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Effect of stitch angle on Tensile and bending properties of nonwoven fabric

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Abstract

The bending and tensile behaviour of stitched nonwoven fabric is studied by varying the stitch density, stitch line spacing and stitch line angle. It has been found that the stitching angle has significant effect on both tensile property and on bending property of spun bond as well as of needle punched nonwoven fabric. The work of rupture of stitched nonwoven fabric is significantly influenced by both stitching angle and spacing between stitch lines.

Keywords— Nonwoven, stitch, tensile, bending.

Introduction

Stitching influences the various fabric properties of woven and knitted fabrics well as of the nonwoven fabric. The effect of sewing on drape [1, 2, 8], tensile and bending [3, 4] properties of fabric have been studied for woven fabric. The effect of stitching angle on fabric properties also have been studied for woven fabric by Eng Manal Seif [4, 5]and the effect of fabric properties on seam quality by Mandal et al [6, 7]. The seam angle have a significant influence on aesthetical value of garment and also on the performance properties5.As in case of apparel manufacturing the garment appearance influences by stitching quality and in technical textile application functional properties of fabric may also be influence by the stitching parameters. Nonwoven fabric may also be stitched for some applications such as in apparel backing, interlining or a layer in combination with woven fabric in such cases it is important to know the effect of stitching parameter on nonwoven fabric as well. In various applications many a times nonwoven fabric needed to be stitch, whether for ornamentation purpose or for functional use. Similar to woven fabric, the stitching may also change the properties of nonwoven fabric, this change likely to affect the property of final product. So it is required to study the behaviour of stitched nonwoven fabric. The fabric may be stitched at various directions at different positions for different application, it is also important to see the effect of stitch line angle and stitch line spacing on nonwoven fabric properties. In this paper the bending and tensile behaviour of stitched nonwoven fabric is studied by varying the stitching parameters.

Methods

A nonwoven needle punched fabric having 140 gsm, made from polypropylene fibre is stitched by using polyester sewing thread. Spun bond nonwoven fabric of 45 and 105gsm are also stitched using nylon and polyester thread.

A. Stitched sample preparation:

Non-woven spun bond nonwoven fabric samples of size 5 cm x 15 cm are stitched on lockstitch machine with parameters as shown in table 1.

Table 1: factors and levels for of spun bond fabric

Sr no.	Factor	No. of level	Levels
1	Angle	4	1- 0^0 2-30^0 3-60^0 4-90^0
2	Stitch density	4	1- 6spi 2- 9 spi 3-12spi 4 -15 spi
3	spacing	4	1- 0.5cm 2-1cm 3-2cm 4-3cm
4	Fabric GSM	2	1- 45gsm 2-105gsm
5	Thread	2	1- Nylon 2-Polyster
6	Needle	2	1- 16 no. 2- 18 no.
7	Tension	2	1- Low 2-High

B. Testing:

Tensile Test: The tensile strength and elongation of needle punched fabric as shown in figure 1 is tested using cut strip test with sample size of 4cm x 16 cm. The tensile strength and elongation of spun bond punched fabric is obtained using cut strip test with sample size of 5cm x 15 cm. Also work of rupture is calculate by platting graphs and by measuring area under the curve.

Bending Stiffness: For carrying out the bending stiffness test, Shirley stiffness tester is used and the bending stiffness is calculated according to DIN (53362).

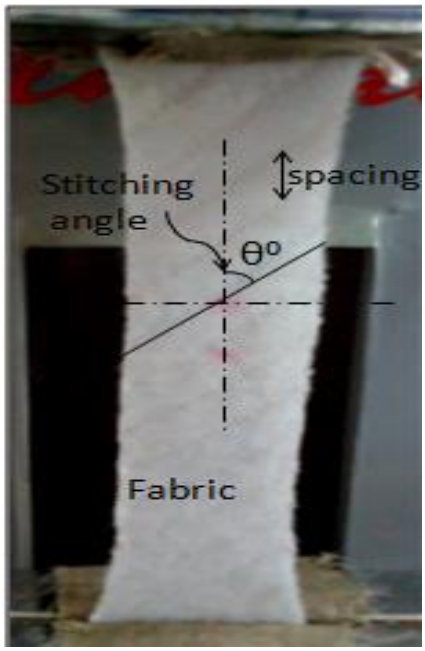


Fig 1 Needle punched fabric sample

Results and Discussions

Before the nonwoven fabric the contribution of various factors which may influence the strength of fabric and flexural rigidity is found out using orthogonal L16 design. The results obtained are shown in table 2 & 3.

