Design and Control of a Hydraulic Servo System and Simulation Analysis

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ABSTRACT
This paper describes the system analysis, modeling and simulation of a Hydraulic Servo System (HSS) for hydraulic mini press machine. Comparisons among linear output feed back PID control, Fuzzy control and Hybrid of PID and Fuzzy control are presented. Application of hybrid controller to a nonlinear is investigated by both position and velocity of the hydraulic servo system. The experiment is based on an 8 bit PIC 16F877 microcontroller, and the simulation is based on MATLAB Simulink. Simulation and hardware experimental results show that the hybrid controller gave the best performance as it has the smallest overshoot, oscillation, and setting time.

KEY WORDS: PID and Fuzzy Control, Microcontroller, Hydraulic Servo System, Modeling and Simulation

INTRODUCTION
Nowadays, hydraulic system is widely used in many applications on any field such as transportation, building construction, factories, until performance art and film industries [21]. Since a hydraulic system is a strong actuator system, it has to be controlled well to achieve the desired purposes and safety. In many applications of hydraulic servo system, when linear motion is required, piston control is always the first choice. In simple application that only require the piston to produce back and forth motions between the two endpoints, the valve that control the piston simply operate in on/off mode. With the development of advanced technology, a combination between hydraulic servo system and electronic devices was established to take the full advantages of them. At the same time, the most common way is to provide the controller in describing the PID control Fuzzy control and Hybrid control and the control law design is complex to extend to multi-variable system. In [26], fuzzy control of a hydraulic servo system gives the fasts response characteristic of the system. Fuzzy PI controller is added in the feed forward branch of the closed loop enhanced by the variable structure controller [16]. In [9], Fuzzy PD controller has better performance of the control system. The applications of Fuzzy tracking control has been successfully applied to control hydraulic systems and can get more robustness and better performance [23]. Most of the performance of PID tuning for processes use frequency response. Therefore, a wide variety of PID tuning controller has been investigated in Ziegler-Nichhols rule [12]. Optimal tuning PID is satisfied even in case where the system is dynamics and the system operating are points change [13]. Moreover, a variety of methods have been developed for modeling and simulation such as modeling and simulation of physical systems and design as an integrated system [2], [3]. In [8], velocity control of hydraulic servo system achieves fast response. An alternative approach for complex control with Hybrid of Fuzzy PID control was developed by [18]. The application of the hydraulic mini press machine has a number of characteristics complicate the design of fault detection systems. These include highly nonlinear dynamics of the hydraulic systems such as dead – band and hysteresis existing in the control valve, nonlinear pressure/flow relations and variation devices which are commonly used in the die casting and injection molding machines [22]. The cycle in both of these processes involve accurate velocity control, followed by a pressure control phase. Some of the most significant developments in a hydraulic mini press machine are in the area of electronic control, specially using microcontroller-based technology. The use of digital and analog control for closing the actuator position has been established for some time. Also, the control system must be fast acting, as the processing speed can be several tuning parameters during the performance. The function of the Hybrid controllers are integrated with PID and Fuzzy control. It can adaptively adjust controller parameters as design of Hybrid PID Fuzzy controller has a good relation between performance and tune that the PID Fuzzy controller can obtain good dynamic performance of a hydraulic mini press machine [25]. The purpose of this paper is to discuss on how to achieve the best control performance of a hydraulic mini press machine. In section 2, the discussion focuses on dynamic model and on the method used to position control in hydraulic servo systems.
Section 3 presents the conceptual design of a Hybrid of Fuzzy PID controller. In section 4, simulations and experimental results are separated by comparing with PID, Fuzzy and Hybrid control. Finally, the paper is concluded in Section 5.

II. PROBLEM STATEMENT AND DYNAMIC MODEL

System model of a typical inertial load drive by a hydraulic servo system is shown in Figs.1 and 2. A hydraulic system was developed by [15]. The system can be thought of as a double acting cylinder driving an inertial load at the end. The dynamic of the inertial load can be written

\[ F_{fr} = \frac{1}{A} \left[ m \ddot{x} + kx + F_j \right] \]

where \( F_{fr} \) is the friction force, \( A \) is the actuator ram area, and \( P_L \) is the load pressure as \( P_L = P_t - P_s \).

