Factors Affecting Thermal Comfort of Nonwoven

Hemant Ladgaonkar and S.B.Mhetre

Abstract-Nonwoven are widely used for protective clothing in the field of defense, medical etc. These are the areas where protection and comfort to wearer while performing are very important. Comfortability helps to maintain a such suitable mind condition for concentration. Total comfort is sum of thermal comfort, moisture vapor transport and aesthetic comfort. Among them thermal comfort is most important.

Keywords: Nonwoven, Thermal Comfort, Heat transfer.

1. INTRODUCTION:

Tiwari M. [1] stated that clothing system must be able to control inward and outward flow of heat to maintain body temperature to avoid serious hazard to body. Slater K. [2] summarized that heat transfer between human and surrounding environment together with the movement of moisture constitutes the major thermal comfort-maintaining mechanism. The resistance offered by fabric to the movement of heat through it is important to maintain its thermal comfort. Slater K. [2] stated that the total thermal resistance to transfer of heat from the body to the surrounding has three effective components as 1) Resistance to heat transfer from the material surface to surrounding 2) Thermal resistance of clothing material itself 3) Thermal resistance of the air trapped inside the fabric. Nonwoven has large number of air voids entrapped inside the fabric structure hence gives better barrier against heat flow.

Choi et al [3] concluded that nonwoven widely accepted as protective garment in medical and industrial areas due to enhanced and tailorable thermal and comfort properties.

2. THERMAL COMFORT:

Hardy et al [4] defined thermal comfort as "absence of any unpleasant sensations of being too cool/warm or too much perspiration on the skin ." Orosa J. [5] stated that thermal comfort is a mental condition and environment contributes a lot in it so it is difficult to measure.

Tiwari M. [1] commented that providing thermal comfort is one of the most important requirements for clothing system. Bhat P. [6] concluded that optimized thermal resistance of clothing is necessary to achieve thermal comfort.

- **Hemant Ladgaonkar is currently pursuing Masters degree program in Technical Textiles at DKTE Society's Textile &Engineering Institute ,Ichalkaranji, Maharashtra, India, PH-+919595953048* E-mail-hemant.ladgaonkar@gmail.com
- *Prof.S.B.Mhetre is currently working as Assistant Professor at DKTE Society's Textile &Engineering Institute, Ichalkaranji, Maharashtra, India, PH-+919822865422, E-mail-sbmhetredkte@gmail.com*

Heat transfer occurs through three modes viz. Conduction, Convection and Radiation. Farnworth B [7] commented that conduction occurs through air and through material itself but heat transfer by conduction is too small to measure. Martin et al [8] 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.

2.1 Factor affecting heat transfer by conduction and convection through Nonwoven:

Mao et al [9] stated that textile fabric is a heterogeneous system of air and fibers, so conduction through air and fibers contributes to total thermal conduction. Li et al [10] concluded that when the surface of fabric comes in contact with skin then a large exchange of heat takes place.

Slater K. [2] summarized that for a 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 [9] 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.

Jirsak et al [11] concluded that in nonwoven well anchoring of fibers is important so that they should not penetrate out through fabric surface ; if happens so the conductivity of fabric increases due to increased conduction caused by their increased contact with heat. Morris G. [12] concluded that if fabric density increases thermal conductivity increases also it's concluded that for constant thickness of fabric , below density of 60kg/m3,the heat transfer by convection is dominant which results reduction in thermal insulation also its stated that increase in fabric weight increases compactness so heat flux increases due to increase in conduction because with increase in fabric weight percentage compression TIV value and air permeability decreases (due to increase in fibers/area), also it is reported that increase in fabric thickness causes increased thermal insulation and reduction in fabric temperature variations (up to a optimum level) , as fabric density increases thermal conductivity and thermal resistance increases.

Debnath et al [13] concluded that poor fiber consolidatation of fabric gives more thickness. Le et al [14] concluded that the absorption capacity of the fiber has large influence on the nature of the heat transfer through the system. Mohammadi et al [15] 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. Barker et al [16] concluded that for nonwoven as number of layers increases due to randomly oriented fibers the probability of pores to be connected get reduced so it increases tortuosity and reduces convective heat flow.

