Discrete Sliding Mode Controller Action With PID Sliding Surface For Non-Linear Plant Along With Changing Set Point

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Abstract: The paper present, a discrete time sliding mode controller (DSMC) is proposed for higher request in addition to postpone time (HOPDT) forms. A sliding mode surface is picked as a component of framework states and mistake and the tuning parameters of SMC are resolved utilizing overwhelming post situation procedure. The control object for "ball in a barrel" is to regulate the speed of a DC supplying fan blowing air into a chamber in order to keep a ball suspended at some foreordained position in the barrel. The DSMC is worked to direct the ball's position consequently. Albeit adroitly straightforward, this is a troublesome control issue due to the non-direct consequences for the ball and the perplexing material science administering its conduct. Besides, the ball is amazingly touchy to any outer aggravations from the fan. Taken together, it is hard to be constrained by the customary science, and not actually caught in reproduced or numerical correlations of control calculations. The reproduction and experimentation results demonstrate that the proposed strategy guarantees wanted following elements. The perfection of current proposed system is it grants following of progress progressively set point. This gadget to tentatively analyze a customary PID controller and DSMC controller. The results show significant differentiations in the execution characteristics of the controllers.

Keywords: ***PID controller, SMC, DSMC, HOPDT***

I. INTRODUCTION

Sliding mode control (SMC) is a nonlinear control framework including striking properties of exactness, healthiness, and basic tuning and execution. SMC structures are planned to drive the system states onto a particular surface in the state space, named sliding surface. At the point when the sliding surface is accomplished, SMC keeps the states on the adjacent neighborhood of the sliding surface. Consequently the SMC is a two area controller structure. The underlying fragment incorporates the arrangement of a sliding surface with the objective that the sliding development satisfies structure specifics. The second is stressed over the decision of a control law that will make the changing surface charming to the structure state.

There are two crucial focal points of sliding mode control. First is that the dynamic direct of the structure may be specially fitted by the particular choice of the sliding limit. Moreover, the shut circle response ends up being completely insensitive to some particular defenselessness. This rule extends to indicate parameter vulnerabilities, agitating impact and non-linearity that are constrained.

A broad class of issues can be advanced toward using nonlinear control strategies that rely upon restricting the state bearing to a particular complex in the state space. SMC methods a high level of strength and cold-heartedness to displaying mistakes, anyway oppose discount selection by the control building system due to the remarkable trading relics or the chattering sway that is habitually introduced by the use of the basic high-recurrence exchanging control. Less outstanding is the subclass of SMC strategies that balance out to focus in limited time the sliding variable, yet in addition its higher-request subsidiaries [1,4]. Appropriately planned, a high-request sliding mode (HOSM) controller can be constant, might be actualized with high precision in discrete time, and can give a level of effortlessness, power, and unsettling influence dismissal that contrasts positively and other vigorous control structure procedures [3].For plants that are appropriate to the system and inside the limits of the accessible control specialist, it tends to be shown that the execution capacity is expanded without the unfortunate antiques of high controller request and restricted aggravation dismissal found in straight structures. The present methodology proposes the utilization of high-request sliding mode unsettling influence spectator (SMDO) [2]and SMC plan to the fueled drop demeanor control issue and incorporates a novel use of a similar super-bending calculation [2]and the widespread settled HOSM SMC [4]. The present methodology proposes the use of high-request sliding mode aggravation eyewitness (SMDO) [2] and SMC plan to the fueled drop frame of mind control issue. The plan incorporates a novel use of the supposed super-contorting calculation [2] and the general settled HOSM SMC law [4]; primer outcomes were displayed in [11] and [15]. Through watchful examination and reenactment in a high-constancy six level of-opportunity (DoF) condition, the sliding mode methods are appeared offer dependable and powerful direction following execution that improves the probability of mission achievement within the sight of obscure aggravations and displaying vulnerabilities.

