ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

OPTIMIZATION OF CONTROLLER PARAMETER BASED ON TAGUCHI –MPSO APPROACH TO CONTROL NONLINEAR SYSTEM

Prof. Prakash Pithadiya[*1], Dr. Vipul Shah[2], Prof. Chintan Shah[3] & Prof. Vipul C. Rajyaguru[4]
[*1]Instrumentation and Control Department, Government Engineering College Rajkot, Gujarat, India
[2]Instrumentation and Control Department, DDIT, Nadiad, Gujarat, India
[3]Instrumentation and Control Department, Government Engineering College Gandhinagar sector 28, Gujarat, India
[4]Instrumentation and Control Department, Government Engineering College Rajkot, Gujarat, India

DOI: 10.5281/zenodo.1199376

ABSTRACT
In this research work proposed MPSO methods for nonlinear complex processes. These processes are implemented in various process control industries, Design and development of new controller to increase the better stability and improve the performance index. This paper goal the minimize parameters for process controller by Taguchi method combined mutation particle swarm optimization algorithm for industrial laboratory highly complex nonlinear QTS. Analysis of means techniques analyses the meaning of means which are effectively different from the output responses combined means to detect nearer values of PID controller parameters while ANOVA method determines the two most effective parameters with the response of Quadruple tanks system. The result shows that TMPSO technique is provided the good result when compared with other approaches. The TMPSO techniques use for setting controller offers enhanced process specification such as better time domain specifications, smooth error reference tracking, remove the coupling effect and minimization of error in the nonlinear system.

Keywords: Mutation- Particle Swarm Optimization, Nonlinear system, Performance Index.

I. INTRODUCTION
In various real-time chemical and petrochemical plants such as spherical tank system Continuous Stirred Tank Reactor (CSTR), other various chemical reactor processes are more nonlinear by characteristics and highly complex in nature. In various process industries, Controller tuning to stabilize these nonlinear multivariable processes and contribute necessary disturbance rejection is the big problem because of their nonlinearity and uncertain phenomena. Most of the processes indicate stable and/or unstable characteristics. Based on the operating condition. In the almost industry process control system essential requirement for proper tuned PID controller for every process. In various literatures of control and nonlinear system, various controllers designing for critical processes are available to stabilize processes [1–5]. Researchers help to tune parameter of PID to control systems by using various techniques to change system better response [1]. It is very simple conception of the controller for a stable operating region, but it's very difficult for nonlinear unstable system, there available increasing and decreeing of controller constant value, and some specific value to be viewed to conception of the controller for the complex system. These nonlinear indicate overshoot and inverse output due to system characteristics [4].

In the recent advanced research on control techniques for process industry such as adaptive control techniques, predictive control, IMC control techniques, soft computing techniques, and conventional controllers are contributing in various process control application reason of their method very simple and robust in nature, also easier to validate [2]. Several years before, in the several manufacturing processes parameter design using particle swarm optimization [14] instead of its requirement for the process of extrusion to design was not better. For the reason that study, they did design on the reduce mandrel eccentricity and output tube bending positions of a billet inside multi-hole extrusion operation optimization. This research access produce the optimize

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

responses with respect to the specific operation variable range on basis of the finding knowledge of the results through the very advanced procedure to again enhance the perfect solution of qualities. Hsiang and Lin analytical thought the gist of many operation parameters of the magnesium alloy tubes hot extrusion by using the statistical approach techniques and another analysis of variance (ANOVA) to improve the better result nature of other different parts. It's involved that temperature, the billet, in extrusion velocity, of heating and temperature of container affect the mechanical characteristics of extruded products.

Diminish costly approximate trails and get the key forces of specific variables to make certain best quality [17]. Required best pairs of parameter values of a process by using PSO combine mutation mechanism (MPSO). PSO was assigned random velocity to each and considerable particle due to its search mechanism associates and its own. In this research work, quadruple tank system is laboratory-based highly nonlinear system standard model for an experimentation setup for research as well as practical aspect. Using Taguchi method find the optimized value for PID controller parameter after again this value optimized by MPSO algorithm so that more optimized result we are getting through Taguchi combine with MPSO.

