APTEFF, 47, 1-265 (2016)
DOI: 10.2298/APT1647129A

UDC: 628.4.042:66.011/.012:532.14
BIBLID: 1450-7188 (2016) 47, 129-142
Original scientific paper

TAPPED DENSITY OPTIMISATION FOR FOUR AGRICULTURAL WASTES: PART II - PERFORMANCE ANALYSIS AND TAGUCHI-PARETO

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In this attempt, which is a second part of discussions on tapped density optimisation for four agricultural wastes (particles of coconut, periwinkle, palm kernel and egg shells), performance analysis for comparative basis is made. This paper pioneers a study direction in which optimisation of process variables are pursued using Taguchi method integrated with the Pareto 80-20 rule. Negative percentage improvements resulted when the optimal tapped density was compared with the average tapped density. However, the performance analysis between optimal tapped density and the peak tapped density values yielded positive percentage improvements for the four filler particles. The performance analysis results validate the effectiveness of using the Taguchi method in improving the tapped density properties of the filler particles. The application of the Pareto 80-20 rule to the table of parameters and levels produced revised tables of parameters and levels which helped to identify the factor-levels position of each parameter that is economical to optimality. The Pareto 80-20 rule also produced revised S/N response tables which were used to know the relevant S/N ratios that are relevant to optimality.

KEY WORDS: optimisation, performance analysis, significance tests, pareto rule

INTRODUCTION

In the composite industry, concerns are often shown for the changing density values of reinforcing filling powders during transportation. Usually, discrepancies are often noticed in the values of the densities. As a solution to this, a scientific approach adopted to solve this dispute is the use of experimental tapped density. Still, this tapped density needs to optimised and the use of Taguchi becomes relevant since the investment of research efforts is just growing in this direction (1, 2). Taguchi method (TM) is an optimisation method based on a special design technique known as design of experiments (3, 4). Its uniqueness lies in the incorporation of statistical methods into various engineering process and its ability to use different factors at the same time, unlike conventional methods which uses one factor at the same time. This makes Taguchi method to be used

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DOI: 10.2298/APT1647129A BIBLID: 1450-7188 (2016) 47, 129-142

Original scientific paper

profitably in various industrial and engineering processes to maximise yield or profit under tough economic conditions. Taguchi method design of experiment uses a robust orthogonal array which allows for all possible combination of factors and levels. Parameters involved in the experiment are known as factors, while levels describe the possible conditions of the factors during the experiment.

A literature review was conducted on the four agricultural wastes to find out to what extent the wastes have been applied in practice (5, 6), as fillers to composites. The search of literature retuned information about some papers on orange peels and particulates as well as on coconut shell and particulates. A scanty number of studies were also sighted based on egg shell particles but composites or independent examinations of fillers of palm kernel shell and periwinkle shell particles are non-existent. The reason for the scanty and sometimes absence of studies of waste agricultural products as fillers is due to their filler characteristics and potentials not being fully appreciated. Another fact is the non- availability of scientific reporting on their properties, such as tapped density optimisation, which compels engineers and scientists to choose fillers that are well-studied and show reported rewards. It is not a surprise to note that majority of studies on orange peels and particulates are outside the composites fabrication domain.

EXPERIMENTAL

This section is dedicated to the materials used in the paper as well as the methods of analysis. The detailed information on the materials used for the experiments has been given in the first paper. Also, the details of the methods have been given in the schematic diagram concerning the research in the first paper also. The information from the schematic diagram (Figure 1 of the first paper) that concerns this work is principally the issue of Taguchi-Pareto. The claim of relevance of Taguchi-Pareto observation is made in this paper and in this section, justification concerning the choice of Taguchi scheme as well as Pareto analysis the necessity to integrate them is promoted. First, we start with the advantage of the Taguchi scheme. The Taguchi scheme principally has the advantage of tremendous cost savings compared with the basic mathematical optimisation steps in literature. This advantage stems from the fact that the required quantities of experimental runs to achieve acceptable results with the employment of Taguchi scheme is often very less in comparison with what is necessary using the basic mathematical optimisation steps.

