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Comparative study: FPA based response surface methodology & ANOVA for the parameter optimization in process control

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ABSTRACT

Optimization plays a key role in a process control industry to optimize and prediction of the system's performance. Most of the process control are multi-variable and to control the parameters to optimized the system performance through the classical method is inflexible, unreliable and time-consuming. Thus, an alternative method will be more effective for parameter optimization & prediction. In this research investigates parameters affecting the liquid flow for the various studied. Design of Experiments based on metaheuristic algorithm is conducted for the analysis of influencing factors. Response surface methodology (RSM) & ANOVA are widely used as a mathematical and statistical tool for system performance optimization. RSM can be employed to optimize and analyze the effects of several independent factors on a treatment process to obtain the maximum output. This paper is to present a comprehensive review on the usability & effectiveness of RSM & ANOVA based on flower pollination algorithm for process parameters modelling and optimization of liquid flow processes. From the appraisal it indicates that the FPA based RSM is gives the more predicted output than the FPA based ANOVA is approximately 9.0389e-6.

1. INTRODUCTION

In industry the traditional method is not used to optimized the system performance as it is a inflexible, unreliable & time consuming. The main drawback of the traditional optimization is to getting the response influenced by individual independent variables. when the response is measured with respect to the influence of a particular variable then keeping the other variables are constant. In traditional optimization interactiveness between the variables are absent thats why it can generate the overall effects on the independent variable with respect to a particular response. Hence the total number experimental trials increased, increased cost function & time consuming [1-4]. Researcher reported the new usage of the ANOVA & response surface methodology (RSM) tool used for the optimization & experimental design of a industrial process. total number of documents published concerning to the RSM & Anova based on the process control since 2000 to 2017 increased exponentially from 552 to 6619. It is also noticed that among all the published journal most of related to the process controlled optimization 15.6%, in biochemistry (11.2%), in agricultural & biological science (10.6%), in chemical science (10.5%), in chmical engineering (9.5%) & in environmental engineering (6%) [6]. RSM has been successfully used to optimized the treatment process like textile dye wastewater, tannery wastewater, industrial paint wastewater, landfil leachate, olive oil effluent, palmoil effluent etc in [7-13]. In the present paper focused on the usage of the ANOVA & RSM based on the FPA in parameter optimization & prediction of the flow rate in a process control industry.

1.1 Design of expert

Design of expert is a program for design of experiments, statistical analysis, modelling & optimization. It includes full factorial, fractional factorial design, response surface methodlogy & Taguchi. the design expert software also be used to analysis the data collected. A regression is performed on the data collected where the response is approximated based on the functional relationship between the estimated input variables. Residual is the difference between the calculated & experimental dependable variables for a given sets of data. A low residual value means the mathematical model is effective.

1.2 Response surface methodology (RSM)

RSM was first innovated by Box & Wilson in 1951using a second degree polynomial mathematical model. RSM is the combination of mathematical & statistical technique which is used to modelling & analysis the problem .Main objective of the RSM is optimized the response with respect to the given set of independent variables [14-15].In modern trends RSM also applied in the field of food technology ,material Engineering, Chemistry & chemical engineering [16-19].Steps for performing the RSM as a optimization tool [20].

1. Selection of the most important independent variables & their level.

2. Choice of the experimental design & perform the experiment according to the matrix formatted selected input independent variables.

3. Applying the mathematical –statistical topology to achieved a fit of polynomial function.

4. Evaluate the fitness value of the mathematical & Statistical model.

5. Verified & then predict the direct of the displacement where optimal response is achieved.

6. Then obtained the optimum values of independent values.

1.3 Analysis of variance(ANOVA)

ANOVA is a statistical tool which is used to investigate the nature of the input parameter and also identify which input parameter is most significantly affects the output parameters. In this analysis Sum of Square (SS), variance, Confidence level, Degree of Freedom (DOF), mean of square (MS), F test. F-test value at 95% the confidence level is used to indicate how the independent parameters affecting the the process. By using this tool we can determining the influence of any given input parameter from a series of experimental results by design of experiments. ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes t-test to more than comparative experiments, those in which only the difference in outcomes is of interest. In ANOVA a statistical significance of the experiment is determined by a ratio of two variances which is independent of several possible alterations or adding a constant or multiplying a constant to all the experimental observation does not affects the nature of statistical significance. Hence ANOVA statistical significance are independent of constant bias , scaling errors and the units which are used in expressing observations. In process control industry the analysis of variance (ANOVA) is used because it helps to investigate which design factors and their interactions affect the response significantly.

