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Study on an Optimal Design of Mechanical Properties for PP/PET Nonwovens

Abstract
This study aimed to determine the optimal process parameters of needle-punched nonwoven fabrics, and obtain the maximal strength of needle-punched nonwoven fabrics. The Taguchi approach and grey relational analysis were used to solve the multi-quality optimisation problem and determine the optimal process parameter combination of needle-punched nonwoven fabrics. The L9 orthogonal array was used to design parameters that affect the needle-punched nonwoven fabric process, including the folding machine oscillating speed, folding machine conveying speed, needle-punch depth, and needle-punch density. Then grey relational analysis was used to overcome the single quality characteristic disadvantage of the Taguchi approach, and the optimal process parameter combination of multiple quality characteristics was obtained from the response graph of the analysis. The quality characteristics of this experiment are the nonwoven fabric tearing strength and tensile strength. Signal-to-noise ratios (S/N ratio) were calculated and an analysis of variance (ANOVA) was conducted to analyse the experiment results. The results of ANOVA showed that the factors with a significant effect on the quality characteristics of needle-punched nonwoven fabrics included the needle-punch depth and needle-punch density. In other words, by controlling these factors the quality characteristics of the needle-punched nonwoven fabrics could be controlled effectively. Finally, the 95% confidence interval of the verification experiment proved that this experiment was reliable and reproducible.

Key words: *needle-punched nonwovens, optimisation, Taguchi approach, grey relational analysis.*

Introduction

Nonwoven fabric [1 - 3] is made of synthetic fibres and is a material formed through high pressure and adhesion without traditional weaving. Nonwoven fabric is a new domain in the textile industry. With features such as a short process, high output, low cost and wide material sources, as well as superior functional properties, nonwoven fabric has been widely applied in industrial use and favoured by consumers over the past half century. Nonwoven fabric is defined as a material formed by applying high pressure or adhesion from various synthetic fibres processed by needle-punch machines or carding machines. Nonwoven fabric is reinforced by nonwoven steel fibres (staple fibre mesh formed by adhesion or heat) to avoid loosening.

To manufacture needle-punched nonwoven fabrics, a roller carding machine combs fibres into filaments, a folding machine folds fibre mesh to a certain thickness, then a needle-punch machine punches the mesh to reinforce and then form the nonwoven fabric. The fibre movement and distribution on the carding machine parts guarantee effective fibre transfer homogeneous mixing, production yield and fibre mesh quality. The fibre performance, characteristics and condition of the card clothing, the relative speed and clearance of the carding machine parts are factors affecting the fibre distribution and transfer.

The needle-punch method is the main reinforcing approach of dry nonwoven fabric. The external force enables fibres to pass needle hooks to entangle into the nonwoven fabric. The feed roller of a needle-punch machine compresses the fluffy fibre mesh between the stripper plate and the web plate. The fibre mesh reciprocates up and down for hooked needles to punch for reinforcement.

Previously, the process parameters of needle-punched nonwoven fabrics were set by the trial-and-error approach and experience, thus resulting in excessive experiments and the waste of cost and labour. The Taguchi approach [4 - 8] is used to improve the process quality, decrease experiments, reduce process variations, and elevate and maintain product quality robustness. However, the Taguchi approach is mostly applied in the process parameter combination optimisation of the single quality characteristic, which usually fails to meet the general quality requirement. The quality characteristics of needle-punched nonwoven fabrics in this study included the tearing strength of MD (machine direction), the tearing strength of CD (cross machine direction), the tensile strength of MD, and the tensile strength of CD. This study applied the Taguchi approach with grey relational analysis [9] to acquire optimal process parameters of multiple qualities and to optimise the overall quality of nonwoven fabric.

Experimental

Experiment conditions: the fibre materials were PET50% + PP50%, the fibre feed rate - 500 g/m^2, and the hooked needle model (needle No.) was No. 40.

