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Design of a thermal waist-pad

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Abstract. The objective of the current study is designing a thermal waist-pad for people who have backaches with a sandwich-like multi-layered structure. Two model is developed; one is three-layered and second is five-layered with waterproof woven outer layer fabric, Thermolite® knitted fabric (for five-layered structures), wool knitted, polyester nonwoven fabric, polypropylene nonwoven fabric and viscose nonwoven fabric for mid-layer. 10 different structures are designed and produced. All samples are tested for thermal comfort properties of waist-pad. Multi-layer structures were tested, and according to their thermal performance and thermal comfort criteria, all results are evaluated for identifying the best product. These three factors are examined by analysis of thermal conductivity, thermal resistance, thermal absorptivity, relative water vapour/air permeability, water absorption. Highest thermal resistance test result, 150,42 mK/Wm^2, is achieved in five-layered sandwich structure with waterproof fabric, Thermolite® fabric, wool based knitted fabric, Thermolite® fabric and waterproof fabric, respectively. Thermal conductivity result of this structure is 46,2 mW/mK, which is one of the lowest results among the alternative structures. Structures with Thermolite® fabric show higher thermal comfort when compared to others.

1. Introduction

It is generally agreed that textile industry has an endless development period with respect to changing customer needs, which depend on not only related with fashionable products but also depend on the technical textiles. On the basis of customer health issues, thermal waistpads are an excellent cure for people who had a backache. With the presence of waistpad, temperature is increased on the aching area locally in order to decrease the pain. Conventional thermal waistpads in the market are mainly composed of neoprene based fabrics with knitted structure, that might not adequate in terms of thermal comfort. Thermal comfort is one of the most important parameters of thermal waistpads. Thermal comfort is examined under thermo-physiological comfort, that is related with heat transfer, air and moisture [1-4].

In this study, a sandwich-like multilayer structure waistpad is aimed to design in terms of improved thermal and comfort properties. It is a known fact that, there is a direct proportion between warm retention and fabric layers. If the fabric is composed of many inner layers, warm retention capability is increased [5]. Heat exchange between multilayer fabric and human skin occurs to resulting from changing climate conditions. The most significant factor effecting multilayer fabric construction is comfort property. Thermal comfort of human body is directly affected from the thickness of the multilayer fabric. If the thickness of the fabric is increased, fabric thermal resistance increases [5].

For the objective of obtaining a multilayer thermal waistpad, fabrics with three different constructions, namely knitted, woven and non-woven, are used and various multi-layered structures are produced. For achieving better thermal insulation in multi-layered structures, it is necessary to use

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nonwoven layers which provide a required thickness for thermal insulation with its fluffy structure in both hot and cold environments [6-8]. This structure also allows transmission of air and water vapour with pores, which means air permeability of nonwovens is effected by thickness of the mat [9]. Thermal conductivity of nonwoven is related with fiber volume fraction, orientation and single fiber thermal conductivity capacity [10]. Besides, thermal comfort properties, nonwoven are widely used due to fast production, low cost, versatility, etc.

2. Materials and method

2.1. Materials

In this study, there are several types of fabrics in different constructions and compositions are used. When they are sorted according to construction; it can be said that woven, knitted and nonwoven fabrics are selected for study. Woven fabric is preferred as a waterproof woven fabric in plain 1/1 design, it is a polyester based and membrane coated fabric which avoiding permeability of water. There are two types of knitted fabrics. First one is single jersey fabric that is knitted with Thermolite Ne 30/1 yarn. Thermolite fabric is made of a special structured fiber; hollow polyester fiber [11]. Air in this hollow structure provides a thermal insulation which makes this fiber proper for cold climates. Moreover, hollow fibers have larger surface area than conventional others, so transportation of evaporation is faster while perspiration [12]. Because of hollows in fibers, Thermolite fabric is lightweight. Durability and softness are another most common properties of these fabrics. Thermolite fabrics also provides good wear comfort for user. It is commonly used as a base layer of sportswears such as skiing clothes, trekking socks, leggings, etc. [13]. Second one is wool on both sides of which raising finishing is applied. Thermal characteristics of wool is the most appropriate among natural fibers in cold climates, and specific weight of wool is lower than those of other natural fibers [14]. There are three nonwoven fabrics which are composed of polypropylene, polyester and viscose. Non-absorbency of polypropylene fibers creates an advantage to transport moisture from body to environment, that is necessary for removing perspiration and evaporation of human body. Moisture absorption capability of viscose is high because of low crystallinity, that is increasing the transportation of moisture from human body to ambient.

