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A Process Optimization Frame Work for a Agrichem Industry Using Taguchi Approach

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ABSTRACT:

In This paper, optimization ofprocess parameters is carried out for the three thermal systems namely reactor, condenser and vacuum pump of Nagarjuna agrichem industry by using taguchi method. In the case of reactor, the output response is taken as heat transfer capacity by taking input responsesas process temperature, jacket temperature and heat transfer coeficient. In condenser we optimize output response of overall heat transfer coeficient using input responses namely hot vapor inlet temperature, hot vapor flow rate and cold vapor flow rate. In vacuum pump we optimize output response of cavitationusing input responses namely discharge, pressure inlet and vapor pressure.At the end of the study, it is identified that It was found that the process parameters for each thermal system in the industry were optimized.

Key words:
Reactor, condenser, vacuum pump, Taguchi.

I.INTRODUCTION:

Taguchi parameter design offers a systematic approach for optimization of various process parameters with regard to performance, quality and cost. Reactor is a place where all the raw materials are thoroughly mixed in the presence of a catalyst and the desired chemical compounds are formed at the outlet. Condenser is a device in which heat is transferred from one medium to another across a solid surface. The vacuum pump is used to drain out non-condensable gases from the condenser.Taguchi method; a Design of Experiment (DOE) technique wasused to optimize the process parameters and improve the efficiency of a Liquid Ring Vacuum Pump (LRVP). The tools and techniques such as, orthogonal array, signal-to-noise ratio (S/N) were employed in Taguchi method to study the process parameters of the liquid ring vacuum pump [1]. This study has shown the application of Taguchi method on the performance evaluation of a chemical process for the production of liquid fuel from waste plastics in a batch reactor [2].This author Data was taken for a reactor, condenser and vacuum pump with different flow rates, temperatures and discharge to predict the performance of the system. The data was incorporated into the ANN model [3]. Neural networks model was developed to predict overall heat transfer coefficient UDesign of the design condenser system and the model was trained, validated and tested for generalization [4].

Taguchi experimental design is a design that differentiates between control factors and noise or uncontrollable factors and treats them separately by means of special design matrices called Orthogonal Arrays (OA) [5]. The use of these arrays helps to determine the least number of experiments needed for a given set of factors.From the above literature survey, it is identified that the optimization of process parameters for thermal systems (condenser, vacuum pump, and reactor) is optimized by applying various techniques which involves complexity and difficult procedures. To mitigate these limitations, in this paper Taguchi method is used in a simpler way to optimize the optimum process parameters of thermal systems as follows. In this work Nagarjuna agrichem industry has been taken as a case study.

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II. TAGUCHI APPROACH TO PARAMETER DESIGN:

In the present work, experimental work has been designed in a sequence of steps to insure that data is obtained in a way that its analysis will lead immediately to valid statistical inferences. This research methodology is termed as DESIGN OF EXPERIMENT (DOE) methodology. DOE using Taguchi approach attempts to extract maximum important information with minimum number of experiments. Taguchi techniques are experimental design optimization techniques which use standard Orthogonal Arrays (OA) for forming a matrix of experiments. Using an OA to design the experiment helps the designer to study the influence of multiple controllable factors on the average of quality characteristics and the variations in a fast and economic way. In the present thermal systems three operating parameters, each at three levels, are selected to evaluate yield of thermal systems optimum process parameters. Based on Taguchi method, the L9-OA was constructed. The reason for using L9-OA is to evaluate the significance of interaction terms.

III. REACTOR SYSTEM:

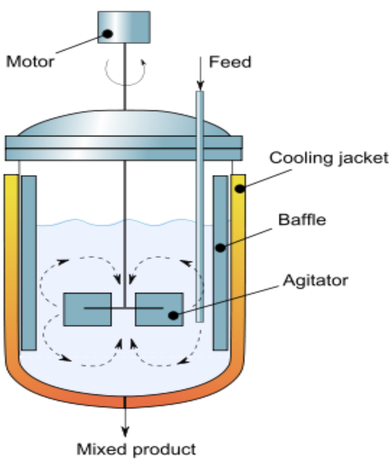

Fig 3.1: Cross sectional diagram for chemical reactor

A. Data obtained from industry :

Three process parameters namely process temperature, jacket temperature and heat transfer coeficient were selected and their data was taken at 3 different levels.

Table 3.1: Factors and their levels in the experimental design

Level	Process temp(°C)	Jacket temp(°C)	Heat transfer coeficient (W/m^{2}K)
1	80	30	11.727
2	83	32	11.325
3	86	34	10.975

The experiments were carried out according to the L9-OA. The yield of heat capacity was considered as Taguchi array response. Output response for reactor system is heat capacity. By considering reactor heat capacity larger the better.