Pareto, as a concept, has gained tremendous attention of quantitative researchers, particularly in industrial engineering as a realistic observation in most practical events that the majority of industrial activities, and in this case, issues concerning tapped density optimisation parametric values, are not distributed in an even manner, but according to an 80:20 percentage observation. The success of the Pareto analysis in industrial applications and theory has therefore motivated its use in our current work. However, it will be integrated with the Taguchi scheme to derive the most benefit from its synergy. The major advantage of Pareto lies in the understanding that it has the capability of prioritising certain problem causal agents in such a way that the most severe problems are

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Original scientific paper

distinguished and arranged in order of strength to the least severe problem. Synergy in the perspective of tapped density optimisation with respect to filler development in the composite industry is the integrated influence of Taguchi scheme and Pareto analysis that produces a situation in which the outcome of the integration is more beneficial to the system than the addition of the individual tools of Taguchi scheme as well as Pareto analysis employed alone to the tapped density optimisation process. The synergic effect of these two tools is positive as it will improve the optimisation results.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA)

The use of the Taguchi method gives information for choosing the optimal parameter condition. It also makes it possible to analyse the relevance of each parameter for subsequent studies. The analysis of variance (ANOVA) makes it possible to measure the effect of the tapped density parameters on the quality characteristics of interest (7). The results of the ANOVA for the CSPs, PSPs, PKSPs and ESPs tapped density are presented in Table 1(a)-(d). Please note that F_{crit} means the critical F while $F_{0.05}$ means the F value at 95% level of significance. Also p-value is called the significant p.

Table 1(a). ANOVA table for CSPs tapped density using arithmetic, harmonic, geometric and quadratic S/N responses

	Source of Variance	**SS**	***df***	**MS**	**F**	**p-value**	**F_{crit}**
Arithmetic S/N response	Factors	1.69 E-12	3	5.63E-13	6.45E-09	1	3.862
	Levels	0.000746	3	0.000249	2.851281	0.097316	3.862
	Error	0.000784	9	8.72 E-05			
	Total		15				
Harmonic S/N response	Factors	2.27E-11	3	7.56E-12	8.67E-08	1	3.862
	Levels	0.000745	3	0.000248	2.846614	0.097638	3.862
	Error	0.000785	9	8.73E-05			
	Total	0.00153	15				
Geometric S/N response	Factors	1.5E-10	3	5E-11	5.73E-07	1	3.862
	Levels	0.000746	3	0.000249	2.849947	0.097408	3.862
	Error	0.000785	9	8.72E-05			
	Total	0.00153	15				
Quadratic S/N response	Factors	1.69E-10	3	5.63E-11	6.45E-07	1	3.862
	Levels	0.000746	3	0.000249	2.850482	0.097371	3.862
	Error	0.000785	9	8.72E-05			
	Total	0.00153	15				

* F_{crit} means Critical F

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Original scientific paper

Table 1(b). ANOVA table for PSPs tapped density using arithmetic, harmonic, geometric and quadratic S/N responses

	Source of Variance	SS	*df*	MS	F	p-value	F_{crit}
Arithmetic S/N response	Factors	3.746E-12	3	1.25E-12	5.97E-08	1	3.862
	Levels	0.0003042	3	0.000101	4.845557	0.028325	3.862
	Error	0.0001883	9	2.09E-05			
	Total	0.0004926	15				
Harmonic S/N response	Factors	1.87E-11	3	6.25E-12	2.99E-07	1	3.862
	Levels	0.000304	3	0.000101	4.85313	0.028209	3.862
	Error	0.000188	9	2.09E-05			
	Total	0.000493	15				
Geometric S/N response	Factors	1.87E-11	3	6.25E-12	2.99E-07	1	3.862
	Levels	0.000304	3	0.000101	4.850653	0.028247	3.862
	Error	0.000188	9	2.09E-05			
	Total	0.000493	15				
Quadratic S/N response	Factors	1.87E-11	3	6.25E-12	2.99E-07	1	3.862
	Levels	0.000304	3	0.000101	4.850653	0.028247	3.862
	Error	0.000188	9	2.09E-05			
	Total	0.000493	15				

* F_{crit} means Critical F

Table 1(c). ANOVA table for PKSPs tapped density using arithmetic, harmonic, geometric and quadratic S/N responses

	Source of Variance	SS	*df*	MS	F	p-value	F_{crit}
Arithmetic S/N Response	Factors	3.167E-11	3	1.056E-11	6.81E-08	1	3.862
	Levels	9.296E-05	3	3.099E-05	0.199988	0.893796	3.862
	Error		9	0.0001549			
	Total	0.0014874	15				
Harmonic S/N response	Factors	1.69E-10	3	5.63E-11	3.63E-07	1	3.862
	Levels	9.29E-05	3	3.1E-05	0.199926	0.893838	3.862
	Error		9	0.000155			
	Total	0.001487	15				
Geometric S/N response	Factors	2.19E-10	3	7.29E-11	4.71E-07	1	3.862
	Levels	9.3E-05	3	3.1E-05	0.20017	0.893672	3.862
	Error		9	0.000155			
	Total	0.001487	15				
Quadratic S/N response	Factors	5E-11	3	1.67E-11	1.08E-07	1	3.862
	Levels	9.28E-05	3	3.09E-05	0.199694	0.893996	3.862
	Error	0.001394	9	0.000155			
	Total	0.001487	15				