Caps et al [17] concluded that wind speed affects thermal insulation of nonwoven because it causes forced convection of heat through trapped air also it is stated that if heat flow is parallel to fiber orientation then conductivity increases. Behra B. [18] stated that increase in moisture regain of material causes increase in thermal conductivity due to conduction or convection through moisture vapor molecules .Paul et al [19] concluded that effective thermal conductivity decreases with decrease in Gas–fill pressure and elimination of bonding material while making multilayered fabrics reduces heat transfer through fabric.

2.2 Factor affecting heat transfer by radiation mechanism through Nonwoven:

Farnworth B. [7] concluded that the effect of radiative heat is significant and the reflection by fiber surface causes surprising increase in thermal resistance of material. Mao et al [9] concluded that the increase in bulk density causes drastic reduction in radiative heat transfer and if fiber orientation and heat flux flow are parallel then radiative heat component increases because of less reflection of incident radiations .Also they concluded that finer fiber diameter increases the insulation as it provides large absorption surface area for radiation.

Martine et al [8] concluded that fibers with reflective coating or fabric compression, reduces conductivity of nonwoven. Jirsak et al [20] concluded that finer fibers gives more packing fraction hence provides better insulation from radiations. Fibers prevent radiant heat transfer and avoid air movement but these tasks are performed only till the heat conducted by them becomes dominant. Hosseini et al [21] concluded that blending of fiber types causes reduction in fabric heat transfer and if fibers' expected percentage elongation is more then they form denser fabric which reduces radiation component of heat. Caps et al [17] commented that during diffusion of radiative heat from high temperature side to cooler side of insulating material, radiation flow is affected by length of mean free distance to be travelled by photon and they also stated that smoother fabric surface reduces radiative component of heat transmission because of more scattering of incident radiations.

Sun et al [22] concluded that for radiant heat protection fabric structure, weight, thickness ,material used are the important factors and fabric comfort is dependent on fabric's transport property which is combination of air permeability, thermal resistance and moisture vapor transmission which are governed by fabric structure itself also it is observed that laundering cycles increases fabric thickness by fuzzier effect so increases radiant heat protection performance and color doesn't affect radiation protection performance (excluding black and white). Stuart et al [23] concluded that the passage of heat causing infrared radiations through a fiber bed is affected by shadowing of fibers in the path of radiations by absorption and scattering.

2.3 Environmental factors affecting Heat Transfer through Nonwoven:

Tiwari M. [1] stated that thermal comfort depends on air temperature (temperature of surrounding), radiant temperature (heat flow from/ to body to /from the environment due to temperature difference between them) and air/wind velocity that causes forced convection of heat through trapped air in clothing system. Caps et al [17] stated that for wider temperature range high thermal insulation values are useful.

2.4 Material dependence of Thermal Comfort:

Abdel-Rehim Z. [12] concluded that fiber with higher melting point gives better insulating nonwoven. Mohammadi et al [15] and Yokura et al [24] concluded that fiber's inherent thermal conductivity plays an important role in defining thermal conductivity of nonwoven apart from the structural aspects of that nonwoven. Yasuda T. [25] concluded that decrease in materials vapor transport rate , temperature rise between two consequent layers decreases (as water vapor transport causes liberation of heat of absorption) also it's observed that increase in water vapor absorption capacity of material increases temperature of air-space between the layers. Li et al [10] concluded that temperature prior to skin increases with increase in hygroscopicity of material.

ACKNOWLEDGMENT

The Author wish to thank The Center of Excellence in Nonwoven and Dept. of Textiles, DKTE Society's Textile & Engineering Institute, Ichalkaranji, Maharashtra, India for providing the valuable resources for this review article.

REFERENCES:

[1] Tiwari,M., "Thermal Comfort of Textile Materials and Its Assessment" ,Textile Review, Sept .2010.

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

[3] Tanabe, Shin-ichi,Choi,J., "Thermal Comfort Aspects of Pesticide Protective Clothing Made with Nonwoven Fabrics", Journal of Korean Home Economics Association English Edition,),vol.3,no.1,pp.55,Dec.2002.