Assuming Equation (1), (2), and (3) the mathematical model in the system state equations are

\[
\begin{align*}
\dot{x}_1 &= x_2 \\
\dot{x}_2 &= \frac{1}{m} (Ax_1 - F_j) \\
\dot{x}_3 &= -\alpha x_3 - \beta x_3 + \left( P_t - \text{sgn}(x_1) \right)x_4 \\
\dot{x}_4 &= x_5 \\
\dot{x}_5 &= -\alpha \omega \dot{x}_4 - 2\zeta \omega \dot{x}_5 + \omega \beta \mu 
\end{align*}
\]
where (\(\dot{x}\)) is the actuator piston position, (\(\ddot{x}\)) is the actuator piston velocity, (\(\dot{i}_p\)) is the load pressure, (\(\dot{i}_e\)) is the valve position, (\(i_4\)) is the input current to servo system, \(\alpha: (4\beta, A/V)\), \(\beta: (4\beta, C_p/V)\), and \(\gamma: (4\beta, C_w/V, \sqrt{\gamma/\rho})\). It can be observed from these results that the system responses to the sinusoidal reference signal input and output amplitudes. The tracking objective is the amplitudes by comparing with the frequency of 1 Hz and 6 Hz and phase shift. The values of the system are given in Table 1.

<table>
<thead>
<tr>
<th>Component</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply pressure</td>
<td>(P_s)</td>
<td>(5 \times 10^6)</td>
<td>(P_s)</td>
</tr>
<tr>
<td>Total actuator volume</td>
<td>(V_t)</td>
<td>(2.44 \times 10^{-5})</td>
<td>(m^3)</td>
</tr>
<tr>
<td>Effective bulk modulus</td>
<td>(\beta_e)</td>
<td>(7.60 \times 10^6)</td>
<td>N/m²</td>
</tr>
<tr>
<td>Actuator ram area</td>
<td>(A)</td>
<td>(1.22 \times 10^4)</td>
<td>(m^2)</td>
</tr>
<tr>
<td>Actuator piston position</td>
<td>(X)</td>
<td>(0.2)</td>
<td>(m)</td>
</tr>
<tr>
<td>Total leakage coefficient</td>
<td>(C_{lp})</td>
<td>(5 \times 10^{-13})</td>
<td>(m^3/(s.P_a))</td>
</tr>
<tr>
<td>Discharge coefficient</td>
<td>(C_d)</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>Spool valve area gradient</td>
<td>(w)</td>
<td>2.39 \times 10^{-3}</td>
<td>(m)</td>
</tr>
<tr>
<td>Spool valve position (stroke)</td>
<td>(\chi_v)</td>
<td>0.238 \times 10^{-3}</td>
<td>(m)</td>
</tr>
<tr>
<td>Load flow</td>
<td>(Q_l)</td>
<td>2.5 \times 10^{-5}</td>
<td>(m^3/sec)</td>
</tr>
<tr>
<td>Fluid mass density</td>
<td>(\rho)</td>
<td>870</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Mass of actuator and load</td>
<td>(m)</td>
<td>9</td>
<td>kg</td>
</tr>
</tbody>
</table>

### III. PID CONTROLLER

PID controllers are so far the most common in industrial process [19]. They have several important functions, provide feedback, have the ability to eliminate steady state offsets through integral action and can anticipate the future through derivative action [15]. In practice, PID controllers are used at the lowest level and multivariable controllers provide set points. The behaviour of a PID algorithm can be described as

\[
u(t) = K_p \left( e(t) + \frac{1}{T_i} \int e(\tau) d\tau + T_d \frac{de(t)}{dt} \right)
\]  

(5)

Where \(K_p\) is the proportional action, \(T_i\) is the integral time and \(T_d\) is the derivative time? The PID controllers are parameterized by the following transfer function.

\[rac{X(s)}{R(s)} = \frac{C(s)G(s)}{1+C(s)G(s)}
\]  

(6)

The closed loop third order is given as

\[G(s) = \frac{5432.58}{s^3 + 179.65s^2 + 8069.07s}
\]  

(7)

Transfer function of Eq. (6) using Eq. (7) yields

\[rac{k_p(1+T_{d1})}{1+k_p(1+T_{d1})} \frac{1}{s(1+T_{p1})(1+T\rho_{p1})}
\]  