* F_{crit} means Critical F

DOI: 10.2298/APT1647129A BIBLID: 1450-7188 (2016) 47, 129-142

Table 1(d). ANOVA table for ESPs tapped density using arithmetic, harmonic, geometric and quadratic S/N responses

	Source of Variance	SS	*df*	MS	F	p-value	F_{crit}
Arithmetic S/N response	Factors	1.785E-08	3	5.951E-09	5.11E-06	1	3.862
	Levels	0.0055136	3	0.0018379	1.577182	0.261804	3.862
	Error	0.0104875	9	0.0011653			
	Total	0.0160012	15				
Harmonic S/N response	Factors	1.19E-10	3	5.951E-09	6.48E-07	1	3.862
	Levels	0.000298	3	0.0018379	1.627956	0.25076	3.862
	Error	0.00055	9	6.11E-05			
	Total	0.000849	15				
Geometric S/N response	Factors	1.88E-11	3	6.25E-12	1.02E-07	1	3.862
	Levels	0.000299	3	9.96E-05	1.629763	0.250377	3.862
	Error	0.00055	9	6.11E-05			
	Total	0.000849	15				
Quadratic S/N response	Factors	7.55E-11	3	2.5E-12	4.09E-07	1	3.862
	Levels	0.000298	3	9.95E-05	1.628067	0.250737	3.862
	Error	0.00055	9	6.11E-05			
	Total	0.000848	15				

* F_{crit} means Critical F

Table 2. Decision table for CSPs, PSPs, PKSPs and ESPs ANOVA

	Method of mean S/N response				
CSPs ANOVA	Description	Arithmetic	Harmonic	Geometric	Quadratic
	F_{crit}	3.86	3.86	3.86	3.862
	$F_{0.05}$	3.862	3.862	3.862	3.86
	Decision made	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis
	Method of mean S/N response				
PSPs ANOVA	Description	Arithmetic	Harmonic	Geometric	Quadratic
	F_{crit}	3.86	3.86	3.86	3.862
	$F_{0.05}$	3.862	3.862	3.862	3.86
	Decision made	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis

DOI: 10.2298/APT1647129A BIBLID: 1450-7188 (2016) 47, 129-142

Table 2. Continuation

	Method of mean S/N response				
PKSPs ANOVA	Description	Arithmetic	Harmonic	Geometric	Quadratic
	F_{crit}	3.86	3.86	3.86	3.862
	$F_{0.05}$	3.862	3.862	3.862	3.86
	Decision made	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis
	Method of mean S/N response				
ESPs ANOVA	Description	Arithmetic	Harmonic	Geometric	Quadratic
	F_{crit}	3.86	3.86	3.86	3.862
	$F_{0.05}$	3.862	3.862	3.862	3.86
	Decision made	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis	Rejection of null-hypothesis

* F_{crit} means Critical F

The decision table for the ANOVA of the particulates tapped density using different methods of S/N mean response is described by Table 2. Since F_{crit} equals 3.862 which exceeds $F_{0.05}$ = 3.86, which is the value for 3 and 9 degrees of freedom for the numerator and denominator, respectively (8, 9). As a result of this difference, we can conclude that there is a difference in the mean values of the various factors for the different levels of the tapped density experimental values.

Performance analysis

The performance analysis of the Taguchi optimisation was measured in terms of percentage improvement of the optimal tapped density over the peak and average tapped density values of the particulates. This was done to find the effectiveness of the Taguchi method (10, 11) in providing lower tapped density values over the average and peak tapped density values obtained from the experiment. This is presented in Table 3(a) as follows.

The average tapped density values was obtained by finding the mean of the tapped density values across all the runs of the tapped density experiments, while the peak tapped density values is the highest tapped density obtained at the application of 48 taps. The optimal tapped density value was derived by dividing the mass by volume obtained from the optimal Taguchi setting. From Table 3(a), the performance analysis of the Taguchi optimal results was carried out by finding the percentage improvement in two directions. First is the percentage improvement of the optimal tapped density over the average tapped density of each particulate fillers. Second, is the percentage improvement of the optimal tapped density over the highest tapped density measurement for each of the particulate filler.

