OPTIMIZATION OF PID PARAMETERS FOR HYDRAULIC POSITIONING SYSTEM UTILIZING VARIABLE WEIGHT GREY-TAGUCHI AND PARTICLE SWARM OPTIMIZATION

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SUPERVISOR'S DECLARATION

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LIST OF SYMBOLS

$\bar{x}$	Square of mean
β	Weight distribution factor
ΔCV	Percent step change of control variable
ΔPV	Change in the process variable
ζ	Damping ratio
η	S/N value
ξ_c	Distinguishing coefficient
σ^2	Variance
ω	Inertia weight factor
ω_d	Damped natural frequency
$\omega_{\max}$	Maximum inertia weight
$\omega_{\min}$	Minimum inertia weight
ω_n	Natural frequency
c_{final}	The steady-state condition
$C(s)$	Transfer function of the controller
e	Error
E_{ss}	Steady-state error
$E(s)$	Laplace transform of the error signal
$e(t)$	Error signal at time t
$iter$	Current number of iterations

$iter_{\max}$	Maximum number of iterations
K	$[K_p, K_i, K_d]$
K_d	Derivative gain constant
K_i	Integral gain constant
K_p	Proportional gain constant
L	Lag time
M_p	Maximum overshoot
n	Number of particles in a group
N	Slope of the system response curve
N_f	Number of factor
$r(t)$	Desired output signal
s	Laplace domain
t	Time
T_p	Peak time
T_r	Rise time
T_s	Settling time
$U(s)$	Laplace transform of the corresponding control input
$u(t)$	Control signal at time t
$V_{\max}$	Limit of change in particle velocity
$W(K)$	Performance criterion
$y(t)$	Measured output signal

LIST OF ABBREVIATIONS

ACO	Ant Colony Optimization
AI	Artificial Intelligence
AVR	Automatic Voltage Regulator
CLF	Control Lyapunov Function
DC	Direct Current
DOE	Design of Experiment
DOF	Degree of Freedom
GA	Genetic Algorithm
GASA	Genetic Algorithm Simulated Annealing
GRA	Grey Relational Analysis
GRC	Grey Relational Coefficient
GRG	Grey Relational Grade
IAE	Integral of Absolute Error
IMC	Internal Model Control
ISE	Integral Square Error
ITAE	Integral Time of Absolute Error
LQR	Linear Quadratic Regulator
MSE	Mean Square Error
OA	Orthogonal Array
P	Proportional
PD	Proportional-Derivative
PI	Proportional-Integral
PID	Proportional-Integral-Derivative

PSO	Particle Swarm Optimization
SI	Swarm Intelligence

ABSTRACT

Controller that uses PID parameters requires a good tuning method in order to improve the control system performance. Especially on hydraulic positioning system that is highly nonlinear and difficult to be controlled whereby PID parameters needs to be tuned to obtain optimum performance criteria. Tuning PID control method is divided into two namely the classical methods and the methods of artificial intelligence. Particle swarm optimization algorithm (PSO) is one of the artificial intelligence methods. Previously, researchers had integrated PSO algorithms in the PID parameter tuning process. This research aims to improve the PSO-PID tuning algorithms by integrating the tuning process with the Variable Weight Grey-Taguchi Design of Experiment (DOE) method. This is done by conducting the DOE on the two PSO optimizing parameters: the limit of change in particle velocity and the weight distribution factor. Computer simulations and physical experiments were conducted by using the proposed PSO-PID with the Variable Weight Grey-Taguchi DOE and the classical Ziegler-Nichols methods. They are implemented on the hydraulic positioning system. Simulation results show that the proposed PSO-PID with the Variable Weight Grey-Taguchi DOE has reduced the rise time by 48.13% and settling time by 48.57% compared to the Ziegler-Nichols method. Physical experiment results also show that the proposed PSO-PID with the Variable Weight Grey-Taguchi DOE tuning responds better than Ziegler-Nichols tuning. In conclusion, this research has improved the PSO-PID parameter by applying the PSO-PID algorithm together with the Variable Weight Grey-Taguchi DOE method as a good tuning method in the hydraulic positioning system.

ABSTRAK

Pengawal yang menggunakan parameter PID memerlukan kaedah penalaan yang baik untuk meningkatkan prestasi sistem kawalan. Terutamanya pada sistem kedudukan hidraulik yang tidak linear dan sukar untuk dikawal, di mana parameter PID perlu ditala untuk mendapatkan kriteria prestasi optimum. Kaedah penalaan kawalan PID dibahagikan kepada dua kaedah iaitu kaedah klasik dan kaedah kecerdasan buatan. Algoritma Pengoptimuman Kawanan Partikel (PSO) adalah salah satu kaedah kecerdasan buatan. Sebelum ini, penyelidik telah menyatupadukan algoritma PSO dengan parameter PID untuk tujuan proses penalaan. Kajian ini bertujuan untuk meningkatkan algoritma penalaan PSO-PID dengan mengintegrasikan proses penalaan dengan kaedah Rekabentuk Experimen (DOE) Pembolehubah Berat Grey-Taguchi. Ini dilakukan dengan melaksanakan DOE pada dua PSO optimum parameter: iaitu had halaju partikel dan faktor pengagihan berat. Simulasi komputer dan eksperimen fizikal telah dijalankan dengan menggunakan cadangan PSO-PID bersama DOE Pembolehubah Berat Grey-Taguchi dan kaedah klasik Ziegler-Nichols. Ia dilaksanakan pada sistem kedudukan hidraulik. Keputusan simulasi menunjukkan bahawa PSO-PID yang dicadangkan dengan DOE Pembolehubah Berat Grey-Taguchi telah mengurangkan masa naik sebanyak 48.13% dan 48.57% oleh masa penetapan berbanding dengan kaedah Ziegler-Nichols. Tambahan pula, ralat keadaan mantap juga diminimumkan. Keputusan eksperimen fizikal juga menunjukkan bahawa algoritma penalaan PSO-PID yang dicadangkan dengan DOE Pembolehubah Berat Grey-Taguchi bertindak balas dengan lebih baik daripada algoritma penalaan Ziegler-Nichols. Kesimpulannya, kajian ini telah menambah baik pengoptimuman parameter PSO-PID dengan menggunakan algoritma PSO-PID bersama kaedah DOE Pembolehubah Berat Grey-Taguchi sebagai kaedah penalaan yang baik dalam sistem kedudukan hidraulik.

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