10C08

Physical Properties of Spunbonded and Melt Blown Nonwovens

Hageun Suh and Eun Ae Kim
Research Institute of Clothing & Textile Sciences, Yonsei University, Seoul, Korea

1. Introduction

Nonwoven fabrics can be produced by several means, one of which is the polymer laying method that consists of two, spunbonding and melt blowing technologies. These relatively new technologies utilize four integrated processing steps which are fiber extrusion, attenuation, laydown and bonding. Like other textile processes, spunbonding and melt blowing involve many processing variables which determine the physical properties of resulted webs. Some studies have been done for characterizing the effects of the processing parameters on the physical properties of spunbonded and melt blown nonwovens [1, 2]. However, the process optimization by empirical data is tedious, and the results are often difficult to be interpreted and extrapolated. One way to simplify the process optimization is the application of a response surface method by a statistical approach [3]. In this study, the physical properties of spunbonded and melt blown webs fabricated from different processing parameters were evaluated, and as one way to optimize the processes, a statistical model fitting technique by regression was employed.

2. Experimental

1. Materials

<u>Spunbonded Webs</u>

Twelve spunbonded webs were fabricated from a polypropylene resin having a 35 melt flow rate (MFR). By using a Reicofil spunbond line and a Kuster thermal calender, the nonwoven fabrics having different basis weights were produced from different calendering temperatures. The throughput rate of the spunbonding process was held constant, 0.3 g/hole/min, and other parameters such as spin pump and die melt temperatures, and cooling air temperatures and speeds were kept optimal. The processing parameters of the spunbonded webs are in Table1.

<u>Melt Blown Webs</u>

Four melt blown webs with different basis weights were produced from a polypropylene resin having a 1200 MFR by using a melt blown line. The throughput rate and die-to-collector distance of the melt blowing process were held constant, 0.4 g/hole/min and 12 inches, respectively. Other parameters such as extruder and die temperatures, and air temperatures and pressures were kept optimal. The basis weights and collector speeds for the melt blowing process are in Table 2.

2. Physical Properties

The thickness, breaking load, tenacity, air permeability, elongation and stiffness properties of the 16 nonwoven fabrics were examined. The air permeability was measured as air resistance, and the stiffness as bending length was obtained by using a Cantilever method.

Table 1. Processing parameters for the spunbonding process.

Sample No.	Basis Weight (g/m^2)		Calender Temp. (top/bottom rolls, °F)		Spin Belt Speed (m/min)	Calender Nip Pressure (lb/in)
	Set	Actual	Set	Actual		
SB1	17	17.0	270/265	258/254	68.0	241.2
SB2	34	33.5	270/265	258/254	33.8	346.8
SB3	51	50.1	270/265	258/254	22.6	452.5
SB4	68	67.8	270/265	258/254	16.6	558.7
SB5	17	17.2	290/285	273/271	68.0	241.2
SB6	34	34.2	290/285	273/271	33.8	346.8
SB7	51	50.1	290/285	273/271	22.6	452.5
SB8	68	67.5	290/285	273/271	16.6	558.7
SB9	17	17.2	310/305	290/291	68.0	241.2
SB10	34	33.9	310/305	290/291	33.8	346.8
SB11	51	51.1	310/305	290/291	22.6	452.5
SB12	68	68.8	310/305	290/291	16.6	558.7

Table 2. Processing parameters for the melt blowing process.

Sample No.	Basis Weight (g/m^2)		Collector Speed (ft/min)
	Set	Actual	
MB1	19	19.9	86
MB2	37	38.8	43
MB3	56	57.4	29
MB4	75	74.6	22

3. Statistical Analyses

The effects of basis weights and calendering temperatures on the physical properties of the spunbonded webs were statistically evaluated by a general linear regression method. After polynomial equations were estimated by model fitting, the response surfaces for the physical properties were generated for further analyses. In addition, the linear relationships among the properties of the spunbonded nonwovens were examined by Pearson coefficients. The effects of basis weights on the physical properties of the melt blown webs were evaluated by a linear regression method.

3. Results

Spunbonded Webs

For the spunbonded webs, the thickness values were decreased slightly when the calendering temperatures increased, but the basis weights were the major factor for the increases in the thickness values. For the breaking loads in machine direction (MD) and in cross direction (CD), the values were increased greatly when both the basis weights and calendering temperatures increased. On the other hand, the results of MD and CD tenacity values indicated that only for the webs with high basis weights the calendering temperatures influenced the tenacity greatly. Also, the tenacity of the nonwovens produced from high calendering temperatures was increased by basis weights up to a certain point. This result can be explained by the fact that thicker webs need higher calendering temperatures for the heat to be completely transferred across the webs.