APTEFF, 47, 1-265 (2016) UDC: 628.4.042:66.011/.012:532.14
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Original scientific paper

Table 3(a). Performance analysis of optimal density with tapped density values of fillers

S/N	Filler particle size	Performance analysis			Performance analysis		
		Average tapped density (g/cm³)	Optimal tapped density (g/cm³)	Percentage improvement (%)	Peak tapped density (g/cm³)	Optimal tapped density (g/cm³)	Percentage improvement (%)
1	0.300 mm Coconut	3.64	3.85	-5.77	3.87	3.85	0.52
2	0.425 mm Coconut	3.6	3.75	-4.16	3.77	3.75	0.53
3	0.425 mm Periwinkle	4.24	4.38	-3.3	4.38	4.39	0.23
4	0.600 mm Periwinkle	4.18	4.29	-2.63	4.30	4.29	0.23
5	0.425 mm Palm kernel	3.55	3.62	-1.97	3.71	3.62	2.43
6	0.600 mm Palm kernel	3.52	3.61	-2.55	3.66	3.61	1.37
7	0.300 mm Egg shell	4.05	4.20	-3.70	4.23	4.20	0.71
8	0.425 mm Egg shell	3.79	3.96	-4.22	3.98	3.96	0.51

The particulate filler with the highest average tapped density is the 0.425 mm periwinkle with an average density of 4.24 g/cm^3, while the optimal tapped density from the Taguchi optimisation gave 4.38 g/cm^3. A negative percentage improvement of -3.3 % was obtained from the performance analysis. This indicates that the average tapped density value is not a reflection of the all the tapped density values obtained at the application of different number of taps. Hence, it cannot be optimised and it did not give a positive percentage improvement. On the other hand, the highest tapped density of the 0.425 mm was obtained as 4.39 g/cm^3 at the application of 48 taps. The performance analysis produced a positive improvement of 0.23 % for the optimal tapped density over the peak tapped density values of the 0.425 mm periwinkle. This means that the Taguchi method was effective in obtaining a lower tapped density value than the highest tapped density value of the particle. For all the particulate sizes, the performance analysis of the optimal values over the average tapped density values produced negative results. The performance analysis of the optimal tapped density values over the peak values of the filler particles gave positive percentage improvements. The effectiveness of the Taguchi method in obtaining lower tapped density results was significantly pronounced in the case of 0.425 mm palm kernel shell particles which had a percentage improvement of 2.43 %, followed by 0.300 mm egg shell particles which had an improvement of 1.89 % .

Taguchi-Pareto (80-20) rule analysis (factor-level dependent)

The Pareto 80-20 rule was used in finding the factor level values which makes the most significant contribution to the overall tapped density of the particulate fillers. This was done by arranging the factor levels in descending order from the highest to the lowest. For each of the filler particles, the overall sum of the factor level values was obtained. The percentage contribution of each factor level to the overall sum was also obtained. This was followed by finding the cumulative percentage contribution of each factor level to the overall sum. At the 80 % threshold, the factor levels are separated using the 80-20 rule. The factor levels from the 80 % threshold and above are rearranged to obtain a revised table of parameters and levels. The Taguchi method is applied to the

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Original scientific paper

revised tables to give a new optimal parametric setting. This new optimal setting is the Taguchi-Pareto optimal setting.

For the CSPs, the revised table is described by Table 3(b). The revised table shows that all the factor levels for 0.300 and 0.425 mm mass (P and R) are retained, while only one factor level was retained for 0.300 and 0.425 mm volume (Q_1 and S_1). The factor levels present in the revised table indicates that it is economical to pursue their optimality. On the other hand, the absence of factor levels from the revised table indicates that their contribution is not significant as revealed by the use of the Pareto 80-20 rule. Therefore, adequate attention may not be given to them. The geometric and quadratic methods of mean S/N response determination have been identified earlier in this investigation to obtain better optimal values than the conventional mean when the LB quality characteristics are required. Using these preferred methods, the Taguchi-Pareto optimal setting for CSPs tapped density is given as $P_4Q_1R_2S_1$. This gives optimal tapped densities of 3.37 and 3.40 g/cm^3 respectively, for the 0.300 and 0.425 mm CSPs particles. Although the Taguchi-Pareto optimal setting differs from the Taguchi optimal setting, both of them produced the same optimal densities for both particle sizes of the CSPs. The Pareto 80-20 rule helped to identify the factor levels of each parameter which are economical to optimise.