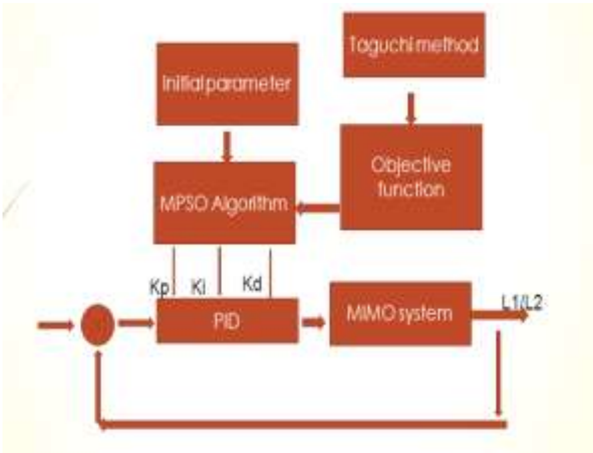

Figure: 1 Block Diagram Taguchi based MPSO for MIMO System

II.QUADRUPLE TANK SYSTEM

The process which has nonlinear characteristics has a more interaction with quadruple tank processes, which are touchstone processes used in many industries application. This frame-up is very simple and rugged but still, the system would elaborate concerning multiple variable techniques. The process flow diagram is viewed in Figure 1. The main object has to maintain to the levels Y1 and Y2 at bottom tanks with prime movers. This mathematical model needed for the present practical lab includes and also the disturbing effect of flows in and out of the upper-level tanks. Inputs voltage is applied to prime movers voltage V1 and voltage V2. This process is represented by the differential equations according to the material balance equation. Process is represented by equations

Here in the QTS infer a mathematical model. A process schematic is shown in Figure 1. Mass balances yield

$$\frac{dh1}{dt} = -\frac{a1}{A1}\sqrt{2gh1} + \frac{a3}{A1}\sqrt{2gh3} + \frac{\gamma 1k1}{A1}v1$$

$$\frac{dh2}{dt} = -\frac{a2}{A2}\sqrt{2gh2} + \frac{a4}{A2}\sqrt{2gh4} + \frac{\gamma 2k2}{A2}v2$$

$$\frac{dh3}{dt} = -\frac{a3}{A3}\sqrt{2gh3} + \frac{(1-\gamma 2)k2}{A3}v2$$

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

$$\frac{dh4}{dt} = -\frac{a4}{A4}\sqrt{2gh4} + \frac{(1-\gamma 1)k2}{A4} v1$$

Where A is tank 1,2,3,4 cross-section area of respective tank, a is the outlet hole cross-section area of respective, and water level h. v1and V2 is the voltage given to Pump and the kivi is respective flow rate. The minimum phase and non minimum phase parameters γ1; γ2 € [0; 1] are supported by how the valves are in position to on and off for trails.