The air permeability values were increased slightly by increasing the calendering temperatures, but greatly by increasing the basis weights. The MD and CD stiffness values were increased tremendously by high basis weights and high calendering temperatures. The MD and CD elongation values were increased with the increases in basis weights. The elongation values were increased up to a certain point and decreased when the calendering temperatures increased, which is related to the fact that the nonwovens bonded at high temperatures show a brittle failure during strength tests.

By regression model fitting, 2-nd order polynomial equations were estimated for all physical properties (Table 3). Response surface and contour plots of the properties were generated from the equations. For example, the response surface and contour plots of the MD breaking load are in Figure 1. The plots (Figures 1-c and 1-d) generated by the regression equation simulated closely the plots (Figures 1-a and 1-b) from raw data. The interaction between the basis weights and the calendering temperatures of the spunbonding process for the MD breaking load could be easily interpreted. From the graphs, one can predict that the MD breaking load will be increased by further increases in basis weights and calendering temperatures.

Table 3. Model fitting for the spunbonded webs.

	Regression Model (T: calender temp. W: basis weight)	**R^2**
Thickness	$-0.047 + 0.00028T + 0.0142W - 0.00002TW - 0.00003W^2$	0.999
MD Breaking Load	$120.15 - 0.475T - 6.358W + 0.029TW - 0.016W^2$	0.944
CD Breaking Load	$63.492 - 0.253T - 4.588W + 0.020TW - 0.0061W^2$	0.962
MD Tenacity	$70.696 - 0.184T - 3.97W + 0.018TW - 0.014W^2$	0.842
CD Tenacity	$-2.871 + 0.026T - 2.095W + 0.01TW - 0.008W^2$	0.822
Air Permeability	$2.7475 - 0.012T - 0.1229W + 0.0005TW + 0.0021W^2$	0.998
MD Elongation	$172.188 - 0.536T - 6.414W + 0.0266TW - 0.017W^2$	0.715
CD Elongation	$-1711.146 + 12.086T - 5.205W + 0.023TW - 0.021T^2 - 0.015W^2$	0.802
MD Stiffness	$37.619 - 0.2514T - 0.0938W + 0.0005TW + 0.0004T^2$	0.979
CD Stiffness	$42.247 - 0.2788T - 0.0982W + 0.0005TW + 0.0005T^2$	0.995

Correlation among the Physical Properties

The results from Pearson correlation coefficients (ρ) indicated the strong linear relationships ($\rho > |0.7|$) among thickness, air permeability and stiffness, between breaking load and stiffness, between tenacity and elongation, and between breaking load and tenacity. Also, all physical properties in MD were strongly correlated with the properties in CD.

Melt Blown Webs

For the melt blown webs, the thickness and air permeability values were increased by the increases in basis weights. The MD and CD breaking load and stiffness values were increased with basis weights, but at higher basis weights the differences between MD and CD values were less. The MD tenacity values were decreased when the basis weights increased. The CD tenacity and the MD and CD elongation values did not show any specific trends, but the CD elongation values were higher than the MD ones. By regression, 1st-order linear equations were estimated for most physical properties except for CD tenacity and MD and CD elongations (Table 4).

Table 4. Model fitting for the melt blown webs.

	Regression Model (W: basis weight)	**R^2**
Thickness	$0.0403 + 0.0102W$	0.998
MD Breaking Load	$3.363 + 0.0912W$	0.936
CD Breaking Load	$0.8572 + 0.1271W$	0.975
MD Tenacity	$10.1 - 0.0683W$	0.984
CD Tenacity	$0.9947 + 0.4468W - 0.0112W^2 + 0.00008W^3$	1.000
Air Permeability	$0.8425 + 0.7774W$	0.984
MD Elongation	$21.5375 - 0.58W + 0.0048W^2$	0.991
CD Elongation	$35.858 + 0.1732W - 0.0014W^2$	0.912
MD Stiffness	$2.7455 + 0.0533W$	0.894
CD Stiffness	$1.0605 + 0.073W$	0.984

4. Conclusions

The physical properties of the spunbonded webs were greatly influenced by the basis weights and calendering temperatures. The interactions between the basis weights and calendering temperatures were significant and complicated. By a regression analysis, the nonlinear effects of the spunbonding processing parameters on the physical properties were estimated. This study showed one way to optimize the processing parameters for interpretation and prediction. In addition, by a correlation analysis, the linear relationships among the properties were examined.