By applying the same principles of Pareto 80-20 rule to the PSPs tapped density parameters, a revised table of parameters and levels is obtained which is described by Table 3(c). The factor levels for 0.425 and 0.600 mm mass (P and R) respectively, were retained in the revised table, while only one from 0.600 volume (S_1) was available. However, no factor level was retained for the 0.425 mm volume (Q). This is an indication that it is not economical to go for its optimality, because the input of the parameter is not significant as shown by the Pareto 80-20 rule. Therefore, Taguchi-Pareto optimal setting is obtained as $P_1R_2S_1$. As a result, only the optimal tapped density for the 0.600 mm particles was obtained as 4.04 g/cm^3. The Taguchi-Pareto and Taguchi optimal settings were found to differ; they however produced the same optimal tapped density for the 0.600 mm particles. The application of the Pareto 80-20 rule showed that the contribution of Q parameter factor levels were less significant to the tapped density and not advisable for optimisation.

Using the same Pareto 80-20 rule for the PKSPs tapped density parameters, a revised table of parameters and levels was obtained which is given by Table 3(d). In the revised table, all the factor levels for 0.425 and 0.600 mm mass (P and R) are available while only one factor level for the 0.425 volume (Q_1) was retained. The revised table did not contain any factor for 0.600 volume (S). The implication of this is that it is not cost effective to go for its optimality because its contribution is not significant going by the use of the Pareto 80-20 rule. As a result of this, the Pareto-Taguchi optimal parametric setting is obtained as $P_1Q_1R_3$. This gives an optimal tapped density of 3.38 g/cm^3 for the 0.425 mm particles which agrees with that obtained by the Taguchi optimal setting while the optimal tapped density could not be determined due to application of the Pareto 80-20 rule. Applying the Pareto 80-20 rule to the ESPs, a revised table of parameters and levels was obtained which is given by Table 12d. From the revised table, all the factor levels for 0.300 and 0.425 mm particles were retained, while only one factor level was available for

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Original scientific paper

the for the 0.300 mm volume (Q_1). However, the 0.425 mm volume (S) did not have any factor level in the revised table. The absence of the S parameter from the revised table shows that its contribution to the overall tapped density is not significant going by the Pareto 80-20 rule. Therefore, it is not economical to go for its optimality. The resulting Pareto-Taguchi optimal setting is given as $P_2Q_4R_1$. The optimal tapped density of the 0.300 mm particles was obtained as 3.87 g/cm^3 which agree with the value obtained by the Taguchi method.

In Table 3, all the factor levels for the 0.425 and 0.600 mm mass (P and R) are retained, while only one factor level for the 0.425 mm volume (Q_1) was retained in the new table. None of the 0.600 mm volume (S) factor levels are however present in the revised table of parameters. Going by the Pareto 80-20 rule, the contribution of the S parameter is low and is not advisable to go for their optimality. Therefore, the Taguchi-Pareto optimal setting is given as $P_1Q_4R_1$. The Pareto-Taguchi optimal tapped density for the 0.425 mm particles is obtained as 3.30 g/cm^3 which is the same with the value obtained by the Taguchi method. Table 3(c) is the optimal parametric settings and tapped densities obtained by Taguchi and Taguchi-Pareto methods.

Table 3(b). Revised table of parameters and levels for particulate fillers

Levels	Parameters			
	CSPs tapped density			
	P: 0.300 mm mass(g)	Q: 0.300 mm vol (g/cm^3)	R: 0.425 mm mass(g)	S: 0.425 mm vol. (g/cm^3)
1	255.293	75.681	259.688	76.366
2	255.283		259.686	
3	255.291		259.687	
4	255.786		259.686	
	PSPs tapped density			
	P: 0.425 mm mass(g)	Q: 0.425 mm vol (g/cm^3)	R: 0.600 mm mass(g)	S: 0.600 mm vol. (g/cm^3)
1	307.162		313.856	77.713
2	307.158		313.857	
3	307.152		313.853	
4	307.155		313.856	
	PKSPs tapped density			
	P: 0.425 mm mass(g)	Q: 0.425 mm Vol (g/cm^3)	R: 0.600 mm mass(g)	S: 0.600 mm vol. (g/cm^3)
1	258.299	76.49	254.548	
2	258.293		256.549	
3	258.285		256.553	
4	258.284		256.54	
	ESPs tapped density			
	P: 0.300 mm mass(g)	Q: 0.300 mm vol (g/cm^3)	R: 0.425 mm mass(g)	S: 0.425 mm vol. (g/cm^3)
1	295.464	76.641	266.84	
2	295.763		266.836	
3	295.76		266.837	
4	295.76		266.838	