Methodology

Taguchi approach

Efficient determination of critical factors can improve manufacturing efficiency. The trial-and-error approach lacks an overall parameter design. Although full experimental data are obtained, there is no discussion and analysis on parameter interaction. In addition, the full factorial experiment is time-consuming, and the process condition is hard to control. Therefore, this study applied the Taguchi approach to the process of needle-punched nonwoven fabric, designed a series of rules for designing an experiment, where critical process parameters are selected with a dedicated experiment plan table to analyse the process parameters of needle-punched nonwoven fabrics in order to optimise the process parameters and improve the quality of needle-punched nonwoven fabrics.

Grey relational analysis

In the process parameter analysis of needle-punched nonwoven fabrics, an appropriate mathematical model has to be built to study the relationship of the four quality characteristics obtained in the orthogonal array experiment and the target values. The main task is to study the quality characteristic difference caused by each process parameter, and their relation with the target values. This study employed grey theory based grey relational analysis to find a correlation between quality characteristics and the target values of needle-punched nonwoven fabrics obtained in the orthogonal array experiments. Grey relational analysis was conducted on the tearing strength of MD, the tearing strength of CD, the tensile strength of MD, and the tensile strength of CD, defined as follows [10, 11].

Reference sequence

$$X_0 = (x_0(1), x_0(2), x_0(3), x0(4))$$

The tearing strength of MD, the tearing strength of CD, the tensile strength of MD, and the tensile strength of CD were obtained in the orthogonal array experiments as:

$$X_i = (x_i(1), x_i(2), x_i(3), x_i(4)),\quad i = 1, 2, ..., 9$$

The correlation of the target values with the experiment observed values is a relational coefficient:

$$\gamma(x_0(k)\ x_i(k)) = \frac{\zeta \max_{1\le m\le 9}\max_{1\le k\le 4}\Delta_{0,m}(k)}{\Delta_{0,i}(k) + \zeta \max_{1\le m\le 9}\max_{1\le k\le 4}\Delta_{0,m}(k)}, \quad (1)$$

$$k = 1, 2, \dots, 4,\ i = 1, 2, ..., 9$$

where $\Delta_{0,m}(k)$ are difference sequences, ζ is the distinguishing coefficient, and $\zeta \in (0,1)$.

It is the point relational degree of X_i at point k with respect to X_0.

The $\gamma(x_0(k), x_i(k))$ shows the relational degree of X_0, X_i at point k, representing the local characteristic of the X_0, X_i relation. The mean of $\gamma(x_0(k), x_i(k))$ is the relational degree of X_i with respect to X_0:

$$\gamma(X_0, X_i) = \frac{1}{n}\sum_{k=1}^{n} \gamma(x_0(k), x_i(k)) \quad (2)$$

The calculation steps of the Grey relational degree:

1. To obtain an initial value of each sequence, it is assumed

$$X'_i = X_i/x_i(1) = = (x'_i(1), x'_i(2), x_i(3), x_i(4)) \quad (3)$$
$$i = 1, 2, ..., 9$$

2. To obtain a difference sequence

$$\Delta_i(k) = |x'_0(k) - x'_i(k)|,$$
$$\Delta_i = (\Delta_i(1), \Delta_i(2), ..., \Delta_i(9)) \quad (4)$$
$$k = 1, 2, \dots 4,\ i = 1, 2, ..., 9$$

3. To obtain a second-order maximal difference and minimal difference

$$M = \max_i \max_k \Delta_i(k),\ m = \min_i \min_k \Delta_i(k) \quad (5)$$
$$k = 1, 2, \dots 4,\ i = 1, 2, ..., 9$$

4. To obtain a relational coefficient

$$\gamma_{0i}(k) = \frac{m + \zeta M}{\Delta_i(k) + \zeta}, \zeta = 0.5, \quad (6)$$
$$k = 1, 2, \dots 4,\ i = 1, 2, ..., 9$$

Commonly distinguishing coefficient ζ=0.5.

5. To calculate a relational degree

$$\gamma = \frac{1}{n}\sum_{k=1}^{n}\gamma_{0i}(k) \quad (7)$$
$$k = 1, 2, \dots 4,\ i = 1, 2, ..., 9$$

After inputting the target values of the tearing strength of MD, the tearing strength of CD, the tensile strength of MD, and the tensile strength of CD as reference sequences, the relational degrees with the observed values of each L_9 orthogonal array experiment were calculated, respectively. Main effect analysis was conducted to acquire a response graph which showed the optimal process parameter combination of needle-punched nonwoven fabrics.