1.4 Experimental setup

This research is done in a flow & level measurement & control unit shown in Fig 1 where the total set up contained the pump, water reservoir, flow rate indicator, control valve, water tank & Anemometer type flow sensor. Flow sensor is designed by the transistor based bridge circuit placed in diametrical plane of the PVC pipe .

Figure 1. Experimental set up for flow measurement

For this work we take 36 sample data which consist of two independent variables sensor output voltage & pipe diameter shown in table1. To conduct this research we had taken the 3 different set of pipe diameter 20mm, 25mm & 30 mm. Each of the cases we collect the flow rate as a experimental output data.Fig1 shown the experimental set up for conducting the research. Althrough for this experiment we take most important two independent variables pipe diameter & sensor while ignore the liquid viscosity & conductivity. Water is considered as an experimental liquid. Anemometer sensor is designed by the transistor based bridge circuit which detects the flow as a nonlinear voltage .Experimental data are taken & represent in a table 1.

Table 1. Experimental datasets

SI no	Sensor output (E)in volt	Diameter (D)in meter	Experimental flow (F)in lpm
1	0.216	0.025	0.0008
2	0.218	0.025	0.0016
3	0.219	0.025	0.0024
4	0.225	0.025	0.0032
5	0.229	0.025	0.004
6	0.233	0.025	0.0048
7	0.234	0.025	0.0056
8	0.237	0.025	0.0064
9	0.241	0.025	0.0072
10	0.244	0.025	0.008
11	0.245	0.025	0.0088
12	0.247	0.025	0.0096
13	0.207	0.02	0.0008
14	0.208	0.02	0.0016
15	0.209	0.02	0.0024
16	0.211	0.02	0.0032
17	0.212	0.02	0.004
18	0.214	0.02	0.0048
19	0.215	0.02	0.0056
20	0.218	0.02	0.0064
21	0.219	0.02	0.0072
22	0.223	0.02	0.008
23	0.225	0.02	0.0088
24	0.227	0.02	0.0096
25	0.226	0.03	0.0008
26	0.228	0.03	0.0016
27	0.23	0.03	0.0024
28	0.234	0.03	0.0032
29	0.237	0.03	0.004
30	0.239	0.03	0.0048
31	0.243	0.03	0.0056
32	0.246	0.03	0.0064
33	0.248	0.03	0.0072
34	0.252	0.03	0.008
35	0.255	0.03	0.0088
36	0.256	0.03	0.0096

2. RESULT ANALYSIS

2.1 RSM method

In response surface methodology, the parameters sensor output, pipe diameter is given as an input & flow rate is given as a output to find the optimal parameters. This study is conduct by taking 36 datasets. The optimal results obtain from the RSM.

Table 2. Analysis of response surface methodlogy

Terms	coef	SE coef	T	P
Constant	-0.0961	0.0390	-2.465	0.020
Voltage	0.9446	0.4217	2.287	0.029
Diameter	-2.837	0.9887	-2.876	0.007
Voltage*voltage	-1.1057	1.2098	-0.914	0.368
Diameter*Diameter	68.5694	13.9432	4.918	0.000
Voltage*Diameter	-5.9900	6.3152	-0.949	0.350

F=a+b*E+c*D+d*E*E+e*D*D+f*E*D (1)

a, b ,c d, e & f are the coefficients of the above non linear equation which is determined by the RSM

F=-0.0961-0.9446*E-2.837*D-1.1057*E*E+68.5694*D*D-5.9900*E*D (2)