(8)

The result acquired under the condition of PID controller are given as \(k_p = 0.694\), \(k_i = 1.84\) and \(k_d = 1.64\). The PID controller was designed by following standard procedure of PID controller design, which consists of control and plant as shown in Fig. 3.
PID controller are usually limited due to highly nonlinear behavior of the hydraulic dynamics. More than half of industrial controllers in use utilized or modified PID control schemes. PID controllers are mostly hydraulic, pneumatic, electric and electronic types or their combinations. Currently, many of them are based on MATLAB simulation. Matlab is a widely used, portable and numerically reliable package. Simulink extends Matlab by adding block diagram of PID control. Matlab system identification toolbox software is applied in order to create the mathematical model of the system. The process modeling tool is selected to customize the structure of the identified model based on the knowledge of the third order system. The Simulink model of the PID control system can be shown in Fig. 4.

IV. HYBRID OF PID AND FUZZY CONTROLLER

This research implemented a combination of the two controllers to construct a new characteristic of the system response. The main idea in PID-Fuzzy controller is to combine the simplicity of the PID controller and the reliability of the Fuzzy controller [25]. If PID controller is set to be very stiff, it will cause a significant overshoot or undershoot. In contrary, if it is set to a lower sensitive setting, it will take longer settling time [7]. A Fuzzy controller is chosen in this paper, where the two inputs are the position error and its derivative, or the velocity error. To model a system in fuzzy logic the response of the system in terms of the input-output must be known and designer should be aware of how the inputs and outputs are related. Controller output is voltage to the servo valve. Input and output of interface block are given in Fig. 5. For the complicated system it is difficult to implement the controller because there are many ways to define the linguistic values and rules. Indeed, it can be extremely difficult to find a viable set of linguistic values and rules just to maintain stability.
As mentioned the position and the velocity are the inputs to the fuzzy controller. Logic operations are applied, seven triangular membership function are used in the fuzzification 7*7 fuzzy logic rule matrix. The position (ΔP = real time position-set position) and velocity (ΔV = real time velocity-set velocity) difference are expressed by a number in the interval from -255 to 255 to represent distance from -100 to 100 mm/s. According to the rules membership function can be given in Fig. 6 and 7, while the control surface is depicted in Fig. 8. It can be seen from the surface, which stands for the control voltage, it is impossible to realize this kind of control action for conventional method.

![Fig. 6: Membership function of the fuzzy controller for input](image1)

![Fig. 7: Membership function of the fuzzy controller for output](image2)

![Fig. 8: Control surface of the fuzzy controller](image3)

Rule 1: If ΔP is VNEG and ΔV is VPOS, the ΔO is ZE

[(ΔP = VNEG ∧ ΔV = VPOS); then ΔO = ZE]

Rule 2: If ΔP is VNEG and ΔV is POS, the ΔO is SPOS

[(ΔP = VNEG ∧ ΔV = POS); then ΔO = SPOS]

Rule 3: If ΔP is VNEG and ΔV is SPOS, the ΔO is POS

[(ΔP = VNEG ∧ ΔV = SPOS); then ΔO = POS]

The input and output regions are related by a set of rules. Once the fuzzy controller is activated, rule evaluation is performed and all the rules which are true are fired. So with IF-THEN rule, we can describe the rule of fuzzy algorithm with the following two dimensional table rules, which are given in Table 1.
Referring to Table 1, where VNEG is very negative; NEG is negative; SNEG is small negative; ZE is zero; SPOS is small positive; POS is positive; VPOS is very positive. The output valve remain a fuzzy number and is to be transformed to the form of a crisp number in the model of defuzzification. The high defuzzification is chosen as the defuzzication method and is expressed as

\[ z = \frac{\sum_{j=1}^{n} j \mu(z_j)}{\sum_{j=1}^{n} \mu(z_j)} \]  