2.2. Method

Two different models are designed with abovementioned fabrics. First one is three-layered structure; waterproof fabric, one of polyester based, viscose based, polypropylene based nonwoven fabrics or wool based knitted fabric, and waterproof fabric, respectively. Modelling of first one is shown in Figure 1.

Figure 1. Model I

Second model is five-layered structure; and it starts with waterproof fabric like first model, then a Thermolite® fabric, one of polyester based, viscose based, polypropylene based nonwoven fabrics or wool based knitted fabric, Thermolite® fabric and waterproof fabric, respectively. Modelling of second one is shown in Figure 2.

Figure 2. Model II

List of three-layered and five-layered thermal waist-pad structures can be seen from Table 1.

Table 1. Waist-pad structures

Sample Code	Order of fabrics
S1	Waterproof fabric – Thermolite® fabric – polyester based nonwoven – Thermolite® fabric – waterproof fabric
S2	Waterproof fabric – Thermolite® fabric – polyester based nonwoven x 2 – Thermolite® fabric – waterproof fabric
S3	Waterproof fabric – Thermolite® fabric – polypropylene based nonwoven – Thermolite® fabric – waterproof fabric
S4	Waterproof fabric – Thermolite® fabric – viscose based nonwoven – Thermolite® fabric – waterproof fabric
S5	Waterproof fabric – Thermolite® fabric – wool based knitted – Thermolite® fabric – waterproof fabric
S6	Waterproof fabric – polyester based nonwoven – waterproof fabric
S7	Waterproof fabric – polyester based nonwoven x 2 – waterproof fabric
S8	Waterproof fabric – polypropylene based nonwoven – waterproof fabric
S9	Waterproof fabric – viscose based nonwoven – waterproof fabric
S10	Waterproof fabric – wool based knitted – waterproof fabric

Multi-layer structures were tested, and according to their thermal performance and thermal comfort criteria all results were evaluated for identifying the best product. These three factors are examined by analysis of thermal conductivity, thermal resistance, thermal absorptivity, relative water vapour/air permeability, water absorption. In this study, thermal comfort properties of waist pads are determined and evaluated according to these parameters.

Water vapour permeability is tested according to BS 7209:1990 standard. Water permeability is tested according to EN ISO 20811:1996 standard. Air permeability is tested according to EN ISO 7231 standard. For thermal conductivity resistance measurements ISO EN 31092 standard is used and measurements are performed with Alembeta®. Permetest® instrument is used for measuring water vapour resistance according to ISO 11092 standard.

3. Results and discussion

Water vapour permeability of waist-pad which is aimed to design in this study should have high water vapour permeability for obtaining thermal comfort with respect to good comfort properties. According to water vapour permeability test results, structures with wool knitted fabric in the middle shows superior effect and gives the highest water vapour permeability values in both three-layered and five-layered sandwich structures.

Water permeability test is applied only on waterproof outer layer fabric and it is found that fabric does not permit water. Air permeability test is applied to all fabrics and it is resulted as all fabrics used in this study is air permeable.

With Alambeta® instrument, all thermal properties of sandwich structures are performed. First of all, thermal conductivity resistance of the samples is measured, that gives thermal resistance, thermal absorption, thermal diffusion and thermal conductivity results of samples. Thermal conductivity results are expected to have higher values for better thermal comfort. Best thermal resistance results of samples in ascending order are S5 (150,42 mK/W.m^2), S2 (142,6 mK/W.m^2) and S10 (121,06 mK/W.m^2) respectively, which is seen from Figure 3. The results show that wool fabric used in the middle layer of sandwich structure improves thermal resistance of waist-pad. Also, using double layers of polyester nonwoven fabric in waist-pad results better than one layer of polyester nonwoven fabric as expected.