[4] Hardy, H.B., Ballou, Jr. J.W. , Wetmore, O.C., "The Prediction of Equilibrium Thermal Comfort from Physical Data on Fabric", Textile Research Journal,vol.23,pp.1, 1953.

[5] Orosa,J.A., "Research on General Thermal Comfort Models, European Journal of Scientific Research,vol.27,no.2,pp.217,2009.

[6] Bhat,P., Bhode,H.U., Comfortable Clothing for Defense Personnel, Asian Textile Journal,pp.73,Nov.2006.

[7] Farnworth,B., "Mechanism of Heat Flow Through Clothing Insulation", Textile Research Journal,pp.717,Dec. 1983.

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

[9] 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.

[10] Li,Y., Plante,M., Holcombe,B.V., "Fiber Hygroscopicity and Perceptions of Dampness Part-II: Physical Mechanisms", Textile Research Journal,pp.316,June 1995.

[11] Jirsak,O., Lubos Hes,I., "Thermal Insulation Properties of Nonwoven Fabrics as a Function of Their Compression", Melliand English,vol.5,pp.E172,1988.

[12] Abdel-Rehim,Z.S., Saad,M.M., El-Shakankery, M.,Hanafy,I., "Textile Fabrics as Thermal Insulators", AUTEX Research Journal,vol.6,no.3,pp.148,Sept .2006.

[13] Debnath,S., Madhusoothanan,M., "Thermal Insulation ,Compression and Air permeability of Polyester Needle Punched Nonwoven", Indian Journal Of Fiber& Textile Research,vol.35,pp.38,March 2010.

[14] Le,C.V., Tester,D.H., Buckenham,P., Postle,R., "Heat and Moisture Transfer in Textile Assemblies Part –II Steaming of Blended and Interleaved Fabric- Wrapper Assemblies", Textile Research Journal,vol.65,no.5,pp.265,1995.

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

[16] Barker,R.L., Guerth-Schacher,C., Grimes,R.V., Hamouda,H., "Effect of Moisture on the Thermal Protective Performance of Firefighter Protective Clothing in Low-level Radiant Heat Exposures", Textile Research Journal,vol.76,pp.27,2006.

[17] Caps,R., Umbach K., "Optimizing Polyester Nonwoven Fabric Thermal Insulation", Melliand English, pp.E201,Jun.1990.

[18] Behera,B.K., Arora,H., Surgical Gown :A Critical Review, Journal Of Industrial Textiles, vol. vol.38no.3,pp. 205-231,Jan.2009.

[19] Paul, H.L., Diller, K.R., "Comparison of Thermal Insulation Performance of Fibrous Materials for the Advanced Space Suit", Journal of Biomechanical Engineering, vol.125, pp. 639, Oct.2003.

[20] Jirsak,O., Sadikoglu,T.G., Ozipek,B., Pan,N., "Thermo-Insulating Propertie of Perpendicular-Laid Versus Cross-Laid Lofty Nonwoven Fabrics", Textile Research Journal,vol.70,no. 2,pp. 121,2000.

[21] Hosseini Varkiyani, S.M.,Rahimazadeh, H.,Bafekrapoor, H., Jeddi,A.A.A., "Influence of Punch Density and Fiber Blends on Thermal Conductivity of Nonwoven", The Open Textile Journal,vol.4,pp.1,2011.

[22] Sun,G., Yoo,H.S., Zhang,X.S., Pan,N., "Radiant Protective and Transport Properties of Fabrics Used by Wild land Firefighters", Textile Research Journal,vol.70,pp. 567,July 2000.

[23] Stuart,I.M., Holcombe,B.V., "Heat Transfer Through Fiber Beds by Radiation with Shading and Conduction", Textile Research Journal,vol.2,no. 3,pp. 153,Sept.2002.

[24] Hiroko,Y., Masae,N. ,Masako,N., "Evaluation of Thermal Transport Properties of Pillows", Journal of Textile Engg.,vol.51,no.3/4,2005.

[25] Yasuda,T., Miyama,M., Muramoto,A., Yasuda,H., "Dynamic Water Vapor and Heat Transport Through Layered Fabrics", Textile Research Journal,vol.64,no,8,pp. 457,Aug 1994.