Analysis of variance

After the product quality characteristic data from the orthogonal array experimental design were obtained, the S/N ratio was calculated and ANOVA was conducted. The purpose of ANOVA [12 - 16] is to check for experiment errors and error variance in order to determine the impacts of each process parameter on the quality of the finished product for references of experiment error estimation.

Results and discussion

Prior to the experiment, the control factors and their levels had to be determined. From the preliminary experiment, four major process parameters of needle-punched nonwoven fabrics were chosen as control factors, namely the folding machine oscillating speed (1400, 1500 and 1600 r.p.m.), the folding machine conveying speed (700, 800, and 900 r.p.m.), the needle-punch depth (8, 11 and, 14 mm), and the needle-punch density (40**,** 50 and 60 punches/cm^2). The L_9 orthogonal array was chosen to set up the process parameters of the needle-punched nonwoven fabrics.

The nonwoven fabric strength is an important factor of its application, hence higher quality characteristics of the needle-punched nonwoven fabrics were expected; in other words, the higher the tearing strength of MD, the tearing strength of CD, the tensile strength of MD, and the tensile strength of CD, the better. Therefore the larger-the-better characteristic was selected, the S/N ratio of which is shown below.

$$S/N = -10 \log MSD \quad (8)$$

$$MSD = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2} \quad (9)$$

where the mean squared deviation (MSD) is the mean of squared deviations, y_i - the quality measurement, and n is the total number of measurements.

Then the control factors chosen and their levels were input into the L_9 orthogonal array as experiment criteria in ***Table 1***. In accordance with the orthogonal array design, nine experiments were conducted. The tearing and tensile strengths were tested for each experiment using ISO9073-3 and ISO9073-4 Test Methods. MD and CD were conducted ten times each. Furthermore, for each set of experiment data collected, the S/N ratio was calculated using ***Equation 8***, the results of which are shown in ***Table 1***. Based on the S/N ratios in ***Table 1***, main effect analysis was conducted to calculate the main effect of each control factor and plot the response graph, as shown in ***Figures 1 - 4***. The optimal factor-level combination for each quality characteristic is shown in the response graph.

As for the tearing strength of MD, the optimal factor-level combination was A2, B2, C3, and D3, where the folding machine oscillating speed was 1500 r.p.m., the folding machine conveying speed - 800 r.p.m., the needle-punch depth - 14 mm, and the needle-punch density - 60 punches/cm^2.

For the tearing strength of CD, the optimal factor-level combination was A2, B2, C3 and D3, where the folding machine oscillating speed was 1500 r.p.m.,

Table 1. Layout, averages and S/N ratios of L9 orthogonal array.

No.	A, r.p.m.	B, r.p.m.	C, mm	D, punches/cm2	Tearing strength of MD		Tearing strength of CD		Tensile strength of MD		Tensile strength of CD	
					Ave., N	S/N, dB	Ave., N	S/N, dB	Ave., N	S/N, dB	Ave., N	S/N, dB
1	1400	700	8	40	0.7002	-3.1351	0.7784	-2.2514	1.4072	2.9630	1.9884	5.9474
2		800	11	50	1.0605	0.3605	1.0979	0.7640	1.7437	4.7668	2.6580	8.4847
3		900	14	60	1.3664	2.6643	1.4616	3.2786	2.0938	6.3854	3.2495	10.2237
4	1500	700	11	60	1.2576	1.9094	1.1319	0.9971	1.9205	5.6468	2.8212	8.9984
5		800	14	40	1.0333	0.1977	1.0265	0.1645	1.7301	4.7552	2.4983	7.9393
6		900	8	50	1.1115	0.8950	1.2610	1.9289	2.0360	6.1468	2.8518	9.0969
7	1600	700	14	50	1.3324	2.4603	1.3902	2.8383	2.1516	6.6432	3.1169	9.8600
8		800	8	60	1.1659	1.1962	1.3018	2.2722	1.8763	5.4628	2.8994	9.2391
9		900	11	40	0.7988	-2.0311	0.7240	-2.8406	1.4786	3.3914	2.1108	6.4857