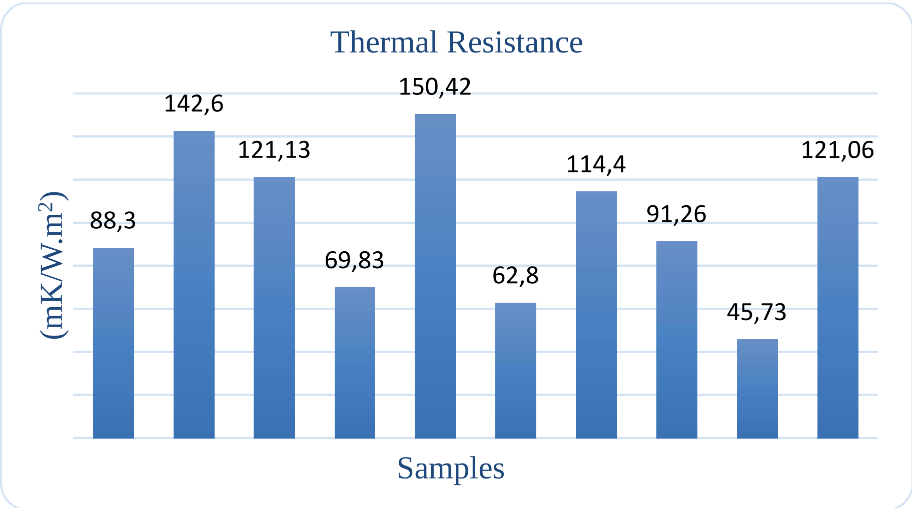

Figure 3. Thermal resistance test results

Thermal conductivity results of samples are shown in Figure 4. It is a known fact that for better thermal comfort, thermal conductivity should be as low as possible. In S3 (57,13 mW/m.K) and S8 (58,86 mW/m.K) resulted in highest numbers, that shows polypropylene nonwoven in the middle of the waist-pad cause worse thermal comfort in terms of thermal conductivity. S2 (44,93 mW/m.K) has the lowest value among those including Thermolite® layer, followed by S5 (46,2 mW/m.K). Moreover, S6 (41,6 mW/m.K) has the lowest value among those not including Thermolite® layer, followed by S7 (42,16 mW/m.K).

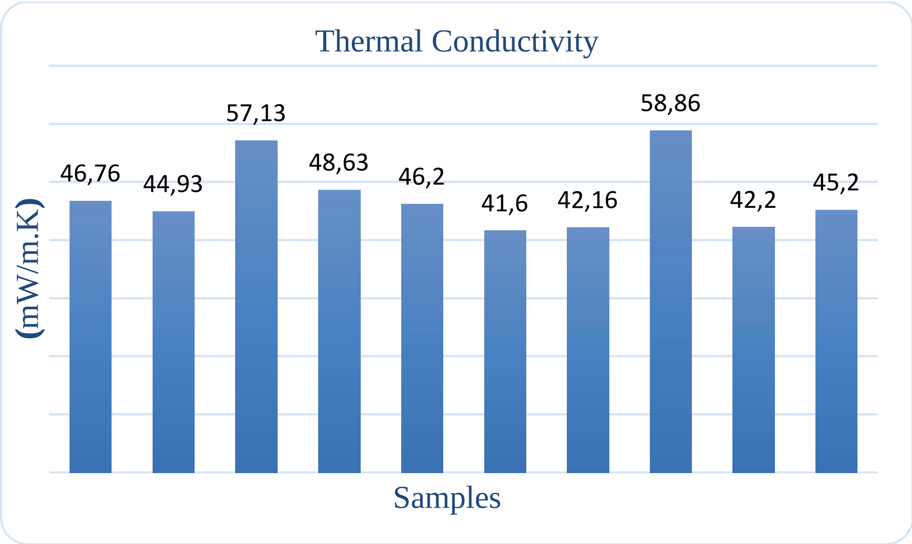

Figure 4. Thermal conductivity test results

Thermal diffusion of samples is shown in Figure 5. The highest thermal diffusion values are gained from S5 (0,162 mm^2s^{-1}) and S10 (0,15 mm^2s^{-1}) which have a common mid-layer, wool.