II. CONTROLLER

Sliding Mode Control (SMC)

The system portraying issues of SMC is as followed:
System is represented using following state model,

$$x^{\cdot}(t) = (A + \Delta A)x(t) + (B + \Delta B)u(t - t_d) + d(x, t, u)$$

$$y(t) = Cx(t) = x_1(t) \qquad \text{eq. (2)}$$

Where x (t) = state vector, u (t) = control flag and y (t) = system yield individually.
A, B and C are state space demonstrate networks of fitting sizes

t_d = time interval
ΔA and ΔB = vulnerabilities
$d(x, t, u)$ = outside aggravation

$$\Delta A = BD, \Delta B = BE, d(x, t, u) = Be(x, t, u) \qquad \text{eq. (3)}$$

Where $e(x, t, u)$ = obscure aggravation
D= system of proper measurements

$$|E| \leq b < 1$$

Eq. (2) can rewrite as:

$$x^{\cdot}(t) = Ax(t) + Bu(t) + BF(x, t, t_d, d, u)$$
$$y(t) = x_1(t) \qquad \text{eq. (4)}$$

$F(x, t, t_d, d, u)$
= bound lumped effect with upper bound F_{max}
PI sliding surface is given by,

$$s(t) = Sx(t) - S\int_0^t (A - BK)x(\tau)d\tau \qquad \text{eq. (5)}$$

S= sliding parameter lattice, K=parameter grid
First time subordinate of eq. (5) is as follows:

$$\dot{s}(t) = S\dot{x}(t) - S(A - BK)x(t)$$

$$= SAx(t) + SBu(t) + SBF(x, t, t_d, d, u) - SAx(t) + SBKx(t)$$

$$= SBu(t) + SBF(x, t, t_d, d, u) + SBKx(t) \qquad \text{eq. (6)}$$

Equating$F(x, t, t_d, d, u) = 0$, eq. (6) becomes

$$ueq(t) = -Kx(t) \qquad \text{eq. (7)}$$

Eq. (6) is independent of parameter matrix S. K obtained using pole placement or LQR approach. Switching control is considered as:

$$u_{sw}(t) = -K_{sw}\text{sign}(s(t)) \qquad \text{eq. (8)}$$

K_{sw} = switching gain

$$u_{sw}(t) = -Kx(t) - K_{sw}\text{sign}(s(t)) \qquad \text{eq. (9)}$$

Proposed SMC model is obtained by substituting eq. (6) in eq. (9)

$$s(t) = SB\left[-Kx(t) - K_{sw}\text{sign}\left(s(t)\right)\right] + SBF(x, t, t_d, d, u) + SBKx(t)$$
$$= SBK_{sw}\text{sign}\left(s(t)\right) + SBF(x, t, t_d, d, u) \qquad \text{eq. (10)}$$

Sliding surface for tracking controller is chosen as:

$$s(t) = S[x(t) - x_d] - S\int_0^t (A - BK)[x(\tau) - x_d]d\tau \qquad \text{eq. (11)}$$

x_d = desired state vector, First time derivative of eq. (11) is:

$$\dot{s}(t) = S[\dot{x}(t) - \dot{x}_d] - S(A - BK)[x(t) - x_d]$$
$$= SAx(t) + SBu(t) + SBF(x, t, t_d, d, u) - SAx(t) + SBKx(t) + SBKx(t) + SAx_d - SBKx_d$$
$$= SBu(t) + SBF(x, t, t_d, d, u) - S\dot{x}_d + SBKx(t) + SAx_d - SBKx_d \qquad \text{eq. (12)}$$

Equivalent control law can be written as:

$$ueq(t) = -K[x(t) - x_d] + (SB)^{-1}S[\dot{x}_d - Ax_d] \qquad \text{eq. (13)}$$

III. SIMULATION RESULTS

Reenactmentresults are tried by utilizing PID and SMC control activity. After reproduction similar computations with some handy preliminaries are tried on the trial setup. Recreation results are as appeared as follows.

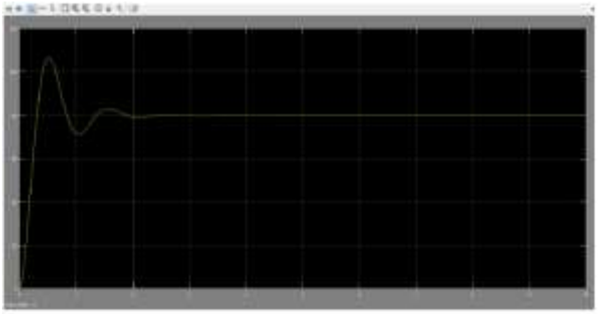

Fig.1. Simulation Results using PID control action

Fig.2. Simulation Results using SMC control action

Figure 1 shows the simulation result of PID control action. While figure 2 reflects that of SMC control action. It gives the complete idea about how SMC control action with PI sliding mode gives better results with suppressed damping and oscillations. Moreover, figure 3 gives idea about how tuning of SMC results in better accuracy.