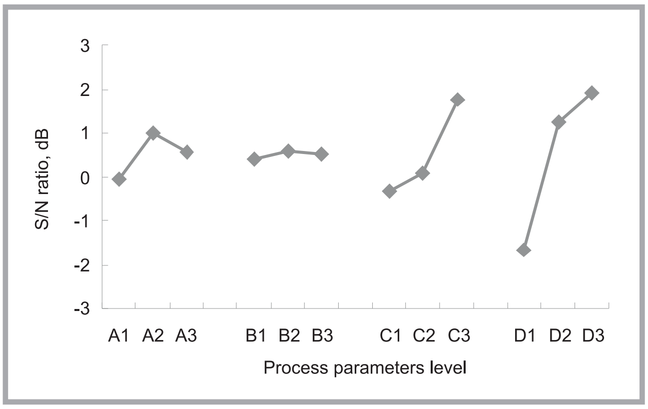

***Figure 1.** Response graph for tearing strength of MD.*

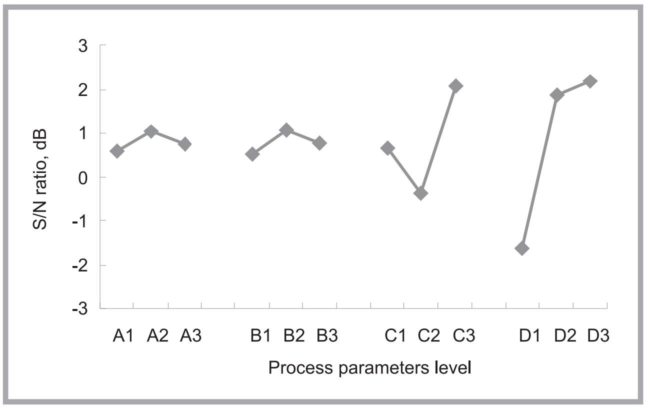

***Figure 2.** Response graph for tearing strength of CD.*

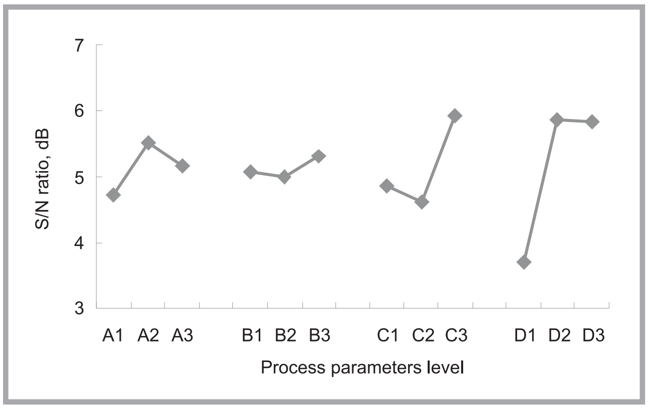

***Figure 3.** Response graph for tensile strength of MD.*

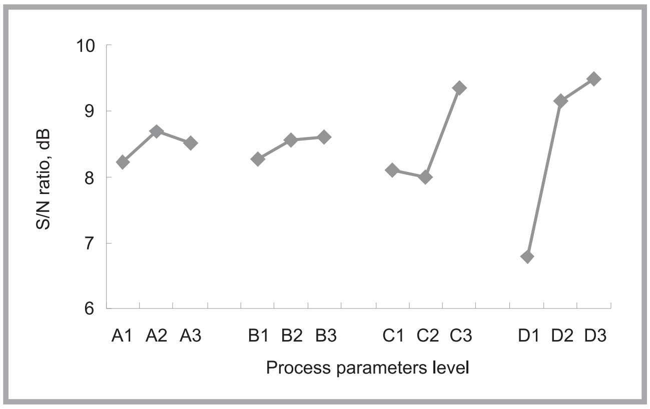

***Figure 4.** Response graph for tensile strength of CD.*

the folding machine conveying speed - 800 r.p.m., the needle-punch depth - 14 mm, and the needle-punch density - 60 punches/cm2.

