The Influence of Pile Weft Knitted Structures On The Functional Properties Of Winter Outerwear Fabrics

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Abstract: This study focuses on the selection of the most adequate structures to be used to represent typical winter outerwear, two groups of weft-knitted structures, fleece and plush knits, were selected. An experimental work is presented to determine the effects of different knit structures on; bursting strength, air permeability, absorption and thermal insulation properties of knitted fabrics. From the analyses of variance, it is seen that the effects of pile knit structure on the functional properties of knitted fabrics are highly significant. These findings are an important tool in the design of typical winter outerwear fabrics.
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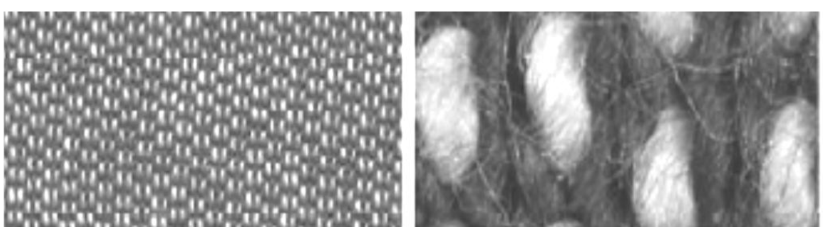
Keywords: Fleece structure, Plush fabrics; French terry; Pile knit structure; Thermal insulation.

1. Introduction

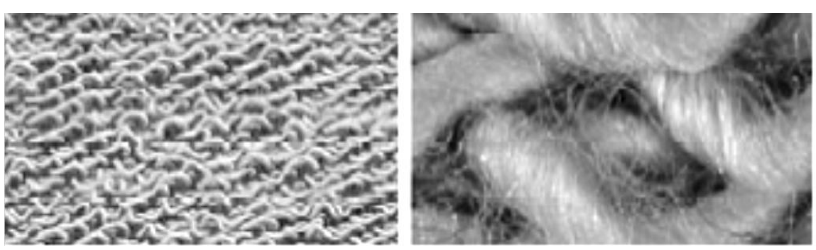
Over the last few years, there has been growing interest in knitted fabrics due to its simple production technique, low cost, easily transmit vapor from the body, high levels of clothing comfort and wide product range which meets the rapidly-changing demands of fashion and usage. Knitting has long been recognized as a leading method of forming fabrics for various end uses, they are commonly preferred for sportswear, casual wear and underwear (Eckert and Stacey, 2003). Specialty knitted fabrics include fleecy, plush and high pile fabrics. Although some constructions are unique to a single type of circular machine, others may be knitted on a range of machinery. The surface effects of fleecy, plush or pile are developed during the finishing process usually on the technical back of single faced fabric (Spencer, 2001).

Fleece is a jersey fabric having weft yarn (fleece yarns) floating at the back side. A visible fleece row fabric is composed of; a ground yarn knitting plain jersey structure that visible at the fabric front side and a fleece yarn knitting tucks and floats that visible at the fabric back side. Fleece yarn is characterized by its low number and low tenacity (Open end or carded yarn) allowing scraping the fabric back side. It increases the thickness of the fabric and its thermal insulation. The term visible is due to the fact that fleece is slightly visible at the fabric front side because of the tuck. The fabric is generally used for sweatshirts and tracksuits (Ray, 2012).

As shown in Figure (1), the technical face of the fabric shown is basically jersey. The technical back containing the un-napped float, this fabric is referred to as French terry.