Table 2: Contribution for breaking load

Sr. No.	Factors	DF	SS	MS	F Value	P Value	Contribution %
1	Angle	3	342	114	1.06	0.402	20.930
2	Stitch density	3	132	44	0.35	0.788	8.078
3	spacing	3	96	32	0.25	0.860	5.875
4	Fabric GSM	1	945.6	945.6	19.22	0.001	57.870
5	Thread	1	112	112	1.03	0.327	6.854
6	Needle	1	2	2	0.02	0.899	0.122
7	Tension	1	0	0	0.00	0.993	0.000
	Residual		4.4				0.269
	Total	**15**	**1634**				

Table 3: Contribution for flexural rigidity

Sr. No.	Factors	DF	SS	MS	F Value	P Value	Contribution %
1	Angle	3	106766	35589	0.05	0.983	1.333
2	Stitch density	3	218606	72869	0.11	0.951	2.728
3	spacing	3	201193	67064	0.10	0.957	2.511
4	Fabric GSM	1	7112960	7112960	110.72	0.000	88.775
5	Thread	1	203295	203295	0.36	0.556	2.537
6	Needle	1	176	176	0.00	0.986	0.002
7	Tension	1	51794	51794	0.09	0.767	0.646
	Residual		169330				2.113
	Total	**15**	**8012326**				

It has been found that the strength of stitched nonwoven fabric is mostly influence by fabric type and stitching parameters while thread type have little influence. Out of stitching parameters stitching line angle is most influencing factor while tension and needle type have negligible effect. Also it has been found that flexural rigidity of stitched nonwoven fabric is mostly influence by fabric type and stitching parameters. Out of stitching parameters tension and needle type have negligible effect.

Table 4: levels and factor for spun bond fabric

Sr. no.	Factor Name	No. of level	Levels
1	Angle	4	1- 0^0 2-30^0 3-60^0 4-90^0
2	Stitch density	3	1- 9 spi 2-12spi 3 -15 spi
3	Spacing	3	1- 0.5cm 2-1cm 3-2cm

Table 5: levels and factor for needle punched fabric

Sr. no.	Factor Name	No. of level	Levels
1	Angle	4	1- 0^0 2-30^0 3-60^0 4-90^0
2	Stitch density	3	1- 9 spi 2-12spi 3 -15 spi
3	Spacing	3	1- 1cm 2-2cm 3-3cm

Table 6: Factorial design for spun bond fabric

Spi	Spacing (cm)	Angle (degree)	Strength (Kg)	Elongation (mm)	FR (mg/cm)
9	0.5	0	8.9	252	80981.9
9	0.5	30	6.9	74	125566.9
9	0.5	60	7	178	200512.6
9	0.5	90	4.4	128	166400.7
9	1	0	6.2	252	70778.9
9	1	30	6.8	134	114116.6
9	1	60	6	191	146334.0
9	1	90	5	135	136578.4
9	2	0	5.6	256	76453.7
9	2	30	7	128	110085.1
9	2	60	6.8	182	140682.5
9	2	90	4.9	147	98469.9
12	0.5	0	7.1	222	188394.2
12	0.5	30	7.6	129	119822.4
12	0.5	60	7.6	264	198379.4
12	0.5	90	5.2	177	157618.0
12	1	0	6.6	166	172782.1
12	1	30	5.6	91	76436.4
12	1	60	6	218	144450.5
12	1	90	4.7	168	124281.5
12	2	0	5.6	263	116611.1
12	2	30	6.1	134	61321.7
12	2	60	6.7	189	148154.4
12	2	90	4.6	180	91006.9
15	0.5	0	7.6	208	75648.5
15	0.5	30	7.4	88	97956.3
15	0.5	60	5.1	249	142781.4
15	0.5	90	4.8	198	114912.5
15	1	0	7.3	48	104185.7
15	1	30	7.3	120	134575.6
15	1	60	7.3	240	136993.7

15	1	90	5.6	240	131293.2
15	2	0	7.3	55	123087.4
15	2	30	7.5	123	154079.9
15	2	60	6.3	219	166382.8
15	2	90	5.8	243	94241.0