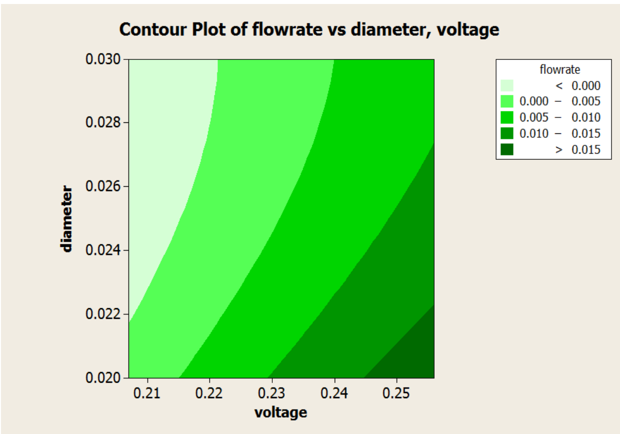

Figure 2. Contour plot of flowrate vs diameter& voltage

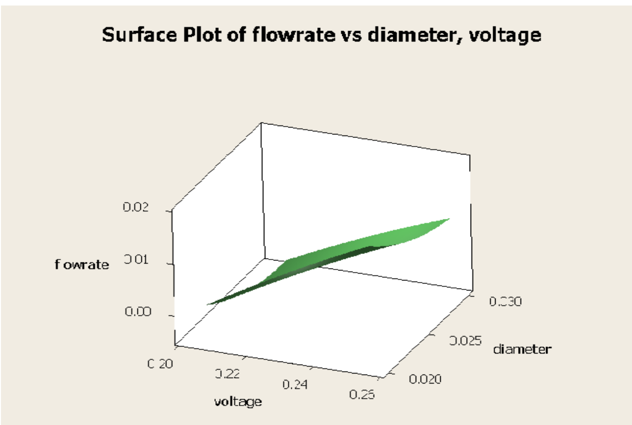

Figure 3. Surface plot of flowrate vs diameter & voltage

From the contour of response fig.2 in surface methodlogy it is seen that deep green area provides better flowrate. the range of the Sensor output voltage just greater than 0.24 to 0.25 gives the better flowrate at the same time the pipe diameter ranging between 0.020 met to 0.022 m provides the better flowrate. In fig.3 the surface plot indicates that as the sensor output voltage increased & the pipe diameter ranging between from 0.020m to 0.025m, flowrate propotionally increased.

A comparative study is conduct for the liquid flow process control where we had taken 36 datasets as a test data. For the prediction of the output we use two non linear equation for find out the fittest value among these two.Both the non linear equation solved with help of metaheuristic flower pollination algorithm.For the FPA based ANOVA & RSM we take the boundary value (-75,75) & we get the co efficient of the non linear equation as well as the optimized value .

2.2 FPA –ANOVA

For FPA based ANOVA we choose the equation for 2 independent & 1 dependent variable is

$F=a*(E)^{b}*(D)^{c}$ (3)

where, F is the flow rate (dependable variable)
E is the sensor output in volt range
D is the pipe diameter in metre &
a ,b & c are the coefficient of the non linear equation of (1) shown in table 3
to achieved the co efficient from the above non linear equation we use the matlab code

$F=0.4542*(E)^{12.0371}*(D)^{-3.5533}$ (4)

Table 3. Coefficient of nonlinear equation by FPA-ANOVA

a	b	c	f_{min}
0.4542	12.0371	-3.5533	3.1266e-05

2.3 FPA-RSM

For the FPA based Response surface methodlogy we use the two independent & 1 dependeable non linear equation

F=a+b*E+c*D+d*E*E+e*D*D+f*E*D (5)

a, b, c d, e & f are the coefficients of the above non linear equation which is determined by the RSM with the help of FPA matlab code shown in table 4.

F=-0.0953718-0.956729*E-2.82164*D-1.07688*E*E+69.0929*D*D-6.19687*E*D (6)

Table 4. Coefficient of nonlinear equation by FPA-RSM

a	b	c	d	e	f	f_{min}
- 0.09537 18	0.9567 29	- 2.821 64	- 1.076 88	69.09 29	- 6.196 87	9.0389 e-06