APTEFF, 47, 1-265 (2016) UDC: 628.4.042:66.011/.012:532.14
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Original scientific paper

Table 3(c). Optimal parametric settings and tapped densities obtained by Taguchi and Taguchi-Pareto methods

S/No.	Particulate filler	Optimal setting		Optimal tapped density (g/cm^3)	
		Taguchi	Taguchi-Pareto	Taguchi	Taguchi-Pareto
1	CSPs	$P_3Q_1R_3S_1$	$P_4Q_1R_2S_1$	(0.300 mm:3.37) (0.425 mm: 3.4)	(0.300 mm:3.37) (0.425 mm: 3.40)
2	PSPs	$P_1Q_1R_2S_1$	$P_1R_2S_1$	(0.425 mm: 4.06) (0.600 mm: 4.04)	(0.600 mm: 4.04)
3	PKSPs	$P_1Q_1R_3S_1$	$P_1Q_1R_3$	(0.425 mm: 3.38) (0.600 mm: 3.35)	(0.425 mm: 3.38)
4	ESPs	$P_2Q_1R_1S_1$	$P_2Q_1R_1$	(0.300 mm:3.87) (0.425 mm: 3.55)	(0.425 mm: 3.87)

Taguchi-Pareto 80-20 rule analysis (s/n ratio-based method)

The Pareto 80-20 rule was applied to the S/N response tables of the particulate fillers tapped density. This was done in order to know which of the S/N ratios are significant to the optimisation of each of the filler particles. All the S/N ratios in each response table for the respective particles were arranged in descending order from the largest to the smallest value. The overall sum of the S/N ratios was obtained and the percentage contribution of each S/N ratio to the total sum was calculated. The S/N ratios are separated using the 80-20 rule at 80 % threshold of the cumulative percentages.

For the CSPs, the revised S/N response table is given by Table 4(b). The Taguchi-Pareto optimal setting is consistent with the optimal setting obtained when the Pareto 80-20 rule was applied to the factor-level based method. However, the revised S/N response table shows the absence of S/N ratios from factor levels S_2, S_3 and S_4. These S/N ratios were cut off by the direct application of the Pareto 80-20 rule to the S/N response table. Applying the Pareto 80-20 rule to the PSPs S/N response table produced a revised table described by Table 4(c). The optimal setting was obtained as $P_1Q_2R_2S_1$ which differs from that obtained when the Pareto rule was applied to the table of factors and levels. The major difference is the inclusion of parameter Q which was left out of the revised table of parameters and levels in the new optimal setting. The S/N ratios of parameter Q were found to be significant to the optimisation of the PSPs tapped density using the Pareto 80-20 rule, although they were not considered when the Q parameter was left out of the revised table of parameters and levels. The S/N ratios absent from the revised S/N response table are from factor level positions S_2, S_3 and S_4. This is as a result of being demarcated by the Pareto 80-20 rule at the 80 % threshold.

Using the Pareto 80-20 rule on the PKSPs S/N ratios gave a revised S/N response table described in Table 4(d). From the table, the Taguchi-Pareto optimal setting is given as $P_1Q_1R_3S_1$. The major difference in the Pareto-Taguchi optimal setting is the presence of the S parameter which was left out in the revised table of parameters and levels. The revised S/N response table shows the S/N ratios from the factor levels that are significant

APTEFF, 47, 1-265 (2016) UDC: 628.4.042:66.011/.012:532.14
DOI: 10.2298/APT1647129A BIBLID: 1450-7188 (2016) 47, 129-142

Original scientific paper

for optimality. The S/N ratios from factor levels Q_2, Q_3 and Q_4 are considered not significant for optimality using the Pareto 80-20 rule and are not included in the revised S/N response table. The revised S/N response table for ESPs is described by Table 4(e). This was obtained after the application of the Pareto 80-20 rule to the S/N ratios of the ESPs response table. The new optimal setting is given as $P_2Q_1R_1S_1$ which varies with when the Pareto rule was applied to the table of parameters and levels. The main difference is the inclusion of the S parameter which was removed from the revised table of parameters and levels and from the optimal setting. The revised S/N response shows the presence of S/N ratios relevant for optimality, while the absence of S/N ratios from factor level positions Q_2, Q_3 and Q_4 indicates they are not relevant for optimality by the Pareto 80-20 rule.