As for the tensile strength of MD, the optimal factor-level combination was A2, B3, C3 and D2, where the folding machine oscillating speed was 1500 r.p.m., the folding machine conveying speed - 900 r.p.m., the needle-punch depth - 14 mm, and the needle-punch density - 50 punches/cm2.

Regarding the tensile strength of CD, the optimal factor-level combination was A2, B3, C3 and D3, where the folding machine oscillating speed was 1500 r.p.m., the folding machine conveying speed - 900 r.p.m., the needle-punch depth - 14 mm, and the needle-punch density - 60 punches/cm2.

From the optimization result of the four quality characteristics, the single quality optimal combinations were not completely the same. Hence, ANOVA was conducted to analyse the quality characteristics of needle-punched nonwoven fabrics and to further determine the impacts of each process parameter on the product quality. ANOVA was used to check experiment errors and error variance so as to find out the impact of each process parameter on the quality of the finished product for references on experiment error estimation. Moreover, according to the key factors affecting the quality, optimal predictive values could be calculated more accurately, with a direct impact on the 95% confidence interval calculation.

In ANOVA, the F-test value represents the relation of the factor effect and the error variance. In other words, the greater the F-test value, the more impact this factor has on the system. Generally when the F-test value is greater than 2, it indi-

*Table 2. ANOVA table of tearing strength of MD/CD; * Pool-up terms.*

Source	Degrees of freedom	Sum of squares	Variance	F-test	Pure sum of squares	Contribution, %
A	2/2	1.6217*/0.2879*	-/-	-/-	-/-	-/-
B	2/2	0.0453*/0.4358*	-/-	-/-	-/-	-/-
C	2/2	7.5573/9.1248	3.7787/4.5624	9.0671/25.2181	6.7239/8.7630	21.7706/23.8456
D	2/2	21.6607/26.9003	10.8304/13.4501	25.9881/74.3439	20.8273/26.5384	67.4347/72.2159
Pooled error	4/4	1.667/0.7237	0.4167/0.1809		3.3339/1.4473	10.7947/3.9385
Total	**8/8**	**30.8851/36.7487**				**100/100**

*Table 3. ANOVA table of the tensile strength of MD/CD; * Pool-up terms*

Source	Degrees of freedom	Sum of squares	Variance	F-test	Pure sum of squares	Contribution, %
A	2/2	0.9932*/0.3296*	-/-	-/-	-/-	-/-
B	2/2	0.1559*/0.1953*	-/-	-/-	-/-	-/-
C	2/2	2.9700/3.3911	1.4850/1.6955	5.1694/12.9243	2.3955/3.1287	18.0541/18.5637
D	2/2	9.1491/12.9380	4.5746/6.4690	15.9244/49.3103	8.5746/12.6756	64.6251/75.2092
Pooled error	4/4	1.1491/0.5248	0.2873/0.1312		2.2982/1.0495	17.3207/6.2272
Total	**8/8**	**13.2682/16.8539**				**100/100**

Table 4. Difference sequences, grey relational coefficients and grades.

No.	$\Delta_{0,i}(1)$	$\Delta_{0,i}(2)$	$\Delta_{0,i}(3)$	$\Delta_{0,i}(4)$	$\gamma_{0,i}(1)$	$\gamma_{0,i}(2)$	$\gamma_{0,i}(3)$	$\gamma_{0,i}(4)$	γ
1	2.1767	1.6867	0.5540	0.4183	0.2382	0.2910	0.5767	0.6484	0.4386
2	0.8647	0.7670	0.2825	0.1701	0.4571	0.4894	0.7373	0.8276	0.6279
3	0.0000	0.0000	0.0388	0.0000	1.0000	1.0000	0.9565	1.0000	0.9891
4	0.2833	0.6959	0.1500	0.1198	0.7367	0.5157	0.8456	0.8737	0.7429
5	0.9258	0.9498	0.2842	0.2234	0.4389	0.4321	0.7361	0.7826	0.5974
6	0.6641	0.4117	0.0747	0.1102	0.5283	0.6523	0.9185	0.8830	0.7455
7	0.0766	0.1343	0.0000	0.0356	0.9166	0.8600	1.0000	0.9600	0.9342
8	0.5510	0.3070	0.1777	0.0963	0.5781	0.7198	0.8209	0.8967	0.7539
9	1.7623	1.8664	0.4895	0.3656	0.2814	0.2692	0.6089	0.6806	0.4600