The physical properties of the melt blown webs were greatly influenced by the basis weights. Most of the physical properties indicated the strong linear relationships with the basis weights.

5. Acknowledgement

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6. References

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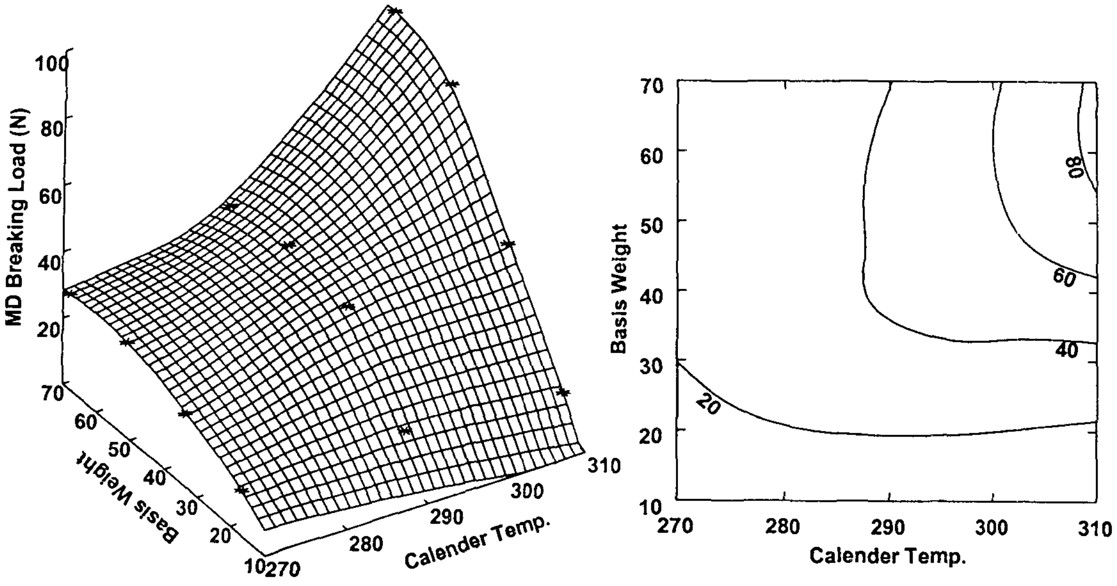
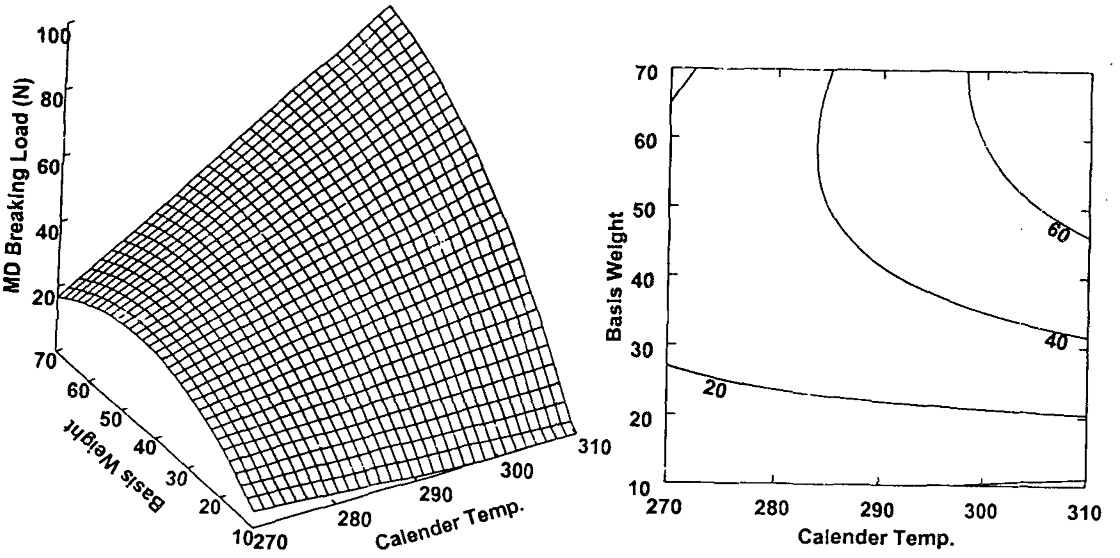


(a) Response surface plot

(b) Contour plot



(c) Estimated response surface plot

(d) Estimated contour plot

Figure 1. Response surface and contour plots for the MD breaking load of the spunbonded nonwovens from different calendering temperatures (°F) and basis weights (g/m^2).