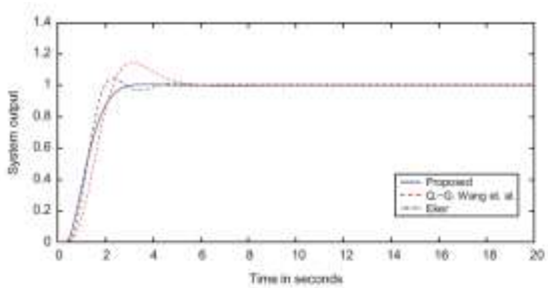

Fig.3. Control signal of SMC for different tuning parameter strategies

IV. EXPERIMENTAL IMPLEMENTATION

The exploratory system includes a straightforward acrylic tube 1m long with distance across of 45mm. The breeze current in the barrel is obliged by a DC fan fitted to the base end of the weight bind as showed up in Figure 4. Ultrasonic sensor is mounted on the most elevated purpose of the chamber so it can check the ball's position.

Ultrasonic sensors emanate a 8 cycle burst of ultrasonic sound at 40 kHz. These spread noticeable all around at the speed of sound. On the off chance that they strike a ball-in-tube, at that point they are reflected back as reverberation signs to the sensor, which itself registers the separation to the objective dependent on the time-length between producing the flag and accepting the reverberation.

Distance = {time-span between emitting the signal and receiving the echo} x velocity of sound / 2.

The DC blower is utilized to supply the air expected to lift the ball inside the cylinder. The wind current provided for lifting a ball is relative to the voltage connected to the fan, which is corresponding to the duty cycle of the PWM signal.

Fig.4. actual hardware

Forces applied on the ball are illustrated in figure 5. The upward applied force from the blower acting on ball-in-tube, F= - mg and downward force exerted on ball, F = mg, where 'm' is mass (here 2.7 gram is the mass of ball) and 'g' is acceleration due to gravity (9.81 m/s^2).

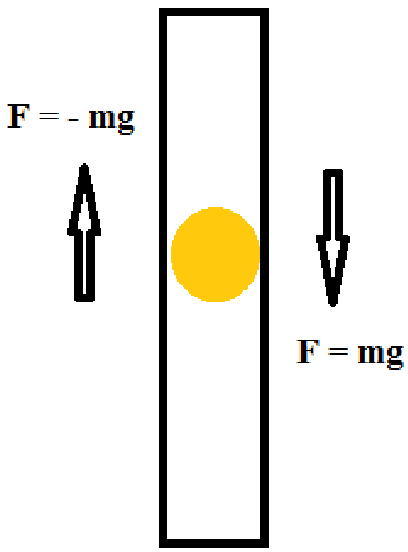

Fig.5. Forces acting on ball in cylinder

For tracking of set point on experimental setup PID and SMC control action is used. It gives good tracking results. For both control actions set point is set as 60cm. Results are as shown in figure below.

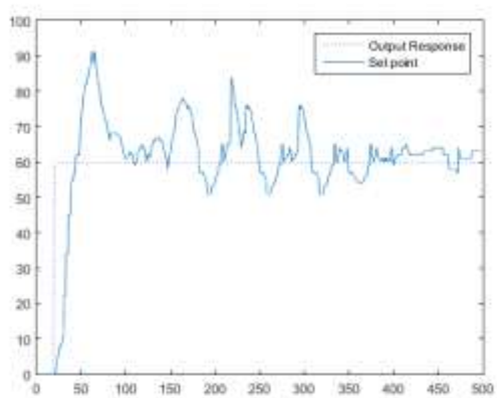

Fig.6. PID control action results on experimental setup

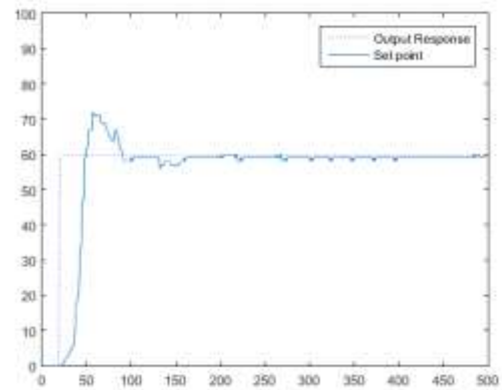

Fig.7. SMC control action results on experimental setup

The result of experimental setup shows that SMC control action gives excellent accuracy and stability. It is the best option for non linear and robust plant. it is clear that the controller actions given by proposed SMC with PI sliding surface is smooth but PID has more chattering.