Table 7: Factorial design for needle punched fabric

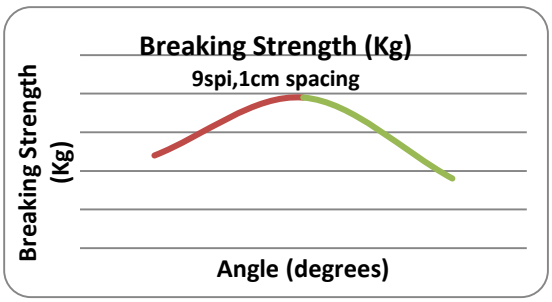
spi	spacing (cm)	Angle (degree)	strength (Kg)	Work of rupture (Kg-mm)	Flexural Rigidity (mg/cm)
9	1	0	12	9212	1310.49
9	1	45	19.5	9271	2102.41
9	1	90	9	5369	980.837
9	2	0	6.5	4181	1015.85
9	2	45	12.5	4973	1197.18
9	2	90	7.2	3822	965.35
9	3	0	9.3	6863	2179.18
9	3	45	13.6	6471	1455.17
9	3	90	5.6	2311	972.41
12	1	0	10.6	8490	1540.3
12	1	45	21.4	6966	2183.63
12	1	90	6.1	8019	927.42
12	2	0	8.8	10225	2254.79
12	2	45	15.6	8260	1202
12	2	90	6.9	9072	892.16
12	3	0	9.5	2585	1810.64
12	3	45	20.9	3925	2340.62
12	3	90	6.5	3717	972.41
15	1	0	7.6	6533	1262.17
15	1	45	19.5	10192	1547.25
15	1	90	4.9	1854	927.42
15	2	0	8.3	4664	1448.3
15	2	45	22.6	8864	2748.78
15	2	90	5.3	2021	892.16
15	3	0	7.4	4200	1117.04
15	3	45	10.9	4593	993.78
15	3	90	6.1	3129	972.41

So the further study for a given nonwoven fabric is done by considering stitching parameters. For this nonwoven spun bond and needle punched fabric is stitched by considering factors and levels as shown in table 4 & 5and analysed using full factorial design.

Effect of stitch line angle on fabric Tensile strength:

Stitching a nonwoven fabric will bond the fibres inside fabric and it will increase its, stitched fabric having more strength than unstitched fabric. When load is applied to stitched nonwoven fabric, the total tension develop on stitched fabric is contributed by the nonwoven fabric and stitching yarn. Tension develop is also depend upon the stitch line angle with respect to applied load, the effect of stitch line angle on breaking load is found to be significant by ANOVA analysis of factorial design. As shown in Fig. 2 and Fig 3 for the vertically stitched fabric the strength is more as compare to horizontally stitched fabric. In case of fabric stitched at bias direction breaking strength is more than horizontally stitched and vertically stitched fabric.

As angle is moving towards the 45 degree the strength will increase and after that it will decrease.



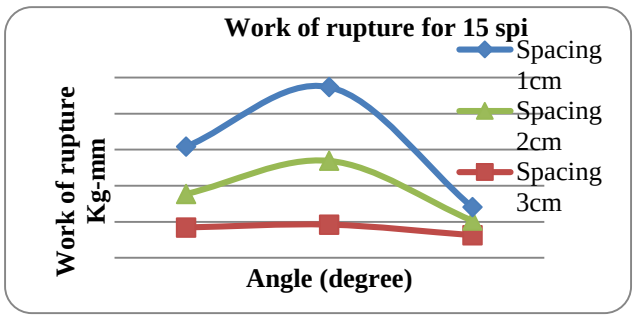


Fig 2 Breaking strength of needle punched fabric at various angle (at 9spi ans 1cm spacing)
Fig 3 Breaking strength of spun bond fabric at various angle (at 15spi ans 2cm ans 3cm spacing)

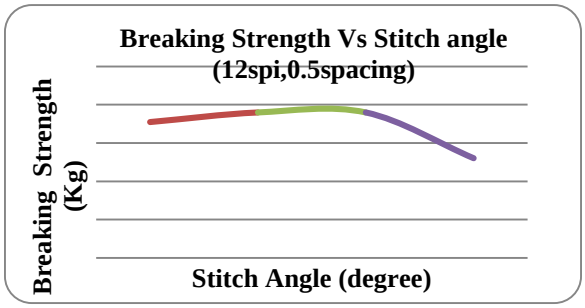


Fig 4 Breaking strength of spun bond fabric at various angle (at 12spi ans 0.5cm spacing)