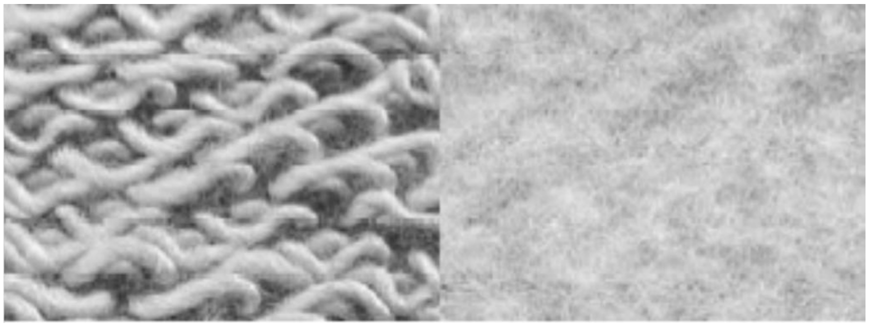
Technical Face



Technical Back

Figure 1. 2 End- Fleece (French Terry)

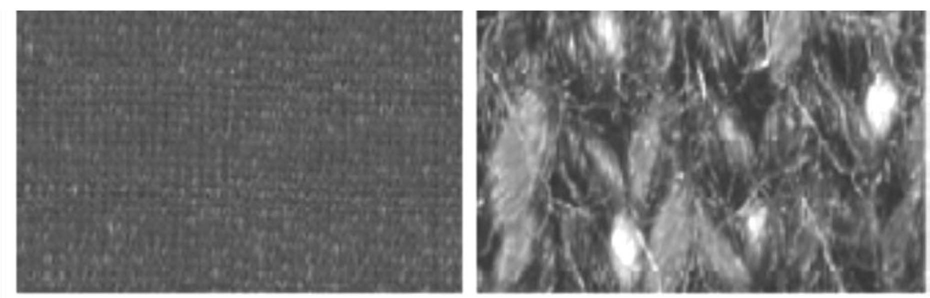
As shown in Figure (2), the yarns to be napped in this fleece fabric are readily available for the napper wire to pull fibers up from the fabric surface and produce the fleecy surface seen on the right. After napping that the float yarns cannot be seen, only the uniform napped surface is apparent (Mayer and Cie, 2007).



Un- napped Napped

Figure 2. 2 End- Fleece Nap Comparison

Invisible fleece fabrics, the term "invisible" is associated to the fact that fleece yarn is invisible at the fabric front side because each row is composed of three yarns ; fleece yarn, binding yarn which links fleece yarn to ground yarn and ground yarn. As shown in Figure (3), the 3-end fleece is thicker and heavier than those previously discussed. Three-end fleece makes the most stable fleece. This fabric cannot be made on a regular jersey machine but needs a special machine for knitting (Ozcan and Candan, 2005).



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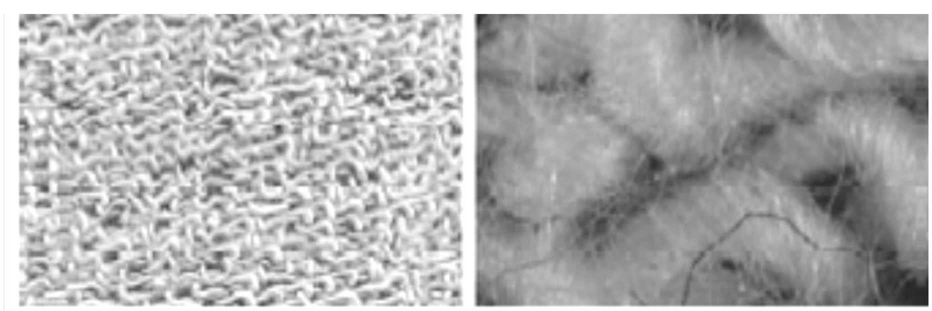
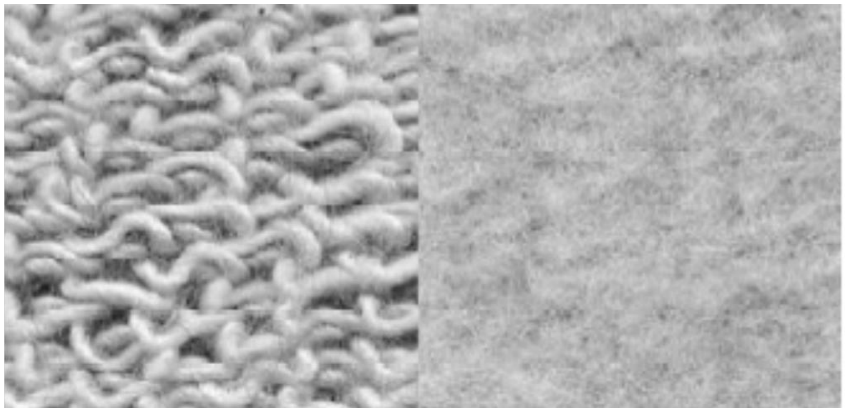


