Effect of Layering on Thermal Comfort of Nonwovens

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Abstract - *Protective properties of nonwovens are more important for the industrial use. This paper studies various thermal properties of nonwoven fabric samples prepared with different number of layers.*

Key Words: Nonwoven, Multilayering, clo values, TIV values.

1. INTRODUCTION:

Mostly nonwovens are used in industry and for protective clothing. In industry they are used for insulation and in protective clothing they are used as thermal barrier [1] and as inner layers because they provide good absorbency and comfort [2].

In both the cases the thermal and comfort properties of nonwovens are important. In industrial insulations their thermal properties are useful to reduce the heat loss and make machines more efficient. In Protective clothing their thermal properties as well as moisture vapor transport rate (both constitutes comfort) are important as to provide increased protection from extreme environments and also to increase working efficiency and comfortable feel during working with this protective clothing. The present study tries to find the thermal performance of nonwoven fabrics with change in only its construction by varying number of layers, without changing its comfort properties especially moisture vapor transport rate, air permeability and q- max value.

Slater K. [3] stated that the total thermal resistance to transfer of heat from the body to the surrounding has three effective components viz - resistance to heat transfer from the material surface to surrounding, thermal resistance of clothing material itself, & thermal resistance of the air trapped inside the fabric. Martin et al [4] stated that conduction is due to fiber to fiber attachment but it counts only 0.3% of total heat transfer, hence major components for heat transfer are convection by air and radiation.

Slater K. also summarized that for a given fixed weight, thermal insulation increases with thickness due to increased quantity of enclosed air, whereas if thickness is maintained constant then thermal insulation decreases with increase in weight as quantity of enclosed air is reduced. Mao et al [5] concluded that thermal insulation value of porous, low density nonwoven is adversely affected by compression, so layered structures gives good insulation because of good compression recoverability. Mohammadi et al [6] concluded that increase in weight to thickness ratio causes increase in effective thermal conductivity because fiber to fiber contact increases and increase in packing density causes increase in tortuosity i.e. mean free path for photons to be travelled increases so less heat flows through the channels in nonwoven.

2. MATERIALS & METHODS:

Material used: Polyester staple fibres of 6 denier with 61mm Staple length.

Preparation of samples:

Type of fiber bonding: By Needle punching

Strokes/Min: 550 & Conveyor speed: 2.30 MPM

Process flow: For manufacturing Nonwoven samples, following sequence was used.

Bales->opening->feeding to criton opener (with spiral beater) ->Partial opening->Gharnet machine->Rando feeder->Web (with randomly oriented) ->Needle punching machine->Take up.

Nonwoven fabric samples were produced by varying number of layers & needle punching them but keeping the final GSM same. The logic of sample preparation is explained in Table 1.

Table 1- Nonwoven Fabric samples construction

Sample No.	No. of Layers	No. of Times the Layers get Punched				Actual GSM of sample (Theoretical GSM=158)
		L1	L2	L3	L4	
1	1	1				162.3
2	2	2	1			155.6
3	3	3	2	1		160
4	4	4	3	2	1	155

L1=First Layer, L2=Second Layer, L3=Third Layer, L4=Fourth Layer

3. RESULTS AND DISCUSSION:

GSM:

Table 2 shows readings of GSM values of Nonwoven Fabric samples with averages.

Table 2 - GSM values of Nonwoven Fabric samples

Sample no.	AVG GSM	1	2	3	4	5
1	162.3	156	164	166	160	165
2	155.6	148	156	156	163	155
3	160	160	160	162	158	160
4	155	172	144	155	142	162

Q-MAX value, TIV% Value & Thermal Resistance value (clo):

Various thermal Properties of Nonwoven Fabric samples are shown in Table 3.

Table 3 - Thermal Properties of Nonwoven Fabric samples

Sample no.	q-max value	TIV % Value	Clo Value
1	0.0330	56.6	1.13
2	0.0334	58.9	1.19
3	0.0333	59.4	1.21
4	0.0329	62.8	1.32

All these values of thermal properties are average of 24 readings tested on KES FB-7 Thermolabo-II.

