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EVALUATION OF THE SURFACE MECHANICAL PROPERTIES OF COTTON BASED THERMAL BONDED NONWOVENS USING A NEW METHODOLOGY

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Introduction

Friction is an important property of both conventional and unconventional textile materials that governs the quality and the performance of products. Nonwovens are flat fibrous structures or webs or sheets that are made by bonding and entangling fibers by mechanical, thermal or chemical means. Nonwovens, due to their unique properties have replaced several conventional fabrics and are also finding high-tech and novel applications. Theses products have diversified use from household items to industrial and military products [1]. In particular, in the case of nonwoven materials, friction plays an important role due to the nature of applications nonwovens are put to use. Although friction is important, in the case of textile materials it is one among the least understood of all mechanical properties.

In this paper the sliding friction method has been used to evaluate the frictional characteristics of cotton based nonwoven fabrics. The method uses the well-established sliding friction apparatus and a newly derived simple friction parameter "R," to compare and characterize the frictional characteristics of different cotton based nonwoven fabrics.

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Experimental Method

Experimental Method to Evaluate the Friction of Fabrics

The sliding friction apparatus as shown in Figure 1 was used to measure the frictional characteristics of nonwoven fabrics. Frictional property of the nonweven fabric was measured over a range of different normal loads using a standard friction substrate or a sledge. A persplex sledge was used as a standard friction substrate in all experiments. The minimum and the maximum loads used were 39.46 and 89.46 gms respectively. The load was incremented in steps of 10 gms. The standard sledge (A) was pulled at a constant rate of 500 mm/min by an inextensible thread. The fabric was attached on the platform (C) over which the standard sledge slid at a constant velocity.

The tensile tester is attached to a microprocessor that stores the friction force values. Friction parameters are calculated using Equation 1.

$$F/A = C\,(N/A)^n \qquad (1)$$

where F is the friction force (Newtons), N is the normal applied load (Newtons) and A is the apparent area of contact (m^2). The above equation is solved to obtain the friction parameters "C" and "n" that are then used to obtain the friction factor "R." The friction factor "R" is given by Equation 2 [2, 3].

$$R = C/n \qquad (2)$$

where "C" is the friction parameter and "n" is material index. The higher is the value of "R"; the higher is the friction of fabrics and vice versa.

Materials Used

The details of different cotton based nonwoven fabrics used in this study are given in Table 1. These samples were acquired from different sources and were kindly donated by Cotton, Inc.

Experimental Results

Friction force values at different normal loads are given in Tables II and III. Fabric friction parameter values are given in Tables 4 and 5 Three repetitions per sample were tested at each normal load. The average and the standard derivation values at each normal load are given in Tables 2 and 3.

Results and Discussion

Influence of Normal Load on Friction Force Values

As is evident from Figure 2, the relationship between the friction force and normal load can be conveniently represented by Equation 1. There is a good relationship between the experimental friction force values and the calculated values. Table 7 gives the correlation between the experimental and calculated friction force values. These results show that the frictional characteristics of cotton based nonwovens can be characterized using the friction factor "R" values.

Friction Parameter

It is evident from Table 6 that the friction factor defined in this paper is a convenient factor to characterize and compare different nonwoven substrates for their frictional properties. It is clear from Table 5 that airlaced cotton wipe has the lowest friction factor value and the carded airlaced/spunlaced composite has the highest friction factor value. Also results show that 100% cotton based nonwoven scored higher fabric ranks indicating that their friction values are lower and hence higher quality. In addition, Fabric# 5 had the highest weight resulting in lowest fabric rank. The presence of carded cotton on the surface of the fabric increased the frictional resistance resulting in second lowest friction rank among fabrics investigated in this study.

Analysis of Frictional Traces

The sliding friction apparatus is a convenient tool not only to quantify the frictional characteristics but also to obtain the stick-slip frictional traces. As is clearly evident from Figures 3a-4c, stick-slip traces vary according to the type of nonwoven materials tested and the normal loads applied during the testing. Fabric# 4 is airlaced cotton wipe and Fabric# 6 is cotton surfaced spunbonded polypropylene substrate. As seen from Figures 4a-4c, stick-slip traces for cotton surfaced nonwovens are rougher and more pronounced than the airlaced wipes. The results obtained show that the sliding method is successful in quantifying and categorizing nonwovens for their frictional properties.