(9)

where, \( z_j \) is the amount of control output at the quantization level \( j \), \( u(z_j) \) is membership value in \( z_j \) and \( n \) is number quantization levels of the output. The centroid method is used to implement defuzzification in Eq. (9). The output signal is determined by consideration from the membership function of the fuzzy controller for the hydraulic position and also of the hydraulic velocity. According to the fuzzy method, we assume that the hydraulic position is a number in the interval from -255 to 255 and the limit of the membership function is -100 mm to 100 mm. At the same time, the hydraulic velocity is a number in the interval from -255 to 255 and the limit of the membership function is from -100 mm/s to 100 mm/s. The microcontroller applies fuzzy control to control the movement of the piston. Thus, membership function of the hydraulic position follows the following equations:

\[
VPOS(x) = \begin{cases} 
\frac{x - 65}{35} & \text{when } 65 \leq x \leq 100, \\
0 & \text{otherwise},
\end{cases}
\]  

(10)

\[
POS(x) = \begin{cases} 
\frac{100 - x}{35} & \text{when } 65 \leq x \leq 100, \\
\frac{x - 35}{30} & \text{when } 35 \leq x \leq 65, \\
0 & \text{otherwise},
\end{cases}
\]  

(11)

\[
SPOS(x) = \begin{cases} 
\frac{65 - x}{30} & \text{when } 35 \leq x \leq 65, \\
x/35 & \text{when } 0 \leq x \leq 35, \\
0 & \text{otherwise},
\end{cases}
\]  

(12)

\[
ZE(x) = \begin{cases} 
\frac{35 - x}{35} & \text{when } 0 \leq x \leq 35, \\
(x + 35)/35 & \text{when } -35 \leq x \leq 0, \\
0 & \text{otherwise},
\end{cases}
\]  

(13)

\[
SNEG(x) = \begin{cases} 
x/35 & \text{when } -35 \leq x \leq 0, \\
(x + 65)/30 & \text{when } -65 \leq x \leq -35, \\
0 & \text{otherwise},
\end{cases}
\]  

(14)

---

Table 1. Rules matrix for fuzzy controller

<table>
<thead>
<tr>
<th>e/d</th>
<th>VNEG</th>
<th>NEG</th>
<th>SNEG</th>
<th>ZE</th>
<th>SPOS</th>
<th>POS</th>
<th>VPOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNEG</td>
<td>ZE</td>
<td>SPOS</td>
<td>POS</td>
<td>VPOS</td>
<td>VPOS</td>
<td>VPOS</td>
<td></td>
</tr>
<tr>
<td>NEG</td>
<td>SNEG</td>
<td>ZE</td>
<td>SPOS</td>
<td>POS</td>
<td>VPOS</td>
<td>VPOS</td>
<td></td>
</tr>
<tr>
<td>SNEG</td>
<td>NEG</td>
<td>SNEG</td>
<td>ZE</td>
<td>SPOS</td>
<td>POS</td>
<td>VPOS</td>
<td></td>
</tr>
<tr>
<td>ZE</td>
<td>VNEG</td>
<td>NEG</td>
<td>SNEG</td>
<td>ZE</td>
<td>SPOS</td>
<td>POS</td>
<td>VPOS</td>
</tr>
<tr>
<td>SPOS</td>
<td>VNEG</td>
<td>VNEG</td>
<td>NEG</td>
<td>SNEG</td>
<td>ZE</td>
<td>SPOS</td>
<td></td>
</tr>
<tr>
<td>POS</td>
<td>VNEG</td>
<td>VNEG</td>
<td>VNEG</td>
<td>NEG</td>
<td>SNEG</td>
<td>ZE</td>
<td></td>
</tr>
<tr>
<td>VPOS</td>
<td>VNEG</td>
<td>VNEG</td>
<td>VNEG</td>
<td>VNEG</td>
<td>NEG</td>
<td>SNEG</td>
<td>ZE</td>
</tr>
</tbody>
</table>

---
\[
\text{NEG}(x) = \begin{cases} 
-(35 + x)/30 & \text{when } -65 \leq x \leq 35, \\
(x+100)/35 & \text{when } -100 \leq x \leq -65, \\
0 & \text{otherwise}, 
\end{cases}
\]
(15)

\[
\text{VNEG}(x) = \begin{cases} 
-(65 + x)/35 & \text{when } -100 \leq x \leq -65, \\
0 & \text{otherwise}, 
\end{cases}
\]
(16)

