Performance Of Current Cycle ILC For Magnetic Levitation System

K.Poomani, S.Sathiyavathi

Abstract: This paper investigates the performance enhancement of magnetic levitation system using current cycle ILC (iterative learning controller). Because the magnetic ball suspension system is unstable, it is difficult to design a suitable control scheme for stabilizing the ball. Hybrid current cycle learning controller is proposed for controlling the position of ball. The current cycle learning controller performance is illustrated using simulation. The superiority of the current cycle learning controller is shown by measuring the parameters like overshoot, settling time, ISE and IAE.

Keywords: hybrid current cycle iterative learning controller; magnetic levitationsystem

I. INTRODUCTION

PID controllers are used in many industries for simple repeatable tasks. For the high frequency trajectory contains components, Standard PID controllers can not be used to meet a good tracking accuracy. So the repetition property is added in a controller design to learn from errors of the previous operations by adding a learning component to PID controller and to improve tracking accuracy with every new operation. Tao liu et al proposed IMC (internal model control) structure based ILC (iterative learning control) for batch processes with time delay mismatch uncertainities [1]. Xu et al presented the various ILC configurations and convergence conditions for each configuration [2]. G. Pinte et al focused on repetitive control (RC) based ILC for high modal density systems [3]. Though Maglev systems have wide spread advantages and acceptance, position tracking is the greatest problem that is still addressed by most of the researchers in the recent years. A high precision intelligent position controller is to be designed to provide a solution to the research problem. There are several tuning methods available for second order unstable system [10]. But only few tuning methods [4,5,6,7] are applicable for magnetic levitation system. To check the performance of the current cycle ILC controller, the magnetic levitation system (MLS) has to be modelled and controller is implemented to analyse the performance for position tracking.

II. SYSTEM DESCRIPTION

The structure of magnetic levitation system is represented in Figure 1. The steel ball is alevitation object. It is attached with a permanent magnet to provide an attractive force. The controlled electromagnet is mounted directly above the ball to control attraction. A light source and sensor are used to determine displacement of ball. The computer is an industrial personal computer with a designed control circuit.

III. TRANSFER FUNCTION OF MAGNETIC BALL LEVITATION SYSTEM

The electromagnetic force maintains the steel ball in levitated position. This magnetic force F is opposite to gravity and depends on electromagnet current i and air gap x. Air gap x is distance between steel ball and electromagnet. The movement of steel ball in electromagnetic field (Jong – Lin 1998) is given as

\[ m \ddot{x} = mg - \frac{i^2}{x^2} \]  

(1)

where,

- \( m \) - mass of the levited steel ball
- \( x \) - air gap between ball and electromagnet
- \( g \) - gravity
- \( i \) - current flowing through electromagnet

On simplifying the above equation, the transfer of the system is obtained as,

\[ \frac{X(s)}{I(s)} = \frac{-c(2i)}{ms^2 - c(\frac{2i}{x^2})} \]  

(2)
Table 1 Values of Constant Parameters

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m$</td>
<td>Mass of steel ball</td>
<td>0.068 kg</td>
</tr>
<tr>
<td>$x_0$</td>
<td>Nominal air gap</td>
<td>0.008 mm</td>
</tr>
<tr>
<td>$i_0$</td>
<td>Equilibrium current</td>
<td>0.76 A</td>
</tr>
<tr>
<td>$g$</td>
<td>Gravitational acceleration</td>
<td>9.8 m/s²</td>
</tr>
<tr>
<td>$c$</td>
<td>Magnetic constant</td>
<td>$7.39 \times 10^{-5} \text{ Nm}^2/\text{A}^2$</td>
</tr>
</tbody>
</table>

On substituting these values in equation (2), the obtained transfer function is,

$$X(s) = \frac{-2.009}{I(s)} = \frac{-2.009}{s^2 - 2.7068}$$

From the above equation, it is clear that magnetic levitation system is unstable.

### IV. CONTROLLER DESIGN

The block diagram of proposed hybrid current cycle ILC to control the ball in the desired position is given in figure 2. Here, $i$ denotes $i$th iteration. The desired ball position is denoted by $y_{d,i+1}$. The current error signal is given by $e_{i+1}$. $U_{i+1}$ denote the current control signal. The actual position of ball is denoted by $y_{i+1}$. The transfer function of magnetic ball levitation system is used to design PID controller ($G_c(s)$). The PID controller parameters are calculated by Rostein and Lewin tuning method.

![Block diagram of proposed hybrid current cycle ILC](image)

Fig.2 Block diagram of proposed hybrid current cycle ILC

### V. SIMULATION RESULTS

To analyse the performance of the system, we simulated the non-linear system with the hybrid current cycle ILC in MATLAB-Simulink. 0.95 cm to 1.25 cm. is operating range of the system. The servo response of the proposed hybrid current cycle ILC is carried out at the 50% of the operating point (1.1 cm). The response is recorded in figure 2 and the performance of the proposed current cycle ILC controller is measured with parameters like overshoot, settling time, ISE and IAE are tabulated in table 2.

![Servo response of proposed current cycle ILC](image)

Fig.3 Servo response of proposed current cycle ILC

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Controller</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proposed current cycle ILC</td>
<td>Overshoot (%)</td>
</tr>
<tr>
<td>1</td>
<td>Proposed current cycle ILC</td>
<td>20</td>
</tr>
</tbody>
</table>

The set point is varied for ball position at 1.025 cm as $\pm 5\%$ and $\pm 10\%$ to examine the robustness of current cycle controller. The robustness test is performed at the 25% of the operating point (1.025 cm). The response of the current cycle ILC controller for the changes in the set point is recorded in figure 3 and parameters to measure the performance are tabulated in table 3.

![Set point tracking of proposed hybrid current cycle ILC](image)

Fig.4 Set point tracking of proposed hybrid current cycle ILC for ball position at 1.025 cm

<table>
<thead>
<tr>
<th>Parameters to measure performance</th>
<th>Proposed cascaded ILC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+5%</td>
</tr>
<tr>
<td>Overshoot (%)</td>
<td>1.05</td>
</tr>
<tr>
<td>Settling Time (sec)</td>
<td>1.03</td>
</tr>
<tr>
<td>ISE</td>
<td>0.008</td>
</tr>
<tr>
<td>IAE</td>
<td>0.591</td>
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</table>

Finally, the controller should be able to reject the disturbance. Disturbance is given at 9 sec and 18 sec. The current cycle ILC controller responds to the disturbance and returns to the desired position in a short time. Figure 4 shows the ability of current cycle ILC controller to reject disturbance.
VI. CONCLUSION
The second order magnetic levitation system is designed with hybrid current cycle ILC (iterative learning controller). The controller performance is analysed through simulation results. From the results, it is concluded that hybrid current cycle ILC is best suited for magnetic levitation system.

REFERENCES