Conclusion

The sliding friction apparatus has been found to be a useful tool to quantify the surface mechanical properties of nonwovens. The new and the simple friction factor was successful in objectively quantifying the frictional properties of nonwoven substrates. Carded composite nonwoven had the highest friction factor value. Cotton surfaced nonwoven had high friction factor compared to that of the airlaced web due to the carded cotton fibers on the surface. Airlaced wipes had the lowest friction factor resulting in smooth fabric with improved quality.

References

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Table 1. Materials Used.

Fabric ID	Fabric Type	Fabric Weight (g/m^2)	Fabric Material
1	Spunlaced Cotton Wipe	30	100% Bleached Cotton
2	Spunlaced Cotton Wipe	66	100% Bleached Upland Cotton
3	Spunlaced Cotton Wipe	80	100% Bleached Cotton
4	Airlaced Cotton Wipe	75	60% Bleached Cotton/ 40% PET
5	Cotton Cosmetic Pad (Carded-Airlaced-Spunlaced Composite)	250	100% Bleached Cotton
6	Cotton Surfaced Nonwoven	43	Core: Spunbonded Polypropylene Surface: Bleached Carded Cotton

Table 2. Static Friction Force Values.

Fabric ID	Static Friction (gms) at Different Normal Loads					
	39.46(N1)	49.46(N2)	59.46(N3)	69.46(N4)	79.46(N5)	89.46(N6)
1	20.03(1.93)	23.80(2.95)	28.43(2.44)	30.70(3.55)	33.60(2.08)	38.50(1.38)
2	18.30(3.38)	21.83(3.96)	22.28(0.93)	28.08(3.55)	28.25(1.45)	35.85(5.10)
3	19.23(2.30)	25.90(2.57)	27.55(3.02)	32.68(4.88)	34.83(3.00)	36.35(2.83)
4	17.35(2.33)	20.15(1.06)	26.15(0.64)	25.95(0.35)	30.65(0.64)	35.60(4.95)
5	27.60(2.23)	28.78(2.64)	30.78(2.63)	36.50(4.25)	37.85(2.00)	42.63(2.52)
6	22.10(1.98)	19.55(0.64)	26.65(0.92)	32.75(5.16)	33.4(3.25)	36.95(2.05)

* Values within parenthesis indicate standard deviation

Table 3. Dynamic Friction Force Values.

Fabric ID	Dynamic Friction (gms) at Different Normal Loads					
	39.46(N1)	49.46(N2)	59.46(N3)	69.46(N4)	79.46(N5)	89.46(N6)
1	14.24(1.24)	17.60(2.95)	20.75(1.40)	23.70(1.49)	26.91(1.78)	29.95(1.86)
2	13.13(0.55)	16.09(0.43)	19.13(0.62)	21.77(0.64)	24.67(0.75)	27.37(0.85)
3	14.03(0.24)	17.29(0.31)	20.55(0.13)	23.51(0.24)	26.44(0.18)	29.53(0.20)
4	14.01(0.22)	16.92(0.19)	20.10(0.32)	23.04(0.58)	25.75(0.60)	28.72(0.57)
5	23.55(2.01)	25.78(1.22)	30.01(2.13)	35.14(1.97)	39.06(2.31)	43.79(2.72)
6	14.06(0.10)	17.44(0.40)	20.39(0.27)	23.24(0.21)	26.11(0.31)	29.16(0.20)

* Values within parenthesis indicate standard deviation

Table 4. Friction Parameter Values.