Table 5. Comparative study between RSM, FPA-RSM & FPA-ANOVA

SI no	E	D	Experimental flow(Lpm)	Flow by using RSM(Lpm)	Flow by using RSM based on FPA(Lpm)	Flow by using ANOVa based on FPA(Lpm)
1	0.216	0.025	0.0008	8.34358E-05	0.000232379	0.002180721
2	0.218	0.025	0.0016	0.000753388	0.000938244	0.002436585
3	0.219	0.025	0.0024	0.001085047	0.001285929	0.002574582
4	0.225	0.025	0.0032	0.003028563	0.003298562	0.003564537
5	0.229	0.025	0.004	0.004280011	0.004570342	0.004406792
6	0.233	0.025	0.0048	0.005496078	0.005786141	0.005428088
7	0.234	0.025	0.0056	0.005794566	0.006081344	0.005715248
8	0.237	0.025	0.0064	0.006676762	0.006945959	0.006662392
9	0.241	0.025	0.0072	0.007822063	0.008049796	0.008149374
10	0.244	0.025	0.008	0.00865782	0.008840937	0.009457949
11	0.245	0.025	0.0088	0.008931983	0.009097653	0.009935231
12	0.247	0.025	0.0096	0.009473674	0.009600588	0.01095669
13	0.207	0.02	0.0008	0.001949221	0.002107265	0.002887114
14	0.208	0.02	0.0016	0.002335155	0.002488822	0.003059549
15	0.209	0.02	0.0024	0.002718878	0.002866881	0.003241381
16	0.211	0.02	0.0032	0.00347969	0.003612501	0.00363511
17	0.212	0.02	0.004	0.003856779	0.003980062	0.003847996
18	0.214	0.02	0.0048	0.004604323	0.00470469	0.004308448
19	0.215	0.02	0.0056	0.004974778	0.005061755	0.004557139
20	0.218	0.02	0.0064	0.006072873	0.006111958	0.005384333
21	0.219	0.02	0.0072	0.006434482	0.006455029	0.005689277
22	0.223	0.02	0.008	0.007858805	0.007792321	0.007074206
23	0.225	0.02	0.0088	0.008557698	0.008439975	0.007876866
24	0.227	0.02	0.0096	0.009247745	0.009073633	0.008762259
25	0.226	0.03	0.0008	0.001214127	0.000582808	0.00196712
26	0.228	0.03	0.0016	0.001779951	0.001227926	0.002187206
27	0.23	0.03	0.0024	0.00233693	0.00185905	0.002429665
28	0.234	0.03	0.0032	0.003424351	0.003079312	0.002990063
29	0.237	0.03	0.004	0.004216697	0.00395777	0.003485584
30	0.239	0.03	0.0048	0.00473387	0.004525916	0.003856608
31	0.243	0.03	0.0056	0.005741681	0.00562022	0.004709485
32	0.246	0.03	0.0064	0.006474319	0.006404212	0.005459051
33	0.248	0.03	0.0072	0.006951687	0.006909378	0.006017921
34	0.252	0.03	0.008	0.007879887	0.007877726	0.007296097
35	0.255	0.03	0.0088	0.008552817	0.00856725	0.008413118
36	0.256	0.03	0.0096	0.008772705	0.008790094	0.008818962

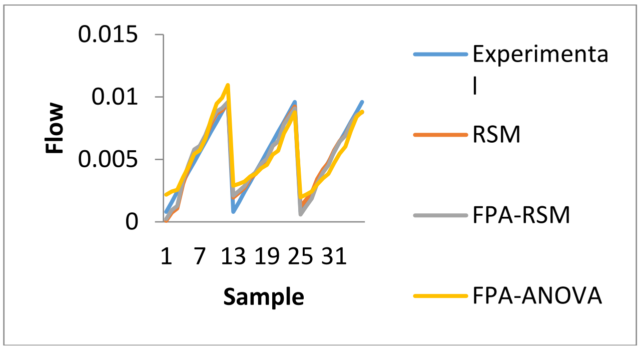

Figure 4. Graphical comparison between the sample & different optimized algorithm

3. CONCLUSION

From the graphical analysis it is seen that FPA based response surface methodology is better than the FPA based ANOVA as the optimized results of RSM is comparatably less deviate from the actual flow rate compare to the FPA-ANOVA shown in fig.4.From the table 5. it is also seen that among the RSM, FPA-RSM & FPA-ANOVA, flower pollination based –response surface methodology predicts the optimized flowrate in respect to the experimental flowrate. Another important advantage of the FPA –RSM is it has least root mean square value f_{min} =9.0389e-06 while for the same input independent parameters FPA-ANOVA has 3.1266e-05 RMSE error.

REFERENCE

[1] Thomas M, Beaucbamp Y, Youssef YA, Masounave I. (1997). An experimental design for surface roughness and built-up edge formation in lathe dry turning. Int. J. Qual. Sci. 2: 167-180.