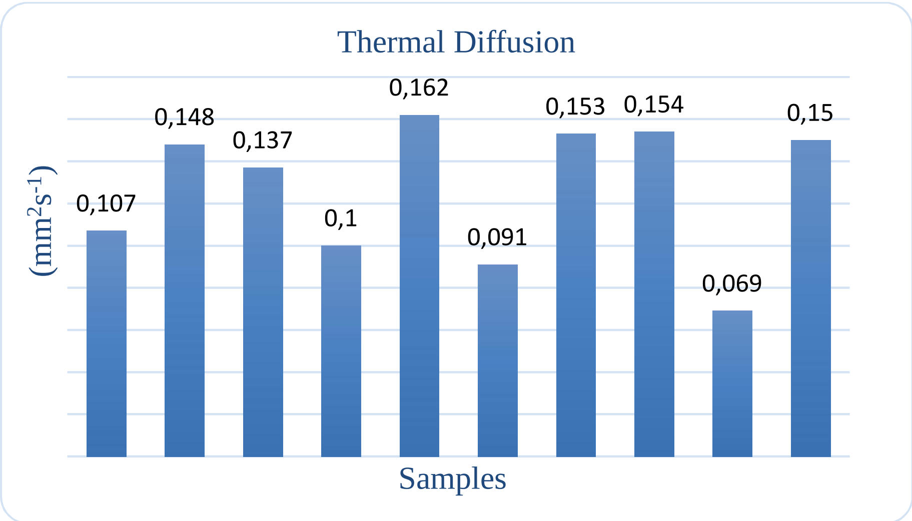

Figure 5. Thermal diffusion test results

With Permetest® instrument, water vapour resistance and water vapour permeability of samples are examined. Absolute water vapour permeability results are shown in Figure 6. First five samples (five-layered) with Thermolite® layer give higher water vapour permeability results when compared with three-layered samples. It can be said that Thermolite® layer between structure improves the water vapour permeability with hollow fiber structure of fabric.

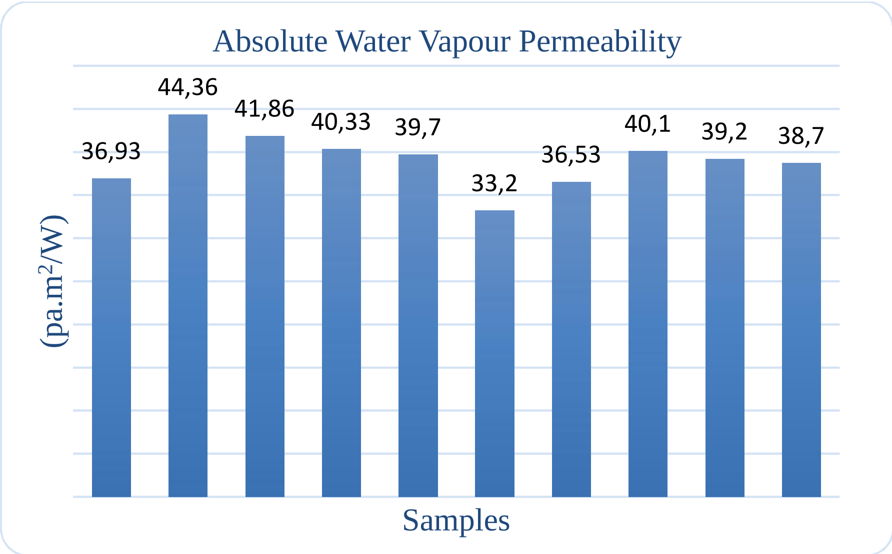

Figure 6. Absolute water vapour permeability test results

All experimental data indicates that using Thermolite® layer in waist-pad improves the thermal comfort properties of samples. While deciding the best option, it is found that wool fabric in mid-layer enhance thermal properties of waist-pad. Best structure can be seen from Figure 7. Thermolite® with the wool used provides better comfort properties. Wool knitted fabric provides flexibility for ease of movement. Thermolite® fabric used provides conservation of heat in between outer layers.

Figure 7. Five layered sandwich structure with highest thermal comfort (S5)

4. Conclusion

In this study, a thermal waist-pad is designed and produced. For this objective, it is decided to design a sandwich-like structure with different layers for improving thermal comfort properties of waist-pad. Water-proof outer layer fabric, Thermolite® fabric, wool fabric, polyester, polypropylene and viscose nonwoven fabrics are selected and 10 different sandwich-like structures are achieved; in which three-layered and five-layered structures are used. Samples are tested according to thermal performance and thermal comfort to identify the best option. Highest thermal resistance test result, 150,42 mK/Wm2, is achieved in five-layered sandwich structure with waterproof fabric, Thermolite® fabric, wool based knitted fabric, Thermolite® fabric and waterproof fabric, respectively. Thermal conductivity result of this structure is 46,2 mW/mK, which is one of the lowest results among the alternative structures. Structures with Thermolite® fabric show higher thermal comfort when compared to other samples without Thermolite® layer.

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