Fabric ID	Static			Dynamic			Average		
	C	n	R	C	n	R	C	n	R
1	1.687	0.772	2.185	0.602	0.904	0.666	1.145	0.838	1.366
2	1.636	0.756	2.164	0.572	0.897	0.638	1.104	0.827	1.336
3	1.799	0.763	2.358	0.587	0.905	0.649	1.193	0.834	1.430
4	0.956	0.850	1.125	0.668	0.879	0.760	0.812	0.865	0.939
5	7.304	0.545	13.402	1.781	0.784	2.272	4.543	0.665	6.836
6	1.781	0.759	2.347	0.673	0.880	0.765	1.227	0.820	1.497

* C and R expressed in Pa^{1-n}

Table 5: Average Fabric Friction Factor Values.

Fabric ID	Fabric Friction Factor "R" [Pa^{1-n}]
1	1.366
2	1.336
3	1.430
4	0.939
5	6.836
6	1.497

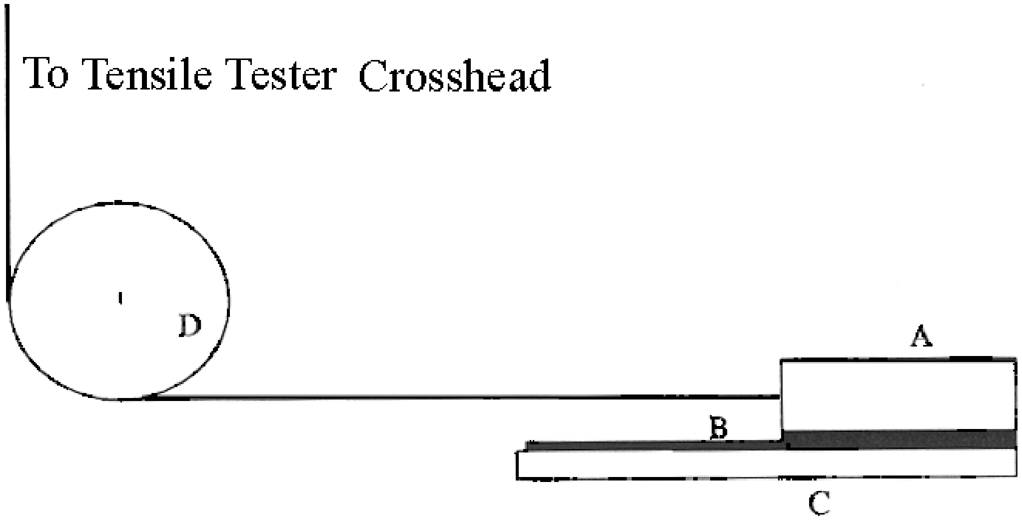
Table 6. Fabric Friction Ranks.

Fabric ID	R	Fabric Friction Rank
1	1.366	4
2	1.336	5
3	1.430	3
4	0.939	6
5	6.836	1
6	1.497	2

* The higher is the rank; the lower is the friction and vice versa
** The higher is the fabric friction rank; the better is the overall fabric quality and vice versa

Table 7. Relationship between Experimental and Calculated Friction Force Values.

Fabric ID	Correction Values (R^2)	
	Static Friction	**Dynamic Friction**
1	0.992	0.999
2	0.927	0.999
3	0.958	0.999
4	0.965	0.999
5	0.934	0.981
6	0.838	0.999



A: persplex sledge, B: fabric, C: aluminum platform and D: frictionless pulley

Figure 1. Schematic of the Sliding Friction Apparatus 1.