cates that the factor effect is significant. If the F-test value is greater than 4, then this factor has a remarkable effect. As shown in ***Tables 2*** and ***3***, the key factors are the needle-punch depth and the needle-punch density, while the folding machine oscillating speed and folding machine conveying speed are pooled into error, excluding their improvement effect. The confidence interval (CI) can be calculated from the following equation.

The S/N ratio under the optimal condition is predicted by means of the following addition model:

$$\hat{S}N = \overline{T} + \sum_{i=1}^{n}(F_i - \overline{T}) \qquad (10)$$

where $\overline{T}$ is the mean of S/N ratios, and F_i is the S/N ratio of the significant factor level.

The CI is calculated as follows to verify the experiment value:

$$CI = \sqrt{F_{\alpha;1,v_2} \times V_e \times \left[\frac{1}{n_{eff}} + \frac{1}{r}\right]} \qquad (11)$$

$$n_{eff} = n_t/(1 + S_d) \qquad (12)$$

where $F_{\alpha;1,v_2}$ is the F-value with significant level α, α - the significant level, the $1-\alpha$ – the confidence level, v_2 - the degree-of-freedom of the pooled error mean square, V_e - the pooled error mean square, n_{eff} - the effective value observed, n_t - total number of experiments, S_d - sum of degrees of freedom used in estimate of mean, and r is the number of verification experiments, $r \neq 0$.

Finally, 95% CI was used to verify the effectiveness of the mean predicted

$$\hat{S}N - CI \le \mu \le \hat{S}N + CI \qquad (13)$$

Hence 95% CIs of the tearing strength of MD, the tearing strength of CD, the tensile strength of MD, and the tensile strength of CD were calculated:

$2.616 < \mu < 3.774$ dB,
$2.0221 < \mu < 4.4916$ dB,
$5.5764 < \mu < 7.7264$ dB and
$9.1509 < \mu < 11.5552$ dB, respectively.

The optimal process parameter combination obtained by the Taguchi approach was for each quality characteristic, which failed to represent the entire needle-punched nonwoven fabric. Therefore, grey relational analysis was conducted to analyse the multiple quality characteristics of needle-punched nonwoven fabrics. As higher tearing strength and tensile strength were expected, the maximum experiment values of the tearing strength of MD, the tearing strength of CD, the tensile strength of MD, and the tensile strength of CD in Table 1 were chosen as the target values, where the tearing strength of MD is 2.6643 dB, the tearing strength of CD - 3.2786 dB, the tensile strength of MD - 6.6432 dB, and the tensile strength of CD - 10.2237 dB. These four target values served as the reference sequence X_0, where X_0 = (2.6643, 3.2786, 6.6432, 10.2237). Then nine experiments in the L_9 orthogonal array were taken as a comparison sequence, which is $X_1, X_2, \ldots, X_9$.

According to the difference sequence of the reference sequence and each of the orthogonal array sequences, the grey relational coefficient and grey relational degree (GRG) were calculated, given in ***Table 4***. Further main effect analysis can result in a response graph of the grey relational analysis, as shown in ***Figure 5***.

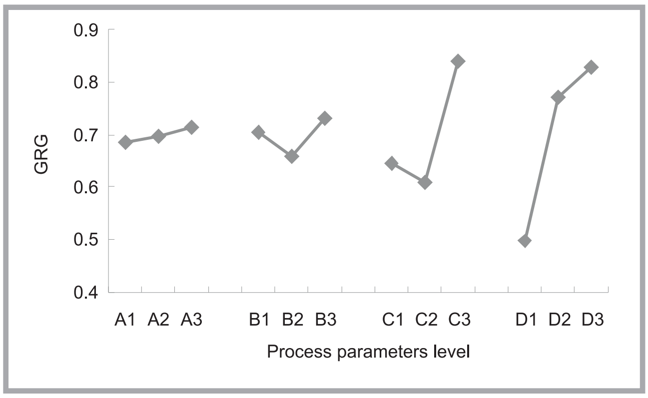

Figure 5. Response graph for GRG.