[2] Bas D, Boyaci IH. (2007). Modeling optimization I: Usability of response surface methodology. J. Food Eng. 78: 836-845.

[3] Bezerra MA, Santelli RE, Oliveira EP, Villar LS, Escaleira LA. (2008). Response surface methodology (RSM) as a tool for optimization in analytical chemistry. Talanta 76: 965-977.

[4] Arslan-Alaton I, Tureliamd G, Olmez-Hanci T. (2009). Treatment of azo dye production wastewaters using Photo-Fenton-like advanced oxidation processes: Optimization by response surface methodology. J.Photochem. Photobiol. A 202: 142-153.

[5] Myers RH, Montgomery DC. (2002). Response surface methodology: Process product optimization using designed experiment 2nd ed., John Wiley & Sons, USA.

[6] Mohammed JK, Bashir SS, Abu A, Shuokr QA, Choon A, Ethupathi S. (2015). Wastewater treatment processes optimization using response surface methodology (RSM) compared with conventional methods: Review comparative study. Middle-East Journal of Scientific Research 23(2): 244-252.

[7] Korbahti BK, Tanyolac A. (2008). Electrochemical treatment of simulated textile wastewater with industrial components Levafix Blue CA reactive dye: Optimization through response surface methodology. Journal of Hazardous Materials 151: 422-431.

[8] Korbahti BK, Aktas N, Tanyolac A. (2007). Optimization of electrochemical treatment of industrial paint wastewater with response surface methodology. Journal of Hazardous Materials 148: 83-90.

[9] Kutty SRM, Mohajeri S, Farooqi IH. (2009). Landfill leachate treatment by electrochemical oxidation. Waste Management 29: 2534-2541.

[10] Aziz SQ, Aziz HA, Yusoff MS, Bashir MJK. (2011a). Landfill leachate treatment using powdered activated carbon augmented sequencing batch reactor (SBR) process: Optimization by response surface methodology. Journal of Hazardous Materials 189: 404-413.

[11] Aziz SQ, Aziz HA, Yusof MSf. (2011b). Optimum process parameters for the treatment of landfill leachate using powdered activated carbon augmented sequencing batch reactor (SBR) technology. Separation Science Technology 46: 2348-2359.

[12] Ghafari S, Aziz HA, Isa MH, Zinatizadeh AA. (2009). Application of response surface methodology (RSM) to optimize coagulation-flocculation treatment of leachate using poly- aluminum chloride (PAC) alum. J. Hazard. Mater 163: 650-656.

[13] Zinatizadeh AAL, Mohamed AR, Abdullah AZ, Mashitah MD, Isa MH, Najafpour G. (2006). Process modeling analysis of palm oil milleffluent treatment in an up-flow anaerobic sludge fixed film bioreactor using response surface methodology (RSM). Water Research 40: 3193-320.

[14] Box GEP, Wilson KB. (1951). On the experimental attainment of optimum conditions. Journal of the Royal Statistical Society Series, pp: 131-145.

[15] Montgomery D.C. (2008). Design Analysis of Experiments. 7th ed., John Wiley Sons, Inc., New York.

[16] Mason RL, Gunst RF, Hess JL. (2003). Statistical Design Analysis of Experiments, Eighth Applications to Engineering Science, 2nded., Wiley, New York.

[17] Jafarzadeh SG, Rahman MNA, Wahab DA. (2012). Optimization of supply chain management based on response surface methodology: A case study of iran khodro. World Applied Sciences Journal 20(4): 620-627.

[18] Fathi HK, Moghadam MB, Taremi M, Rahmani M. (2011). Robust parameter design in optimization of textile systems using response surface dual response surface methodologies, World Applied Sciences Journal 14(7): 973-979.

[19] Salamantinia B, Bhatia S, Abdullah A. (2011). Response surface methodlogy based modelling of temperature variation in an ultrasonic assisted biodisel production process. World Applied Sciences, Journal 12(9): 1549-1557.

[20] Steppan DD, Werner I, Yeater RP. (1998). Essential regression experimental design for chemists engineer. http://llgeocities.com/SiliconValley/Network/1032/CGPage.html.

[21] Aggarwal A, Singh H, Kumar P, Singh M. (2008). Optimizing power consumption for CNC turned parts using response surface methodlogy taguichi's technique –Acomparative analysis journal of materials processing technology 2003: 373-384.