S/N Ratio (dB): $\eta = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{yi^2}\right)$ - (1)

The L9-OA and response values for yield of heat capacity are shown in Table 3.2.

Table 3.2 L9-OA response values and S/N ratio for yield of Heat capacity

S. No	Process temp(°C)	Jacket temp(°C)	Heat transfer coefficient (W/m^{2}K)	Heat capacity (W)	S/N Ratio
1	80	30	11.727	116.32	41.31
2	80	32	11.3	114.13	41.14
3	80	34	10.975	111.99	40.98
4	83	30	10.975	110.27	40.84
5	83	32	11.727	117.91	41.43

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6	83	34	11.325	114.41	41.16
7	86	30	11.325	113.03	41.06
8	86	32	10.975	109.69	40.80
9	86	34	11.727	116.80	41.34

Then the mean S/N ratios at each level for various factors have to be calculated by using equation(1). The factor levels corresponding to the highest average S/N ratio will optimize the condition of heat capacity. In order to evaluate the influence of each factor on the heat capacity of reactor, the S/N ratio for each factor should be computed. The S/N ratio for single factor can be calculated by averaging the values of S/N ratios at different levels as given below.

$SP_1 = (\eta_1+\eta_2+\eta3)$ $SP_2 = (\eta4+\eta5+\eta6)$ $SP_3 = (\eta7+\eta8+\eta9)$
$SJ_1 = (\eta_1+\eta4+\eta7)$ $SJ_2 = (\eta2+\eta5+\eta8)$ $SJ_3 = (\eta3+\eta6+\eta9)$ (2)
$SU_1 = (\eta_1+\eta5+\eta9)$ $SU_2 = (\eta2+\eta6+\eta7)$ $SU_3 = (\eta3+\eta4+\eta8)$

S/N ratios for different factors at different levels were calculated using (2) and tabulated in Table 3.3.

Table 3.3.Sum and average S/N ratios for different factors at different levels.

Level	Process Temp(deg °C)		JacketTemp(deg °C)		Heat transfer coefficient (W/m^2K)	
	Sum(S_{cj})	AvgS/Nratio	Sum(S_{sj})	AvgS/Nratio	Sum(S_{pj})	AvgS/Nratio
1	123.43	41.14	123.24	41.07	124.08	41.36
2	123.53	41.17	123.37	41.12	123.36	41.12
3	123.20	41.06	123.48	41.16	122.62	40.87

The optimum factor levels can be easily identified from graphs between S/N ratios of each factor on the Y- axis and Levels on the X- axis. The graphs of which are shown on the results page.

IV. Condenser system

A condenser has two main advantages: The primary advantage is to maintain a low pressure (atmosphere or below atmosphere pressure) so as to obtain the maximum possible energy from vapor and thus to secure a high efficiency, The secondary advantage is to supply pure feed water to the hot well, from where it is pumped back to the reactor.

A. Condenser setup in industry:

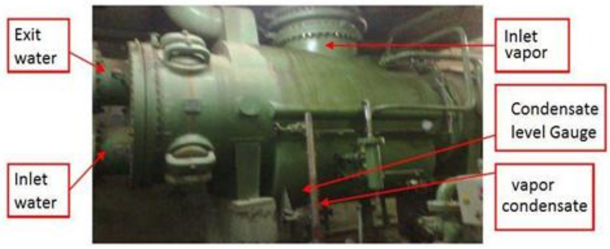

Fig 4.1: Condenser setup in industry

B. Data obtained from industry:

Three process parameters namely hot vapor inlet temperature, cold water flow rate were selected and their data was taken at 3 different levels.

Table 4.1: Factors and their levels in the experimental design

Level	Hot vapor inlet temp(°C)	Hot vapor flow rate(LPH)	Cold water flow rate (LPH)
1	56	230	350
2	59	250	375
3	62	270	400

The experiments were carried out according to the L9-OA. The yield of overall heat transfer coeficient was considered as Taguchi array response. Output response for condenser system is overall heat transfer coeficient. By considering condenser overall heat transfer coeficient larger the better.

S/N Ratio (dB): $\eta = -10\log_{10}(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{yi^2})$ - (3)

The L9-OA and response values for yield of overall heat transfer coefficient are shown in Table 4.2.

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Table 4.2: L9-OA response values and S/N ratio for yield of overall heat transfer coeficient.

S.no	Hot vapor inlet temp(°C)	Hot vapor flow rate(LPH)	Cold water flow rate (LPH)	overall heat transfer coeficient(w/m^{2}k)	S/N Ratio
1	56	230	350	4.21	12.50
2	56	250	375	5.93	15.46
3	56	270	400	5.80	15.26
4	59	230	400	6.29	15.97
5	59	250	350	5.70	15.11
6	59	270	375	5.42	14.67
7	62	230	375	5.36	14.58
8	62	250	400	5.91	15.43
9	62	270	350	5.49	14.79

Then the mean S/N ratios at each level for various factors have to be calculated by using equation (3). The factor levels corresponding to the highest average S/N ratio will optimize the condition of overall heat transfer coeficient. In order to evaluate the influence of each factor on the overall heat transfer coeficient of condenser, the S/N ratio for each factor should be computed. S/N ratios for different factors at different levels were calculated using (3) and tabulated in Table 4.3.