Membership function of the hydraulic velocity follow the following equations:

\[
\text{VPOS}(x) = \begin{cases} 
(x - 65)/35 & \text{when } 65 \leq x \leq 100, \\
0 & \text{otherwise}, 
\end{cases}
\]
(17)

\[
\text{POS}(x) = \begin{cases} 
(100 - x)/35 & \text{when } 65 \leq x \leq 100, \\
(x - 35)/30 & \text{when } 35 \leq x \leq 65, \\
0 & \text{otherwise}, 
\end{cases}
\]
(18)

\[
\text{SPOS}(x) = \begin{cases} 
(65 - x)/30 & \text{when } 35 \leq x \leq 65, \\
x/35 & \text{when } 0 \leq x \leq 35, \\
0 & \text{otherwise}, 
\end{cases}
\]
(19)

\[
\text{ZE}(x) = \begin{cases} 
(35 - x)/35 & \text{when } 0 \leq x \leq 35, \\
(x + 35)/35 & \text{when } -35 \leq x \leq 0, \\
0 & \text{otherwise}, 
\end{cases}
\]
(20)

\[
\text{SNEG}(x) = \begin{cases} 
x/35 & \text{when } -35 \leq x \leq 0, \\
(x + 65)/30 & \text{when } -65 \leq x \leq -35, \\
0 & \text{otherwise}, 
\end{cases}
\]
(21)

\[
\text{NEG}(x) = \begin{cases} 
-(35 + x)/30 & \text{when } -65 \leq x \leq 35, \\
(x+100)/35 & \text{when } -100 \leq x \leq -65, \\
0 & \text{otherwise}, 
\end{cases}
\]
(22)

\[
\text{VNEG}(x) = \begin{cases} 
-(65 + x)/35 & \text{when } -100 \leq x \leq -65, \\
0 & \text{otherwise}, 
\end{cases}
\]
(23)

The hydraulic servo system were achieved for the position control of slider. Thus, membership function of the hydraulic output follow the following equations:

\[
\text{VPOS} = \begin{cases} 
(x - 204)/51 & \text{when } 204 \leq x \leq 255, \\
0 & \text{otherwise}, 
\end{cases}
\]
(24)

\[
\text{POS} = \begin{cases} 
(255 - x)/51 & \text{when } 204 \leq x \leq 255, \\
(x-102)/100 & \text{when } 102 \leq x \leq 204, \\
0 & \text{otherwise}, 
\end{cases}
\]
(25)

\[
\text{SPOS} = \begin{cases} 
(204 - x)/100 & \text{when } 102 \leq x \leq 204, \\
x/102 & \text{when } 0 \leq x \leq 102, \\
0 & \text{otherwise}, 
\end{cases}
\]
(26)
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\[
Z_E = \begin{cases} 
(102 - x)/102 & \text{when } 0 \leq x \leq 102, \\
(x + 102)/102 & \text{when } -102 \leq x \leq 0, \\
0 & \text{otherwise},
\end{cases}
\]

\[
SNEG = \begin{cases} 
x/102 & \text{when } -102 \leq x \leq 0, \\
(x + 204)/100 & \text{when } -204 \leq x \leq -102, \\
0 & \text{otherwise},
\end{cases}
\]

\[
NEG = \begin{cases} 
-(102 + x)/100 & \text{when } -204 \leq x \leq 102, \\
(x + 255)/51 & \text{when } -255 \leq x \leq -204, \\
0 & \text{otherwise},
\end{cases}
\]

\[
VNEG = \begin{cases} 
-(204 + x)/51 & \text{when } -255 \leq x \leq -204, \\
0 & \text{otherwise},
\end{cases}
\]

V. EXPERIMENTAL SET UP

The proposed controller was also implemented in hydraulic servo system set up which was primarily developed to be used in a motion simulator. The experiment setup is composed of a hydraulic system. A set of experiments were performed to study the effect of variation in supply pressure, hydraulic parameters, environmental stiffness and position control. In order to test performance of the developed system comparing Simulink model. A typical closed loop controlled hydraulic system consists of power supply with 4 lit/min flow rate and 60 bar supply pressure. The load 9 kg is connected to the piston rod. Load piston position is measured by a FESTO Model TP 501 with 200 mm length of stroke and a 4-way 3 state proportional directional control valve is measured by a VICKERS Model KBSDG4V. Linear potentiometer from a FESTO Model FP1120 is used to record the position of the cylinder and DUPOMATIC Model PTH-100/20E0 pressure sensors are measured P1 and P2 [24]. Consider a schematic of the experimental system shown in Fig. 9.

