variable,

$$s=\dot{e}_n+\lambda e_n \qquad (15)$$

And λ can define as,

$$\lambda=\frac{B_n}{J_n} \qquad (16)$$

Average value of *J* and *B* are define as a,

$$J_a=\frac{1}{2}\left(J_m+J_M\right) \qquad (17)$$

$$B_a=\frac{1}{2}\left(B_m+B_M\right) \qquad (18)$$

And select the controller as a,

$$u=-Ks-h\cdot\operatorname{sgn}(s)+J_n\left(\frac{1}{J_n}\mu-\lambda\dot{\theta}\right)+B_n\dot{\theta} \qquad (19)$$

Where K>0.
And,

$$h=d_M+\frac{1}{2}\left(J_M-J_m\right)\left|\frac{1}{J_n}\mu-\lambda\dot{\theta}\right|+\frac{1}{2}\left(B_M-B_m\right)\left|\dot{\theta}\right| \qquad (20)$$

Let Lyapunov function can be,

$$V=\frac{1}{2}Js^2 \qquad (21)$$

Therefore the value of,

$$J\dot{s}=u-d-\frac{J}{J_n}\mu-B\dot{\theta}+\lambda J\dot{\theta} \qquad (22)$$

From equation (19),

$$J\dot{s}=-Ks-h\operatorname{sgn}(s)-d+\left(J_n-J\right)\left(\frac{1}{J_n}\mu-\lambda\dot{\theta}\right)+\left(B_a-B\right)\dot{\theta}$$

And,

$$\dot{V}\le -Ks^2-h|s|+|s|\left\{|d|+|J_a-J|\left|\frac{1}{J_n}\mu-\lambda\dot{\theta}\right|+|B_a-B|\dot{\theta}\right\}$$

From equation (17) and (18)

$$\frac{1}{2}\left(J_M-J_m\right)\ge|J_a-J| \qquad (23)$$

$$\frac{1}{2}\left(B_M-B_m\right)\ge|B_a-B| \qquad (24)$$

Therefore,

$$h\ge|d|+|J_a-J|\left|\frac{1}{J_n}\mu-\lambda\dot{\theta}\right|+|B_n-B|\left|\dot{\theta}\right| \qquad (25)$$

Then,

$$\dot{V}\le -Ks^2 \qquad (26)$$

From,

$$V=\frac{1}{2}Js^2$$

We get,

$$s\dot{s}\le-\frac{K}{J}s^2 \qquad (27)$$

Therefore we have exponential convergent as,

$$s(t)\le|s(0)|\exp\left(-\frac{K}{J}t\right) \qquad (28)$$

V. Simulation Results

To verify the control system MATLAB is widely used in control and instrumentation field, simulation of sliding mode control applied on dual servo system is given as,

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A. *Simulink model in MATLAB*

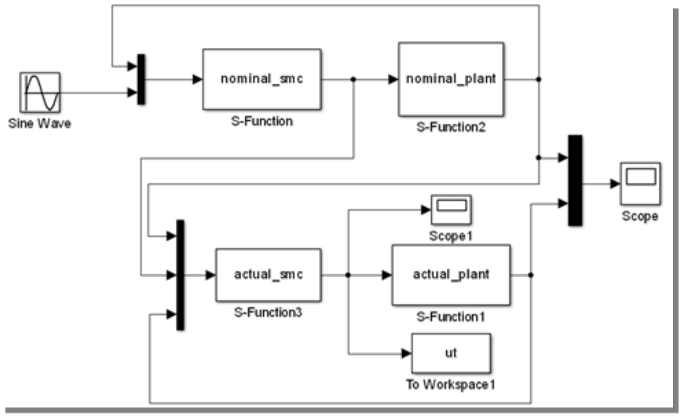

Figure 2 Simulink model

As shown in figure 2 , the input given as a sine wave, in servo system the tracking parameter is angular velocity and rotational angle, here rotational angle is θ and velocity denoted as V.

According to figure (2) the simulation output shown on scope, scope outputs are.

B. *Simulink output*

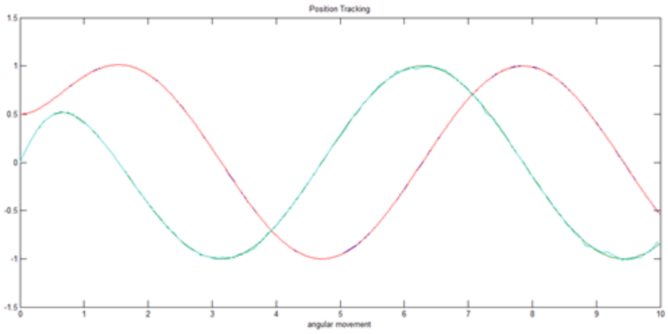

Figure 3 Simulink output

In figure 3 velocity and angular position tracking both denoted as different color.

Its output only given for open system without disturbance, to see what happen when some disturbance arrive in input sine wave, disturbed output denoted below,

Here disturbance given as input step to sine wave, in shown in figure 4 after some revolution sliding mode control again track the exact path of input.

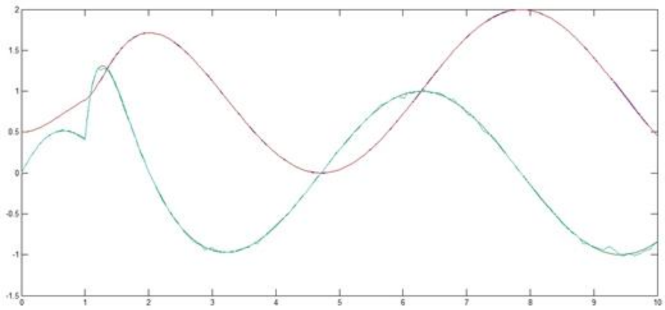

Figure 4 output with disturbance

As shown in figure 4 disturbed step input given after several time, at a disturbed input we show that velocity and angular position are track as usual as before.

VI. Future Implementation on Cross Couped controller

To reduce chattering phenomena in sliding mode control its implemented as cross-coupled Sliding Mode Control, the cross-coupled sliding mode technique given as,

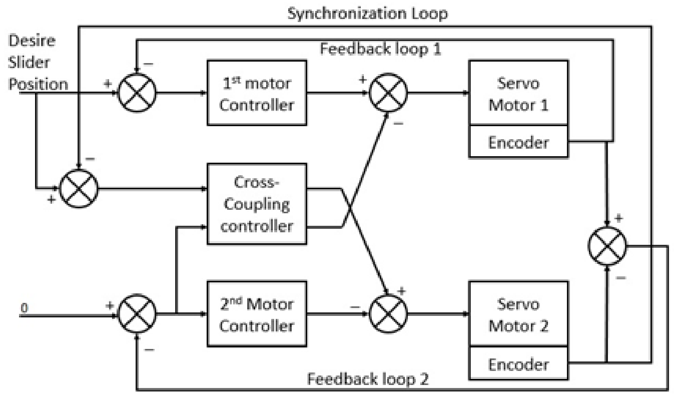

Figure 5 Cross-coupled Sliding mode technique

Error between both encoder given to both individual controller as well as cross-coupled controller. This technique known as a cross coupled sliding mode control.

VII. Conclusion

After study on sliding mode control for dual servo system and simulation result of it, Sliding mode control gives best performance in tracing of dual servo motor. To avoid chattering phenomena cross-coupled sliding mode control gives better performance to compare simple sliding mode control algorithm.

Refereces

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