Technical Back

Figure 3. 3 End- Fleece – Not Napped

As shown in Figure (4), the napped surface of this 3-end fleece fabric is slightly fuller when compared to the 2-end fleece. This fabric is a more expensive fleece due to the added yarn and the need for a more specialized machine (Lawler and Wilson, 2002).

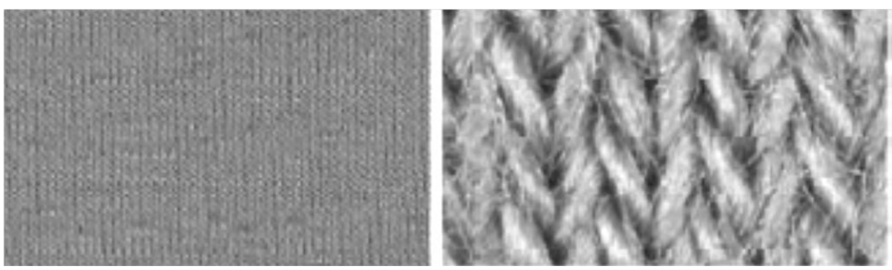


Un- napped Napped

Figure 4. 3 End- Fleece Nap Comparison

Plush fabrics or terry fabrics are obtained by knitting two yarns at the same feeder; a ground yarn knitting plain jersey structure that visible at the fabric front side and a plush yarn knitting plain jersey forming plush loop that visible at the fabric back side In pile and plush structures the pile and plush is clearly distinguishable from the base. Pile is considered to stand out at right-angles to the base, whereas plush lies at less of an angle from the base surface (Anon., 1996).

As shown in Figure (5), Terry velour fabric can also be knitted on a single knit machine. The face of the fabric is jersey and the terry loops of yarn appear on the technical back of the unfinished fabric. Therefore the fabric is turned inside out for finishing. During finishing, the tops of the loops are sheared, converting a knit terry into a terry velour. This produces a soft plush surface on the fabric (Schäch, 1989).



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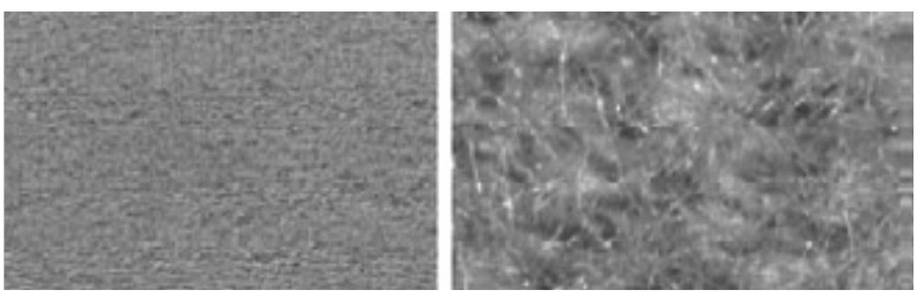


Technical Back

Figure 5. Terry Velour Fabrics

The loops of the terry are formed with the assistance of the sinkers as illustrated in Figure (6). The top row of vertical lines represent sinkers, not needles. The sinkers are specially designed for knitting terry. One part of the sinker holds the fabric in place while another slot of the sinker allows the yarns to loop over it to form the terry loops. Sinkers can be designed so that different heights of terry loops can be formed, leading to different pile heights in the velour (http://www.academia.edu/Weft_Knitting).