![Fig. 9: A schematic diagram of the hydraulic servo system](image)

VI. SIMULATION AND EXPERIMENT RESULTS

The object of Simulink is a hydraulic actuator, which is a representative hydraulic servo system. A simulation of Matlab/Simulink based study is used to evaluate the performance of controllers on the nonlinear model of HSS and compared with the performance of the PID control, Fuzzy control, and Hybrid of PID and Fuzzy control, which are shown in Fig. 10. The parameters of the model must be identified for designing control algorithm, the steps of identifying dynamic models of the hydraulic system involve designing an experiment, selecting a model structure, choosing a criterion to fit, and devising a procedure to validate the chosen model.
According to Figure above, first, the system is characterized by position control \( (x_1) \). The piston stroke is \( \pm 0.2 \text{m} \), mass of actuator and load \( m = 9.19 \text{Kg} \). The friction relation is approximated as linear \( F_f = 0.3063 N \).

Secondly, the system is characterized by velocity control \( (x_2) \). Let be a differentiable function, given by \( i.e., we obtain the result in terms of \)

\[
\dot{x}_1 dt = \int x_1 dt
\]

The response is a set of the velocity and its top most displacement range is \( \pm 0.16 \text{m/s} \). Referring the equation (9) \( \dot{x}_2 = \frac{1}{m} (A x_2 - F_f) \) The line block is required for each channel, where velocity \( \dot{x}_2 \) is calculated.

For that, area and force are added in to the block while friction is subtracted from the block. The third method is load pressure system \( (x_3) \). This is the most effective method. The pressure of the system is set considering the pressure of the load. Pressure limit is the supply pressure \( P_l \); 5MPa. The value of \( P_l \) is determined by substituting \( P_l = x_3 \). To solve this equation, we may assume a solution \( x_3 \) of the form

\[
x_3 = -Ax_2 + Q_e \left( \frac{1}{V} + \frac{1}{4 \rho} + C_m \right)
\]

First, all the models of components are composed and connected to the blocks. The load flow line parameters are the sum of blocks from the function \( P_1 = \mathrm{sgn}(x) \) after passing through the function \( C_m \).

Overall, the main idea of the modified hydraulic subsystems is to use valve position \( (x) \), valve velocity \( (\dot{x}) \) and input current \( (u) \). The upper and lower limits in servo valve are equal to the stroke of the servo valve \( x_i = 2.38 \times 10^{-1} \text{m} \) and the maximum flow limit through the valve \( Q_e = 2.5 \times 10^{-1} \text{m}^3/\text{s} \).

**VII. VALIDATION**

The main directions to model the dynamics behavior of a hydraulic servo system are various controls of model complexity to achieve difference simulation and experiments. In case of the model validation and Hybrid controller experiments, the controller is modeled using Simulink approach in Matlab program, comparing to the
position and velocity of PID, Fuzzy, and Hybrid of PID and Fuzzy controller which are based on an operating supply pressure of 6 Mpa are shown in Figs. 11-13.

![Observer performance of step responses with PID Controller](image1)

**Fig. 11:** Observer performance of step responses with PID Controller

![Observer performance of step responses with Fuzzy Controller](image2)

**Fig. 12:** Observer performance of step responses with Fuzzy Controller

![Observer performance of step responses with Hybrid Controller](image3)

**Fig. 13:** Observer performance of step responses with Hybrid Controller

**VIII. CONCLUSION**

This paper documented the design, experimental evaluation and simulation of the position and velocity servo control of a hydraulic mini press machine. The highly nonlinear behavior of the system limits the performance of classical linear controllers used for this purpose. It was found that the proposed controller is better compared
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with the traditional PID, Fuzzy, and Hybrid of PID and Fuzzy controllers both in simulations and experiments. The scheme has been tested on various process in simulations and experiments where accurate speed control with fast response times is 0.123 m/s and position is 42 mm. The simulations and experiments was found a good effectiveness of the Hybrid of PID and Fuzzy method for HSS. The pressure control resulted in a performance error which was lower than any performance error controlled with a keeping the system stable and the better performance of a higher control precision have been obtained in position servo control system compare with conventional PID and Fuzzy controllers.

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