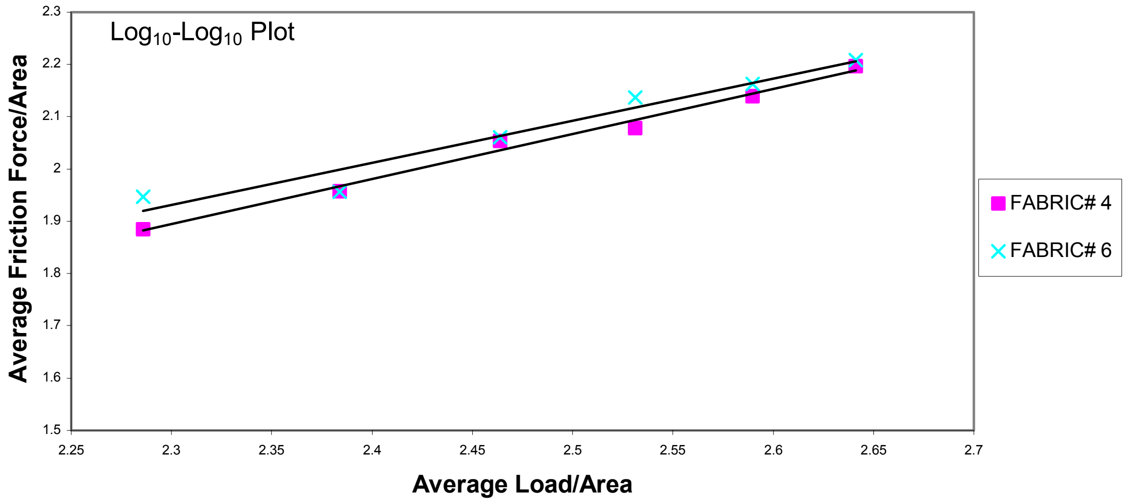


Figure 2. Average Friction vs. Average Load.

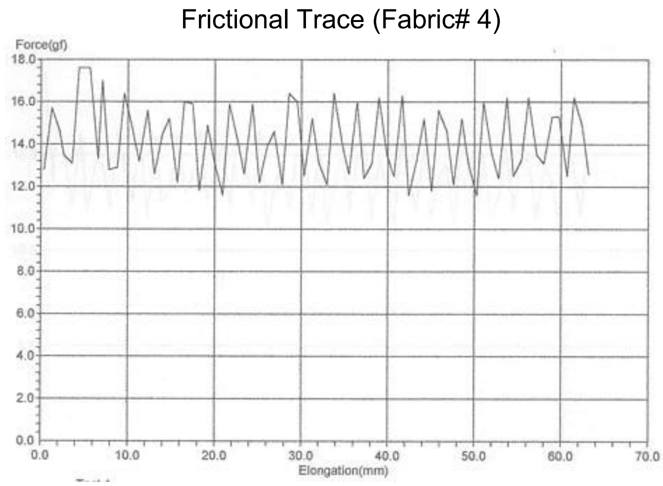


Figure 3a. Stick-slip trace at 39.46 gms.

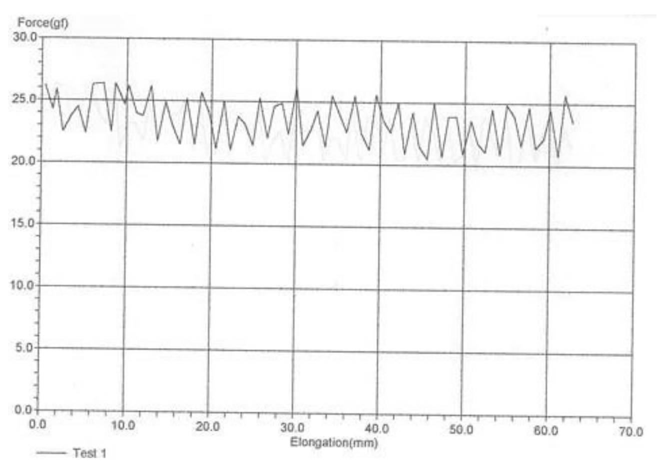


Figure 3b. Stick-slip at trace 69.46 gms.

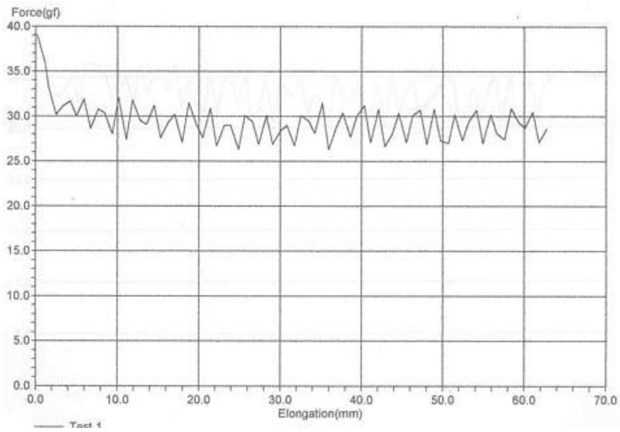


Figure 3c. Stick-slip trace at 89.46 gms.