As is seen, the optimal process parameter combination for needle-punched nonwoven fabrics was acquired: A3, B3, C3 and D3, where the folding machine oscillating speed is 1600 r.p.m., the folding machine conveying speed - 900 r.p.m., the needle-punch depth - 14 mm, and the needle-punch density - 60 punches/cm^2.

Then, based on the multiple quality optimal combination, ten verification experiments were conducted. The results showed that the S/N ratio for the tearing strength of MD is 3.3409 dB, the S/N ratio for the tearing strength of CD - 4.1007 dB, the S/N ratio for the tensile strength of MD - 6.9981 dB, and the S/N ratio for the tensile strength of CD - 10.0736 dB. S/N ratios of these four quality characteristics fell within 95% CIs, thus proving that the multiple quality optimal process parameter combination obtained from the grey relational analysis was reliable.

Conclusions

This study employed grey relational analysis with the Taguchi approach, used the fewest experiments to find the multiple quality characteristic optimal process parameters of needle-punched nonwoven fabrics, and further obtained the maximal strength of needle-punched nonwoven fabrics. As shown in the response table and the response graph derived from grey relational analysis, the optimal process parameter combination for needle-punched nonwoven fabrics is as follows: a folding machine oscillating speed of 1600 r.p.m., a folding machine conveying speed of 900 rpm, a needle-punch depth of 14 mm, and a needle-punch density of 60 punches/cm^2. As shown in ***Tables 2*** and ***3***, the significant factors of the quality characteristics of needle-punched nonwoven fabrics are the needle-punch depth and needle-punch density. Ten verification experiments proved that the experiment result is reproducible, and the choice of significant factors is suitable. In other words, by controlling the significant factors, the quality characteristics of needle-punched nonwoven fabrics were under control as well. Therefore, this study succeeded in using grey relational analysis and the Taguchi approach to obtain the optimal process parameter combination of needle-punched nonwoven fabrics with multiple quality characteristics. Moreover grey relational analysis with the Taguchi approach could be applied to other process parameter optimisation in order to improve the process efficiency.