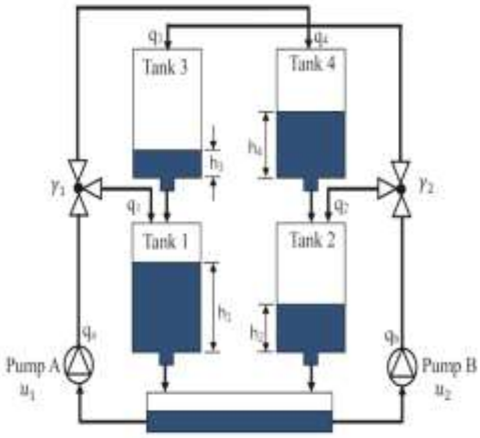

Figure: 2 Quadruple Tank MIMO system

This process presents interacting multiple variable dynamics; complex system because of each of the prime movers involves both of the outputs. This process exhibits nonlinear model and the nonlinear model convert to a linear model of the quadruple-four tank process has multivariable zero, which are to be situated in the left or the right half - s plane by adjusting the throttle valves position γ1 and γ2. It's showed that the reverse response (non-minimum phase) will happen when the value of this valve in the range of $0 < \gamma 1 + \gamma 2 < 1$ and minimum phase for $1 < \gamma\ 1 + \gamma 2 \leq 2$. The setting of the valve will be given to the whole overall system dissimilar characteristics from a multiple variable control point of view. Immeasurable disturbances can be enforced through forced water out of the main upper tanks and into the main bottom man-made space small tank. It has been exhibited reject interference as well as mention covering the point. Using the multiple variable four tank process different aspects of multiple variable control systems can be illustrated. Using this algorithm we are getting the good result and improve the performance index ISE and IAE goes minimum. Now all-over system performance increase and index of stability also minimize. For example:

- Development and analysis of decoupling compensator.
- Development and analysis of state feedback compensator for different locations of the zeros.
- The valve settings effect on the location of the zeros.
- Recognize when a process is easy or not to control
- Design and evaluation of decentralized control.
- Development and analysis of mathematical model based predictive Strategy. Development and analysis of μ-analysis-based H∞ control.
- The locations of the zeros on the process output effect in different input directions

III.TAGUCHI METHOD (ANOVA)

The Taguchi method provides a very long meaning of explaining of the separate and mix results of different design principles based on the lowest number of trials (Al-Arifi et al., 2011) Taguchi approach for design variables is available in several categories as a result of an output of every variable to quality characteristics. The different levels of the process outcome are converts into s/n ratio. The standard ratio of signal to Signal to noise basically utilized are as follows: first is the Smaller value the Better, Second the Nominal value the Better, and third is the Higher value -The Better. This research study uses the ratio of Signal to Noise of the ISE and IAE performance to minimize the better stability of the nonlinear quadruple tank system process. The Signal to Noise ratio the Smaller-The Better (STB), characteristics is as follows (Lin and Chou, 2010):

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

$$\frac{S}{N} = -\log\left(\frac{1}{n}\sum vi^2\right) \quad 5$$

Where, n is the number of counts under the same design parameters, yi indicates the measured results and i presents the number of application based variables in the Taguchi OA. An output of S/N ratio figure of paramater levels indicates a better concept with preferable quality within the specified values. The ANOVA techniques utilized for in the Taguchi is a novel statistical approach first excepted to an analysis of the major values of application parameters and also the output of each variable, yi denoted the measured output results and i denotes the number of application parameters available with the Taguchi Orthogonal Array due to ratio of signal and noise, Effect of the Process parameter obtain based on ANOVA. The output of S/N ratio diagram of variable values shows a application with considerable prime within the specified value of variables.

IV. MUTATION COMBINED WITH PARTICLE SWARM OPTIMIZATION

The roots of PSO were instigated through the social behavior of fish schooling or bird flocking. Eberhart and Kennedy counseled the particle swarm computer program optimization pso methodology in 1995. In the search space indicates a good performance for each particle to the minimization specific task and representing as a bunch of different specific variables. This is linked with two path which name is the positioning and velocity path, which called name is the position and acceleration vectors In nth -dimensional search space, the two vectors associated with each particle i are **Xi = (xi,1, xi,2, . ., xi,n) and Vi =(vi,1, vi,2, . . ., vi, n), respectively. E**very particle changes the levels its result will depend on it is own good survey and the good swarm overall involvement to search it is good fitness level using iterative changing. Moving ahead this iteration process, the change of position and velocity of each and every particle are evaluated as shown in the equation. The global best position and acceleration are change after each iteration value. Equation suggests the updated design variables after mutation of each up to date particle from previous equation. The proposed algorithms were designed to continuous change parameter in specified equation for specific method up to reach termination states.