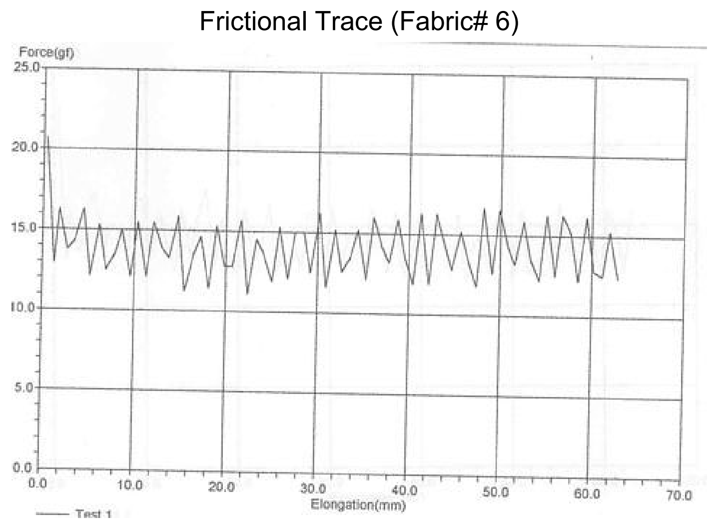


Figure 4a. Stick-slip trace at 39.46 gms.

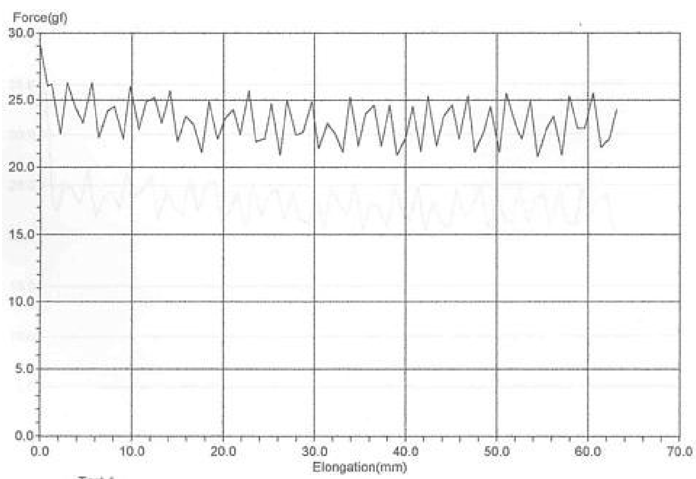


Figure 4b. Stick-slip trace at 69.46 gms.

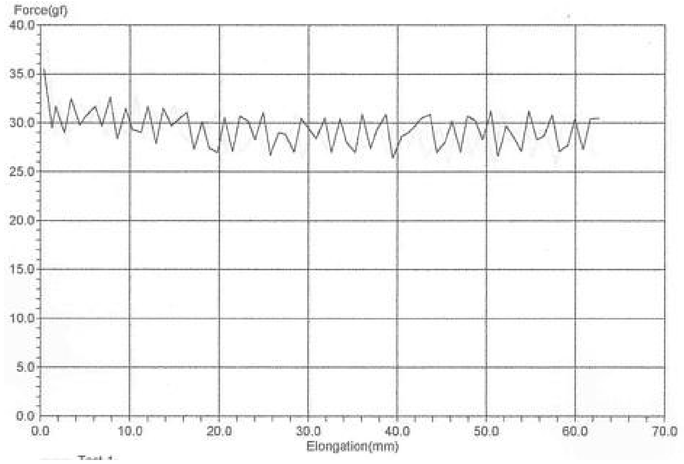


Figure 4c. Stick-slip trace at 89.46 gms.