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References

1. Bo Z. Experimental Study and Numerical Analysis for Prediction of the Fibre Diameter of Polylactic Acid (PLA) Spunbonded Nonwovens. *Fibres & Textiles in Eastern Europe* 2009; 17(5): 82-86.
2. Połowiński S, Stawski D. Thermogravimetric Measurements of Poly(Propylene) Nonwovens Containing Deposited Layers of Polyelectrolytes and Colloidal Particles of Noble Metals. *Fibres & Textiles in Eastern Europe* 2007; 15(4): 82-85.
3. Huang KS, Lian HS, Chen JB. Study on the Modification of PP Nonwoven Fabric. *Fibres & Textiles in Eastern Europe* 2011; 19(3): 82-87.
4. Su TL, Chen HW, Ma CM, Lu CF. Improving the Combed Yarn Qualities of OE Rotor by Using Grey-Taguchi Method. *Fibres & Textiles in Eastern Europe* 2011; 19(2): 23-27.
5. Mavruz S, Ogulata RT. Taguchi Approach for the Optimisation of the Bursting Strength of Knitted Fabrics. *Fibres & Textiles in Eastern Europe* 2010; 18(2): 78-83.
6. Su TL, Kuo YL, Wu TJ, Kung FC. Experimental Analysis and Optimization of the Synthesizing Property of Nitrogen-modified TiO_2 Visible-light Photocatalysts. *Journal of Chemical Technology & Biotechnology* 2012; 87(1): 160-164.
7. Su TL, Lai CC, Tsai PC. Interactions and Solubilization of Disperse Dye with Modified Gemini Surfactants: Investigation Using the Taguchi Method. *Journal of Surfactants and Detergents* 2011; 14(3): 363-369.
8. Su TL, Lu CF. Automated Vision System for Recognising Lycra Spandex Defects. *Fibres & Textiles in Eastern Europe* 2011; 19(1): 43-46.
9. Kuo CFJ, Su TL. Optimization of Multiple Quality Characteristics for Polyether Ether Ketone Injection Molding Process. *Fibers and Polymers* 2006; 7(4): 404-413.
10. Kuo CFJ, Su TL. Gray Relational Analysis for Recognizing Fabric Defects. *Textile Research Journal* 2003; 73(5): 461-465.
11. Su TL, Kuo YL, Chen HW, Kung FC. Grey Relational Analysis of an Automatic Identifying System for Clothing Texture. *Fibres & Textiles in Eastern Europe* 2010; 18(2): 60-64.
12. Su TL, Chen HW, Lu CF. Systematic Optimization for the Evaluation of the Micro Injection Molding Parameters of Light Guide Plate with TOPSIS-based Taguchi Method. *Advances in Polymer Technology* 2010; 29(1): 54-63.
13. Hasani H, Tabatabaei SA. Optimizing Spinning Variables to Reduce the Hairiness of Rotor Yarns Produced from Waste Fibres Collected from the Ginning Process. *Fibres & Textiles in Eastern Europe* 2011; 19(3): 21-25.
14. Su TL, Kuo CFJ, Wei HJ. Prediction System of Open-End Rotor Spinning Process Based on LM-Neural Network for Bamboo Charcoal and CVC Blended Fibers. *Fibers and Polymers* 2011; 12(5): 657-663.
15. Sekerden F. Investigation on the Unevenness, Tenacity and Elongation Properties of Bamboo/Cotton Blended Yarns. *Fibres & Textiles in Eastern Europe* 2011; 19(3): 26-29.
16. Shanbeh M, Baghaei B, Alidadi S, Tabibi A. Coating of Core Yarn. An Alternative Method of Decreasing the Strip-back Phenomenon of Core-spun Yarns. *Fibres & Textiles in Eastern Europe* 2011; 19(5): 28-32.

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LABORATORY OF BIODEGRADATION

The Laboratory of Biodegradation operates within the structure of the Institute of Biopolymers and Chemical Fibres. It is a modern laboratory with a certificate of accreditation according to Standard PN-EN/ISO/IEC-17025: 2005 (a quality system) bestowed by the Polish Accreditation Centre (PCA). The laboratory works at a global level and can cooperate with many institutions that produce, process and investigate polymeric materials. Thanks to its modern equipment, the Laboratory of Biodegradation can maintain cooperation with Polish and foreign research centers as well as manufacturers and be helpful in assessing the biodegradability of polymeric materials and textiles.

The Laboratory of Biodegradation assesses the susceptibility of polymeric and textile materials to biological degradation caused by microorganisms occurring in the natural environment (soil, compost and water medium). The testing of biodegradation is carried out in oxygen using innovative methods like respirometric testing with the continuous reading of the CO_2 delivered. The laboratory's modern MICRO-OXYMAX RESPIROMETER is used for carrying out tests in accordance with International Standards.

The methodology of biodegradability testing has been prepared on the basis of the following standards:

- **testing in aqueous medium:** 'Determination of the ultimate aerobic biodegrability of plastic materials and textiles in an aqueous medium. A method of analysing the carbon dioxide evolved' (PN-EN ISO 14 852: 2007, and PN-EN ISO 8192: 2007)
- **testing in compost medium:** 'Determination of the degree of disintergation of plastic materials and textiles under simulated composting conditions in a laboratory-scale test. A method of determining the weight loss' (PN-EN ISO 20 200: 2007, PN-EN ISO 14 045: 2005, and PN-EN ISO 14 806: 2010)
- **testing in soil medium:** 'Determination of the degree of disintergation of plastic materials and textiles under simulated soil conditions in a laboratory-scale test. A method of determining the weight loss" (PN-EN ISO 11 266: 1997, PN-EN ISO 11 721-1: 2002, and PN-EN ISO 11 721-2: 2002).

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The following methods are applied in the assessment of biodegradation: gel chromatography (GPC), infrared spectroscopy (IR), thermogravimetric analysis (TGA) and scanning electron microscopy (SEM).

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