Water Vapor Transport Rate (g/m2/24 hrs):

Table 4 shows Water Vapor Transport Rate of fabric samples (g/m2/24 hrs)

Table 4 - Water Vapor Transport Rate of Nonwoven Fabric samples

Sample No.	Water Vapor Transport Rate ($g/m^2/24$ hrs)
1	1063.2
2	970.3
3	1008.6
4	951.4

These Water Vapor Transport Rate values are average of 3 readings and are tested using KES FB-7 Thermolabo-II.

Thickness:

Thickness results of various nonwoven samples are as per table 5.

Table 5 - Thickness of Nonwoven Fabric samples

Sample no.	Number of layers	Thickness(mm)
1	1	2.306
2	2	2.154
3	3	2.682
4	4	2.40

Single Factor ANOVA was used to study the statistical significance of the results of tested nonwoven samples for various thermal & physical properties for observing effect of layering. Significance of results tested by Single Factor ANOVA is shown in table 6.

Table 6 - Significance of results tested by Single Factor ANOVA

Sr No.	Property	P-value	Significant(S)/ Non-significant(N)
1	GSM	0.409428	N
2	Q-max	0.503906	N
3	Thickness	0.018589	**S**
4	TIV	5.68E-15	**S**
5	Clo	3.17E-15	**S**
6	WVTR	0.010655	**S**

It is observed that the q-max values of all samples remain constant because it is dependent on material and surface structure of fabric, also these two parameters remain same for all sample formations.

In case of water vapor transport rate it is observed that there is decreasing trend for all samples except sample 3.This decreasing trend may be due to effective separation of layers leading to discontinuous channel formations in nonwovens. Also it may be due to increased compaction of previous layers in case of multilayered structures by multiple cycles of needle punching over previous layers. The increase in compaction reduces the radiative component of heat transfer so the results show increase in thermal insulation value. The exceptional rise for sample 3 is due to the availability of clear channels for water vapor. These channels may be formed due to multiple times punching of needles at the same point. This shows that while formation of multilayered needle punched nonwovens, the arrangement of needles on needle board affects the water vapor transport rate.

It is observed that there is increasing trend in clo values which may be because of increase in number of layers. The separation of layers cause increase in quantity of air pockets. In multiple time punching the air pockets are more tightly bound hence restricts the free air movement so there may be increase in clo values.

The statistical analysis shows that thickness changes significantly as the number of layers goes on increasing. But the rise in TIV and clo is not because of thickness change as sample 2 is having more TIV and clo even if it is thinner than sample 1. Similarly TIV and clo of sample 4 is more than 3 though the sample 4 is thinner than sample 3.

4. CONCLUSION

For the constant GSM of needle punched-nonwoven fabrics, the thermal performance i.e. TIV and Thermal Resistance value (clo) are significantly affected by increase in number of layers. The Warm or Cool feel of fabric (Q-max) remains same for all multilayered samples. The arrangement of needles on needling board plays important role in moisture vapour transport rate during the formation of multilayered structures. Multilayering also causes significant effect on the thickness of fabric.

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REFERENCES

[1] Lu Jin a, Kyoung-A Hong a, Hyun Do Namb, Kee Jong Yoon a, “Effects of Thermal Barrier on Thermal Protective Performance of Fire Fighter Garments” Journal of Fiber Bioengineering & Informatics,4:3 ,pp 245-252,2011.

[2] D. Gopalakrishnan, M. Nithiyakumar and Arpita Nayak, “Development of chemical protective clothing”, www.fiber2fashion.com.

[3] Slater, K., Comfort Properties of Textiles, The Textile Institute, Manchester, England, pp.1-11, 1977.

[4] Martin, J.R., Lamb, G.E.R., “Measurement of Thermal Conductivity of Nonwovens Using a dynamic Method”, Textile Research Journal, pp.721, Dec.1987.

[5] Mao, N., Russell, S.J., “The Thermal Insulation Properties of Spacer Fabrics with a Mechanically Integrated Wool Fibber Surface”, Textile Research Journal, vol.77, no.12, pp.914, 2007.

[6] Mohammadi M., Lee-Banks., “Determining Effective Thermal Conductivity of Multilayered Nonwovens Fabrics”, Textile Research Journal, vol.73, no.9, pp.802, 2003.

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