Table 4.3.Sum and average S/N ratios for different factors at different levels.

Sl. No	Hot vapor inlet temperature(°C)		Hot vapour flow rate (LPH)		Cold water flow rate(LPH)	
	Sum(S_{cj})	AvgS/Nratio	Sum(S_{sj})	AvgS/Nratio	Sum(S_{pj})	AvgS/Nratio
1	43.22	14.40	43.05	14.35	42.4	14.13
2	45.75	15.25	44.57	14.85	44.71	14.96
3	44.80	14.93	44.72	14.90	46.66	15.55

The optimum factor levels can be easily identified from graphs between S/N ratios of each factor on the Y- axis and Levels on the X- axis. The graphs of which are shown on the results page.

V. VACUUM PUMP SYSTEM:

Vacuum pump sucks non-condensable gases from condenser and discharges to atmosphere.

A. Vacuum pump setup in industry:

Fig5.1: Vacuum pump setup in industry

B. Data obtained from industry:

Three process parameters namely discharge, pressure inlet and vapor pressure were selected and their data was taken at 3 different levels.

Table 5.1: Factors and their levels in the experimental design

Level	Discharge (m^3/hr)	Pressure inlet(Kpa)	Vapor pressure (Kpa)
1	430	97.725	3.60
2	450	96.05	4.68
3	470	93.99	7.33

The experiments were carried out according to the L9-OA. The yield of Cavitation was considered as Taguchi array response.

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Output response for vacuum pump system is Cavitation. By consider the vacuum pump system is Cavitation is lower the better.

S/N Ratio (dB): $\eta = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} yi^{2}\right)$ –(4)

The L9-OA and response values for yield of Cavitation are shown in Table 5.2.

Table 5.2: L9-OA response values and S/N ratio for yield of Cavitation.

S.No	Discharge (m3/hr)	Pressure inlet (Kpa)	Vapor pressure(Kpa)	Cavitation	S/N Ratio
1	430	97.725	3.6	1.617	-8.348
2	430	96.05	4.68	2.064	- 6.294
3	430	93.99	7.33	1.334	-2.503
4	450	97.725	7.33	2.126	-6.551
5	450	96.05	3.6	1.811	- 5.158
6	450	93.99	4.68	1.441	- 2.990
7	470	97.725	4.68	1.888	- 5.520
8	470	96.05	7.33	1.479	-3.399
9	470	93.99	3.6	1.954	-5.818

Then the mean S/N ratios at each level for various factors have to be calculated by using equation (4). The factor levels corresponding to the highest average S/N ratio will optimize the condition of Cavitation. In order to evaluate the influence of each factor on the Cavitation of vacuum pump, the S/N ratio for each factor should be computed.

S/N ratios for different factors at different levels were calculated using (3) and tabulated in Table 5.3.

Table 5.3.Sum and average S/N ratios for different factors at different levels.

Sl. No	Discharge(m^3/hr)		Pressure inlet (Kpa)		Vapor pressure(Kpa)	
	Sum(S_{cj})	AvgS/Nratio	Sum(S_{sj})	AvgS/Nratio	Sum(S_{pj})	AvgS/Nratio
1	-17.148	-5.716	-20.419	-6.806	-19.324	-6.441
2	-14.699	-4.899	-14.851	-4.950	-12.453	-4.151
3	-14.737	-4.912	-11.131	-3.770	-14.81	-4.936

The optimum factor levels can be easily identified from graphs between S/N ratios of each factor on the Y- axis and Levels on the X- axis. The graphs of which are shown on the results page.

VI. RESULTS AND DISCUSSIONS

6.1: REACTOR SYSTEM:

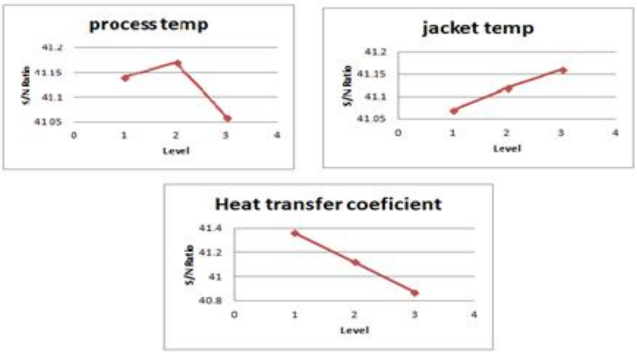

Fig 6.1: S/N Ratio's Vs Levels for Reactor

From the above Fig 6.1 it is identified For Reactor system, process temperatureof S/N Ratio is optimum for level2, jacket temperature of S/N Ratio is optimum for level3 and overall heat transfer coeficient is optimum for level1.