A new optimal setting of $P_1Q_1R_1S_2$ was obtained which differs significantly when the Pareto 80-20 rule was applied to the parameters and levels. This is a result of the inclusion of the S parameter which was excluded from the revised table of parameters and levels. The S/N ratios present in the revised S/N response table are economical for optimality. The S/N ratios from factor level Q_2, Q_3 and Q_4 are absent from the revised S/N response table which indicates that they have been removed by the application of Pareto 80-20 rule. The application of the Pareto 80-20 rule to the S/N response table helps to identify the relevant S/N ratios that are economical for optimality for a given process. The S/N ratios not relevant for optimality were cut off by the Pareto 80-20 rule and are not included in the revised S/N response table. Hence, their significance is minimal and cannot be considered for optimality (Table 4).

Table 4. Revised S/N response tables for the particulate fillers

Levels	Parameters			
	Table 4b. Revised S/N response table for CSPs tapped density			
	P: 0.300 mm mass(g)	Q: 0.300 mm vol (g/cm^3)	R: 0.425 mm mass(g)	S: 0.425 mm vol. (g/cm^3)
1	45.296	45.436	45.298	45.438
2	45.298	45.254	45.300	
3	45.298	45.254	45.300	
4	45.306	45.254	45.300	
	Table 4c. Revised S/N response table for PSPs tapped density			
	P: 0.425 mm mass(g)	Q: 0.425 mm vol (g/cm^3)	R: 0.600 mm mass(g)	S: 0.600 mm vol. (g/cm^3)
1	46.865	46.865	46.865	46.966
2	46.865	46.865	46.865	
3	46.865	46.865	46.865	
4	46.865	46.8651244	46.8651309	

APTEFF, 47, 1-265 (2016) UDC: 628.4.042:66.011/.012:532.14
DOI: 10.2298/APT1647129A BIBLID: 1450-7188 (2016) 47, 129-142

Original scientific paper

Table 4. Continuation

Levels	**Table 4d.** Revised S/N response table for PKSPs tapped density			
	P: 0.425 mm mass(g)	Q: 0.425 mm vol (g/cm^3)	R: 0.600 mm mass(g)	S: 0.600 mm vol. (g/cm^3)
1	45.253	45.384	45.219	45.244
2	45.241		45.252	45.244
3	45.241		45.253	45.244
4	45.241		45.252	45.244
	Table 4e. Revised S/N response table for ESPs tapped density			
	P: 0.425 mm mass(g)	Q: 0.425 mm vol (g/cm^3)	R: 0.600 mm mass(g)	S: 0.600 mm vol. (g/cm^3)
1	46.021	46.151	46.028	46.028
2	46.042		46.028	46.028
3	46.026		46.028	46.028
4	46.026		46.028	46.028

CONCLUSION

In the current research, which is the second part of an article, the following conclusions are made. The analysis of variance (ANOVA) technique was used to calculate the individual contributions of each parameter to the tapped density of each particle. The performance analysis produced negative percentage improvements when the optimal tapped density was compared with the average tapped density except for orange peels which yielded 0%. However, the performance analysis between optimal tapped density and the peak tapped density values yielded positive percentage improvements for the four filler particles. The F_{crit} was found to exceed the $F_{0.05}$ value which implies that we can conclude that there is a difference in the mean values of the various factors for the different levels of the tapped density experimental values. The performance analysis results validate the effectiveness of using the Taguchi method in improving the tapped density properties of the filler particles.

The application of the Pareto 80-20 rule was carried in two main directions. First, it was applied to the table of parameters and levels to find the most significant factor levels that are economical for optimality of the particulate tapped density. Second, it was used on the S/N response tables to find the S/N ratios that are relevant to optimality of the particulate tapped density.

- The application of the Pareto 80-20 rule to tables of parameters and levels produced revised tables of parameters and levels. New optimal settings were obtained for the PSPs, PKSPs and ESPs tapped density, while that of CSPs remain unchanged. The new optimal settings obtained for the particulate fillers is due to the removal of one of the parameters in the revised table of parameters and levels by the Pareto 80-20 rule.