Work of rupture of stitched nonwoven fabric:

For needle punched fabric by ANOVA analysis it have been found that the stitching angle and spacing having significant effect on work of rupture. Work of rupture is more for vertically stitched fabric than horizontally stitched fabric and maximum at bias direction as shown in Fig. 4. As in case of bias direction continues increase in load with elongation and more contraction of nonwoven fabric. As far as spacing is concern it has been observed that the work of rupture is more for 1cm spacing then 2cm spacing and minimum for 3cm spacing for all angle. If spacing between stitch lines is less means more number of threads therefore the tension developed will also be more by thread component. Also if the spacing is less the strength is more this may due to the more number of fibre are caught in between the stitching lines and more fibres take parts in direct tension development and less slippage. While in case of more spacing there is more sliding of fibres and less tension development. In case of horizontally stitched fabric the effect spacing between lines is less to that of the vertically stitched fabric as in this case fabric potion mainly contributing for strength. For bias direction the length of cell formed is decided by the spacing while width of fabric strip under contraction is decided by the angle of stitching, with increase in angle the width also increased. In this case tension development is decided combined effect of thread and fabric portion.

Effect of stitch line angle on fabric bending rigidity:

The stitch angle is significantly affects the bending rigidity of stitched nonwoven fabric as shown in. As compare to unstitched sample stitched sample having more bending rigidity this may be due to increase in mass linear density particularly at the point of stitching. Also the stiffness is more if the stitching length is more, as shown in Fig. 5 and 6, the vertically stitched fabric having more bending rigidity then horizontally stitched fabric and for fabric stitched at bias direction having maximum bending rigidity.

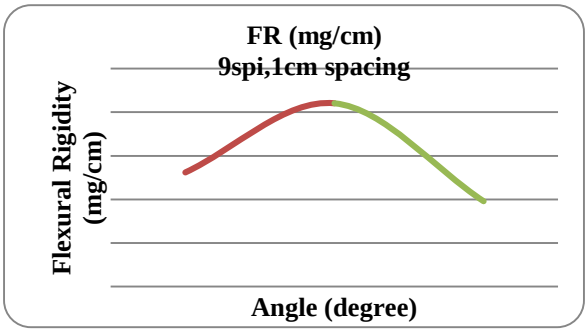


Fig 5 Flexural rigidity of needle punched fabric at various angle (at 9spi and 1cm spacing)

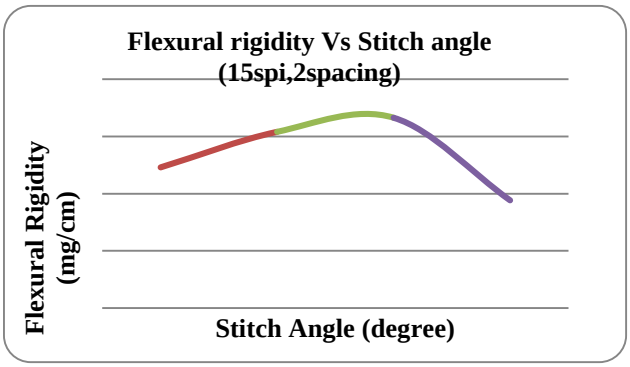


Fig 6 Flexural rigidity of spun bond fabric at various angle (at 15spi and 2cm spacing)

Conclusion

Fabric weight is the main factor that decides the strength of nonwoven fabric. Further it is possible to increase the strength of a given weight of fabric by stitching, in which stitch line angle is most influencing factor than other stitching parameters. For vertically stitched fabric the tensile strength is more as compare to horizontally stitched fabric and it is increasing as angle is moving towards the biased direction. Work of rupture is significantly influenced by stitch line angle as well as spacing between lines. Work of rupture is more for vertically stitched fabric than horizontally stitched fabric and maximum at bias direction. Flexural rigidity is also mainly decided by fabric weight and further it is influenced by stitching line angle. The vertically stitched fabric having more bending rigidity than horizontally stitched fabric and for fabric stitched at bias direction shows maximum bending rigidity.

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