6.2: CONDENSER SYSTEM:

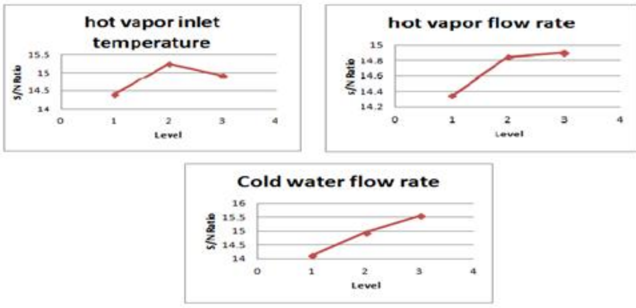

Fig 6.2: S/N Ratio's Vs Levels for condenser

For condenser system, hot vapor inlet temperature of S/N Ratio is optimum for level2, hot vapor flow rate of S/N Ratio is optimum for level 3 and cold water flow rate is optimum for level 3.

6.3: VACUUM PUMP SYSTEM:

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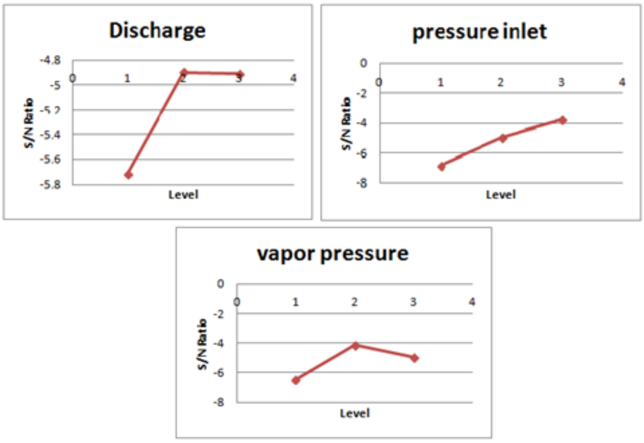

Fig 6.3: S/N Ratio's Vs Levels for vacuum pump

For vacuum pump system, Discharge of S/N Ratio is optimum for level 2, pressure inlet of S/N Ratio is optimum for level 3 and vapor pressure is optimum for level 2.

VII. CONCLUSIONS

This study has discussed an application of the Taguchi method for investigating the optimum process parameters on the thermal systems. From the analysis of the results using the conceptual signal-to-noise (S/N) ratio approach, and Taguchi optimization method, the following can be concluded from the present study. Statistically designed experiments based on Taguchi methods were performed using L9 orthogonal array to analyze heat capacity for reactor, overall heat transfer coefficient for condenser and cavitation for vacuum pump as response variable. In this study, the analysis of the experiments for thermal systems has shown that Taguchi parameter design can successfully verify the optimum process parameters for reactor (P2,J3,U1), which are process temperature of 83(°C), jacket temperature 34(°C), overall heat transfer coefficient 11.727 (W/m^2K).condenser (T_2,Vf_3,Wf_3),which are hot water inlet temperature59(°C), hot vapor flow rate270 (LPH) and cold water flow rate 400 (LPH). Vacuum pump (Q_2, Pi3, VP2), which are discharge 450 (m^3/hr), pressure inlet 93.99(Kpa) and vapor pressure 4.68(Kpa).It was found that the process parameters for each thermal system in the industry were optimized.

REFERENCES:

[1].YathiAjay.A.V, Ramkumar.B, Vishnu Unni, John Paul "Optimization of Process Parameters to Maximize the Efficiency of a Vacuum Pump Using Taguchi Method and ANOVA"International Journal of Science, Engineering and Technology Research (IJSETR) Volume 4, Issue 4, April 2015.

[2]. Achyut K. Panda, R. K. Singh "Optimization of Process Parameters by Taguchi Method:Catalytic degradation of polypropylene to liquid fuel" IJMCR, ISSN: 2321-3124 July-August-2013 issue.

[3].M.SrinivasaRao, B.Bharath Kumar, "A Frame work for performance evaluation of a process industry: A case study" International Journal of Engineering Trends and Technology (IJETT) – Volume 26 Number 4- August 2015.

[4].M.SrinivasaRao, B.Bharath Kumar, "Performance prediction of a thermal system using Artificial Neural Networks" e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com Volume 11, Issue 07 (July 2015), PP.16-22.

[5].Roy, R. (1990). "A Primer on the Taguchi Method". Van Nostrand Reinhold.

[6].Phillip j.Ross,"Taguchi techniques for quality engineering". Second edition, Tata McGraw Hill Education Private limited.