- The application of the Pareto 80-20 rule to the S/N response tables produced revised S/N response tables for CSPs, PSPs, PKSPs and ESPs tapped density. The revised S/N response tables for PSPs, PKSPs and ESPs contains the parameter that was removed by the application of the Pareto 80-20 rule to the tables of parameters and levels. This is majorly responsible for the new optimal settings for PSPs, PKSPs and ESPs tapped density. The revised S/N response tables retains the S/N ratios that are significant for optimality, while the S/N ratios that are absent indicates they are not relevant to optimality by the Pareto 80-20 rule.

REFERENCES

1. Anthony, J.; Anthony, F. J. Teaching the Taguchi method to industrial engineers. *Work Study* **2001,** *50* (4), 141-149.
2. Zareh, B.; Gorji, A.; Bakhshi, H.; Nourouzi S. Study on the effect of forming parameters in sheet hydrodynamic deep drawing using fem-based Taguchi method. *Int. J. Adv. Des. Manufact. Technol.* **2013,** *6* (1), 87-99.
3. Kumar, R.; Kumar, K.; Bhowmik, S. Optimisation of mechanical properties of epoxy based wood dust reinforced green composite using Taguchi method. *Procedia Materials Science* **2014,** *5*, 688-696.
4. Mehboob, H.; Chang S.-H. Optimal design of a functionally graded biodegradable composite bone plate by using the Taguchi method and finite element analysis. *Composite Structures* **2015,** *119*, 166-173.
5. Alam, S.; AlShaikh, A.A. Use of palm fronds as shaded cover for evaporation reduction to improve water storage efficiency. *J. King Saud Univ. – Eng. Sci.* **2013,** *25* (1), 55-58.
6. Idris, U.D.; Aigbodion, V.S.; Abubakar, I.J.; Nwoye, C.I. Eco-friendly asbestos free brake-pad: Using banana peels. *J. King Saud Univ. – Eng. Sci.* **2015,** 27 (2), 185-192.
7. Yang, W.H.; Tarng, Y.S. Design optimization of cutting parameters for turning operations based on the Taguchi method. *Journal of Materials Processing Technology* **1998,** *84* (1-3), 122-129.
8. Williams, R. B. G. *Intermediate Statistics for Geographers and Earth Scientists*, Macmillan, 1986; p. 712.
9. Lee, C.-F.; Lee, J.C.; Lee, A.C. *Statistics for Business and Financial Economics*, Springer-Verlag New York, 2013.
10. Ramabalan, S.; Rajan, H.B.M.; Dinaharan, I.; Vijay, S.J. Experimental investigation of MRR on in-situ formed AA7075/TiB_2 cast composites machining by wire EDM. *International Journal of Machining and Machinability of materials* **2015,** *17* (3), 295-318.
11. Lin, J.L.; Wang, K.S.; Yan, B.H.; Tarng, Y.S. Optimization of the electrical discharge machining process based on the Taguchi method with fuzzy logics. *Journal of Materials Processing Technology* **2000,** *102* (1-3), 48-55.

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DOI: 10.2298/APT1647129A BIBLID: 1450-7188 (2016) 47, 129-142

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ОПТИМИЗАЦИЈА СТРЕСЕНЕ ГУСТИНЕ ЧЕТИРИ ОТПАДНА МАТЕРИЈАЛА ПОЉОПРИВРЕДЕ: ДЕО II – АНАЛИЗА ПЕРФОРМАНСИ МЕТОДАМА ТАГУЧИЈА И ПАРЕТА

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Овај рад, који је други део студије о оптимизацији стресене густине четири отпадна материјала пољопривреде: честице кокоса, зимзелени, палмине коштице и коре јајета, бави се компаративном анализом перформанси. Новина у раду је то да је оптимизација варијабли процеса извршена применом Тагучијеве методе у спрези са Паретовим правилом 80-20. Негативна побољшања су резултирала када је оптимална стресена густина упоређена са просечном стресеном густином. Међутим, анализа перформанси у којој су вредности оптималне стресене густине и пика стресене густине дала позитиван проценат побољшања за честице сва четири пуниоца. Резултати анализе перформанси валидирају успешност Тагучијеве методе у побољшању карактеристика стресене густине честица пунилаца. Примена Паретовог 80-20 правила на табелу параметара и нивое дала је ревидиране табеле параметара и нивоа на основу којих је било могуће идентификовати фактор-ниво позиције за сваки параметер који је економски оптималан. Паретово правило 80-20 је такође дало као резултат ревидиране табеле за S/N одговоре који су били коришћени за одређивање S/N односа који су релевантни за оптималност.

Кључне речи: оптимизација, анализа перформанси, тест значајности, Паретово правило

Received: 6 May 2016.
Accepted: 5 October 2016.