Flowchart of the Taguchi based MPSO techniques

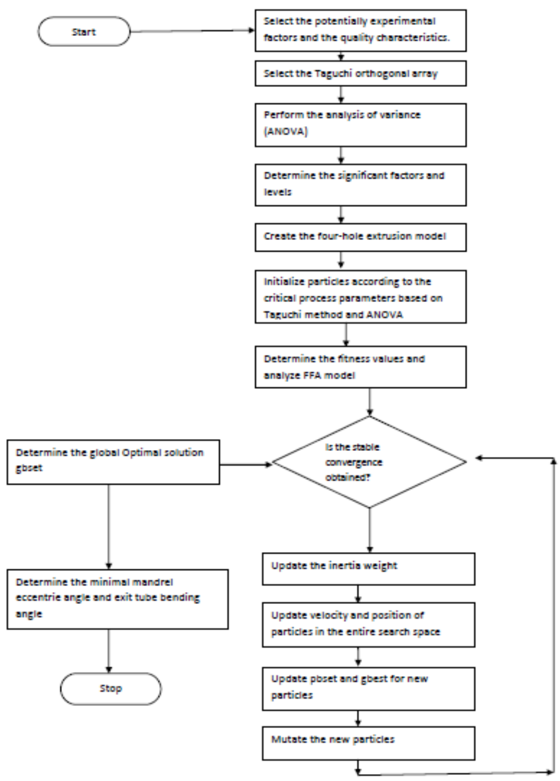

Figure :3 Flow chart Mutation PSO algorithm

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

V. SIMULATION RESULT AND DISCUSSION

Taguchi and ANOVA

Using Mutation based PSO we can also optimize again for the value from the Taguchi method So that we can more optimized value for the parameter of PID and getting good response for nonlinear system Result for Taguchi with MPSO KP1 = 7, KI1 = 6.9, KP2 = 5.4, KI2 = 9.3

TABLE I: Design Variables and Their Coded Levels

Tuning constant	stage 1	stage 2	stage 3
Kp1	10	11	12
Ki1	7	8	9
Kp2	11	12	13
Ki2	8	9	10

Orthogonal Array

TABLE II: DESIGN VARIABLES and THEIR CODED LEVELS

Exp.	Kp1	Ki1	Kp2	Ki2	ISE1	ISE2	E^2	S/N
1	1(10)	1(7)	1(11)	1(8)	4.9889E-03	5.2678E-03	5.2639E-05	50.33819
2	1(10)	2(8)	1(11)	2(9)	2.4900E-02	2.5500E-02	1.2703E-03	36.62965
3	1(10)	3(9)	1(11)	3(10)	5.3089E-02	6.3759E-02	6.8837E-03	28.63005
4	1(10)	2(8)	2(12)	1(8)	1.9877E-02	2.5804E-02	1.0609E-03	36.53014
5	1(10)	3(9)	2(12)	2(9)	5.3474E-02	6.4229E-02	6.9848E-03	28.56553
6	1(10)	1(7)	2(12)	3(10)	4.1322E-03	4.4209E-03	3.6619E-05	51.8607
7	1(10)	3(9)	3(13)	1(8)	6.0211E-02	6.4456E-02	7.7799E-03	28.52313
8	1(10)	1(7)	3(13)	2(9)	3.6644E-03	4.4261E-03	3.3018E-05	51.85055
9	1(10)	2(8)	3(13)	3(10)	2.0020E-02	2.5368E-02	1.0443E-03	36.67813
10	2(11)	2(8)	1(11)	1(8)	1.1220E-04	1.7820E-03	3.1881E-06	59.75304
11	2(11)	3(9)	1(11)	2(9)	1.0111E-02	1.0167E-02	2.0560E-04	44.62558
12	2(11)	1(7)	1(11)	3(10)	7.2311E-06	8.2351E-06	1.2011E-10	106.4578
13	2(11)	3(9)	2(12)	1(8)	2.0000E-07	1.0039E-02	1.0078E-04	44.73697
14	2(11)	1(7)	2(12)	2(9)	1.2100E-04	1.0033E-02	1.0068E-04	44.74216
15	2(11)	2(8)	2(12)	3(10)	1.2121E-03	1.7884E-03	4.6676E-06	59.72189
16	2(11)	1(7)	3(13)	1(8)	2.1313E-05	2.3482E-05	1.0056E-09	97.35651
17	2(11)	2(8)	3(13)	2(9)	1.3264E-03	1.7918E-03	4.9699E-06	59.70539