On the same setup, when PID fuzzy action is tested as proposed by Ouyang Ziwei et. al., the resultant response is illustrated in figure 8.

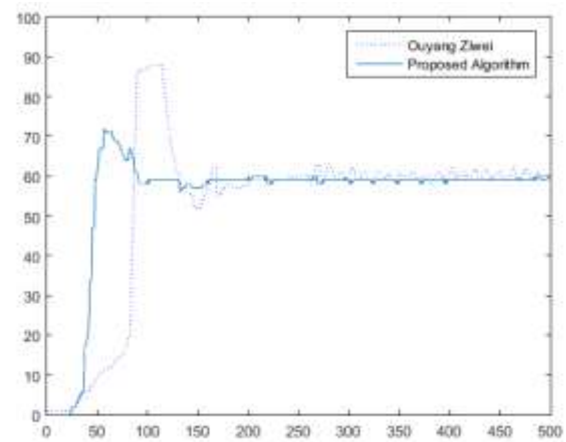

Fig.8. Comparison on setup between proposed algorithm and Ouyang Ziwei

It clearly indicates that the results tested by using the Ouyang Ziweiet. al. gives more oscillations along with peak overshoot.

	Fuzzy PID (OuyangZiwei et. al.)	**Proposed SMC with PI sliding surface**
Rise time (sec)	1.06	0.9698
Settling time (sec)	5.496	3.15
Overshoot (%)	46.667	22.0339

Table 1. Comparison of controllers' performance

The beauty of the proposed system is it gives the best results even for the changing set point system. It also with quick response than PID control action. The set point is set as 60 and then after some time the set point is changes to 70. Result of the same is shown in following figure.

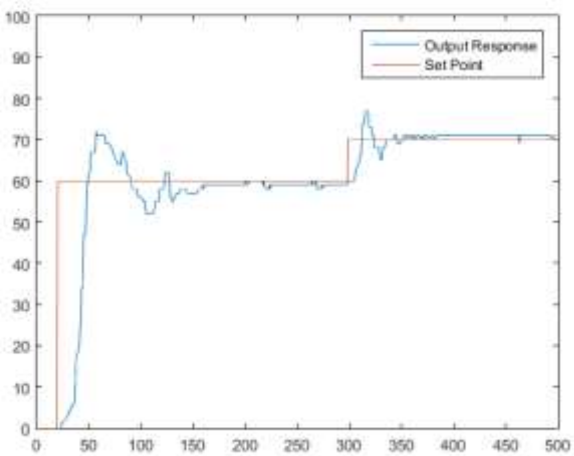

Fig.9. SMC control action results on experimental setup with changing set point

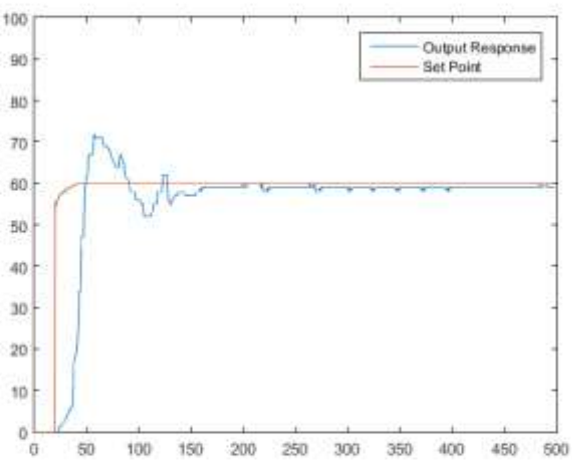

Fig.10. Comparison between Simulation Results and Experimental Results

V. CONCLUSION

SMC control activity with PI sliding surface is proposed for set-point following of higher request in addition to time defer forms by predominant post arrangement approach. Overpowering posts are gained from the perfect shut hover judgments, for instance, settling time and apex overshoot. The arrangement procedure is apparently fundamental as it incorporates figuring of only a solitary tuning parameter. The proposed methodology has no restrictions in regards to changing set point, framework request, time deferral, coordinating and oscillatory conduct, open circle shakiness or non-least stage framework. The experimentation results show the materialness of the technique for continuous applications. The controller movement by the proposed procedure is thump less and the expulsion of the disrupting impacts are better when stood out from PID controller. In the proposed technique the trading control law is kept little to diminish motions which have an exchange off with the strength.

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