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

18	2(11)	3(9)	3(13)	3(10)	1.2640E-04	1.0158E-02	1.0320E-04	44.6346
19	3(12)	3(9)	1(11)	1(8)	3.1216E-05	4.7059E-04	2.2243E-07	71.31836
20	3(12)	1(7)	1(11)	2(9)	3.1216E-05	4.7059E-04	2.2243E-07	#NUM!
21	3(12)	2(8)	1(11)	3(10)	5.2164E-06	5.9019E-07	2.7559E-11	129.3514
22	3(12)	1(7)	2(12)	1(8)	3.2515E-05	4.3521E-04	1.9046E-07	#NUM!
23	3(12)	2(8)	2(12)	2(9)	1.4550E-07	1.7885E-06	3.2199E-12	119.7214
24	3(12)	3(9)	2(12)	3(10)	3.2154E-05	4.5731E-04	2.1017E-07	71.567
25	3(12)	2(8)	3(13)	1(8)	1.6432E-07	1.8151E-07	5.9947E-14	139.5932
26	3(12)	3(9)	3(13)	2(9)	3.2515E-05	4.3521E-04	1.9046E-07	71.99723
27	3(12)	1(7)	3(13)	3(10)	1.6432E-07	1.8151E-07	5.9947E-14	#NUM!

Results of ANOVA

TABLE III: ANOVA method for QTS

Factor	S1	S2	S3	DOF	Sum of Squares	Mean Square	Factor Effect (percent)
KP1	10	11	12	2	307	153	45
KI1	7	8	9	2	95	47	14
KP2	11	12	13	2	259	130	38
KI2	8	9	10	2	14	7	2

Result Comparison of GA and MPSO PID controller performance time domain specification

TABLE IV: Comparison Taguchi based GA and MPSO for QTS

Controller	Para meter	Minimum phase		Non minimum phase	
		Lev 1	Lev 2	Lev 1	Lev 2
PID with Taguchi based GA	Settling time	5	5.5	20	700
	Peak overshoot	1	2	30	20
	Rise time	12	12	39	32

PID with Taguchi based MPSO	Settling time	5	5.5	22	700
	Peak overshoot	1	2	30	20
	Rise time	7.5	4.5	20.5	120

Performance Index Specification

TABLE V: Comparison Performance Index Taguchi based GA and MPSO for QTS

Methods	Tank1 (height 1)		Tank2 (height 2)	
	ISE	IAE	ISE	IAE
PID Taguchi based GA	12	2.35	15.6	5.6
PID Taguchi based MPSO	10.02	5.5	8.38	3.5

VI. CONCLUSION

This research paper presented for finding the best optimal solution for the nonlinear dynamic system. These techniques to find optimize the parameter of the controller for multiple inputs and multiple output dynamic system using Taguchi statistical method based on MPSO techniques.

This method utilized to find optimal parameter Kp, Ki, and Kd of PID controller based on the performance index to increase the stability and performance of the dynamic nonlinear mimo system. By using the orthogonal array and ANOVA in Taguchi method based on a signal to noise ratio determine the level of the parameter of quadruple tank system based on performance index ISE and IAE. Taguchi based MPSO techniques could be utilized for the better response than Taguchi based in GA for quadruple tank system. These techniques to search optimal value from Taguchi method after that again Taguchi combine with MPSO with the better optimal value of controller parameter. That parameter gives the best result and optimized (minimize) performance index. Minimize performance index all over system performance increase. The results indicate that the Taguchi based MPSO methods can act as the best techniques of the mimo nonlinear system and it can be extended to other nonlinear process control parameter for the various industrial process control system.

The effect indicate that the taguchi based MPSO strategies can act as quality strategies of the MIMO nonlinear process and might be extended to different nonlinear method controller parameter for the industrial process control system.

VII. REFERENCES

[1] A. O'Dwyer, Handbook of PI and PID Controller Tuning Rules, Imperial College Press, London, UK, 3rd edition, 2009..
[2] R. Padmasree and M. Chidambaram, Control of Unstable Systems, Narosa Publishing House, New Delhi, India, 2006.
[3] C. J. Einerson, D. E. Clark, and B. A. Detering, "Intelligent control strategies for the plasma spray process," in Proc. Thermal Spray Coatings: Research, Design and Applications, 1993, pp. 205-211.
[4] R. C. Panda, "Synthesis of PID controller for unstable and integrating processes," Chemical Engineering Science, vol. 64, no. 12, pp. 2807–2816, 2009.
[5] Kennedy, J. and R. Eberhart, 1995. Particle swarm optimization. Proceeding of IEEE International Conference Neural Networks, 4: 1942-1948.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

[6] Thomas E. Merlin, Process Control Designing Processes and Control Systems for Dynamic Performance, McGraw-Hill Inc., 1995.
[7] Geem, Z.W., Kim, J.H., and Loganathan, G.V. (2001). A new heuristic optimization algorithm: harmony search. Simulation, 76: 60–68.
[8] Grebeck, Micheal, A Comparision of Controllers for Quadruple Tank System," Dept. of Automatic Control, Lund University, Lund, Sweden, 1998.
[9] Jignesh Patel and Hasan Vhora http://www.iaeme.com/IJARET/index.asp 104 editor@iaeme.com
[10] Alvarado, D. Limon, W. Garc'ıa-Gab'ın, T. Alamo, E.F. Camacho, "An Educational Plant Based on the Quadruple-Tank Process, in Int. Federation of Automatic Control, Madrid, Spain, 2006.
[11] Tomi Roinila, Matti Vilkko, Antti Jaatinen, Corrected Mathematical Model of Quadruple-Tank Process, in The International Federation of Automatic Control, Seoul, Korea, 2008.
[12] R. D. Braatz and Rusli, A Quadruple-Tank Process Control Experiment, the University of Illinois at Urbana Champaign, 2004.
[13] J. Kennedy and R. Eberhart, "Particle swarm optimization," in Proc. International Conference on Neural Networks, 1995, vol. 4, pp. 1942-1948.
[14] K. H. Johansson. Relay feedback and multivariable control. Ph.D. thesis, Department of Automatic Control, Lund Institute of Technology, Sweden, November 1997.
[15] K. H. Johansson. The Quadruple-Tank Process - A multivariable laboratory process with an adjustable zero. IEEE Transactions On Control Systems Technology, Vol. 8, No. 3, May 2000.
[16] Abeykoon, C., K. Li, M. McAfee, A.L. Kelly and J. Deng, P.J. Martin, Q. Niu, , 2011. A new model-based approach for the prediction and optimisation of thermal homogeneity in single screw extrusion. Cont. Eng. Pract., 19(8): 862-874.
[17] Roy, R.K, Design of Experiments Using the Taguchi Approach: 16 Steps to Product and Process Improvement, Wiley, New York, NY,2001.
[18] Dr. Ali Rıza Yildiz, An effective hybrid immune-hill climbing optimization approach for solving design and manufacturing optimization problems in industry. Journal of Materials Processing Technology 2009c
[19] Wang, Z.G., Rahman, M., Wong, Y.S. and Sun, J. (2005). Optimization of multi-pass milling using parallel genetic algorithm and parallel genetic simulated annealing. International Journal of Machine Tools & Manufacture, 45: 1726- 1734.
[20] T. F. Edgar, D. E. Seaborg, Duncan A. Mellichamp, Process Dynamics and Control, John Wiley & Sons Inc., 2004.

CITE AN ARTICLE

Pithadiya, P., Prof., Shah, V., Dr, Shah, C., Prof., & Rajyaguru, V. C., Prof. (n.d.). OPTIMIZATION OF CONTROLLER PARAMETER BASED ON TAGUCHI –MPSO APPROACH TO CONTROL NONLINEAR SYSTEM. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *7*(3), 463-470.