Figure 6. Terry Velour Needle Diagram

Polyester fleece or plush is a remarkably comfortable and adaptable fabric, and will doubtless find many new uses. Polyester fleece is a soft, fuzzy fabric used for sweaters, sweat shirts, jackets, mittens, hats, blankets, and in any other applications where a warm, wool-like material is needed. It is a two-sided pile material, meaning that both the front and back surface of the fabric sprouts a layer of cut fibers, similar to corduroy or velvet. Polyester fleece or plush is an extremely durable fabric that not only holds in warmth but resists moisture and dries quickly. Polyester fleece is extremely warm because of its structure. The pile surface provides space for air pockets between the yarns, and this goes for both sides of the fabric. Because it is moisture-resistant, it can keep wearers warm even under extreme weather conditions (http://www.madehow.com).

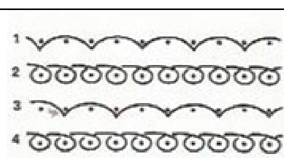
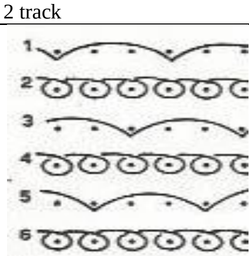
To achieve the particular fuzzy texture of fleece or plush, the knitted material is next fed through a napper. The napper runs mechanical bristles along the cloth, raising the surface of the textile. Next, the cloth is sent to a shearing machine, which uses a precision blade to cut the fibers raised by the action of the napper. This same process is used to make velvet, corduroy, and other textured pile fabrics. The fabric may next be sprayed with a waterproof material, or with some other chemical finisher that sets the texture of the material. The material is next cut into lengths, according to the customer's needs. The lengths of cloth are wrapped around boards or cardboard planks. These wound lengths are called bolts. At this point, the bolts are ready to be sent to the garment manufacturer. The manufacturer will cut the fabric according to a pattern, and sew the cloth into a garment (Rotenier and Nancy, 1993).

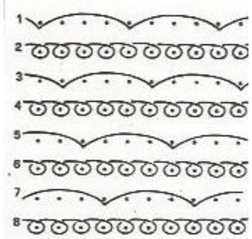
The aim of this research is investigation of mechanical behavior of different knitted fabrics in both kinds of fleece and plush with various constructions to find suitable fabric with super high functional properties which could be applicable in representing typical winter outerwear.

2. Material and Methods

Regarding to theoretical modeling, it is assumed that various fabric structures demonstrate different mechanical and functional properties. This matter is base of sample preparation and plan of experiments. The fleece knitted fabrics were knitted in one circular knitting machine with diameter 30 " and gauge 20 (needles/inch). Table (1) shows the specifications of produced fleece knitted fabrics.

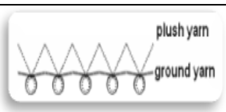
Table 1. The Specifications Of Produced Fleece Knitted Fabrics

Sample No.	Fabric Structure	Fabric Composition	Yarn Count Nec	Courses/inch	Wales/ inch	Stitches Density Stitches /inch^2	Fabric Weight gm/m2	Fabric Thickness mm
1	 Fleece 1-1 visible 2 track	80% polyester +20% cotton	30/1+20/1	40	25	1000	207	0.8
2	 Fleece 2-1 visible 3 track			45	28	1260	226	1.01

3	 Fleece 3-1 visible 3 Tracks			49	31	1519	242	1.2

The plush knitted fabrics were knitted in one circular knitting machine with diameter 30 " and gauge of 20 (needles/inch) using different pile sinker height. Table (2) shows the specifications of produced plush knitted fabrics.

Table 2. The Specifications Of Produced Plush Knitted Fabrics

Sample No.	Fabric Structure	Fabric Composition	Yarn Count Denier	Courses/ inch	Wales/ inch	Stitches Density Stitches / inch^2	Raw Fabric Weight Gm/m2	Fabric Thickness mm	Pile Sinker Height mm
1	 **Terry Velour** " Plush	100% polyester	150/1+ 150/1	50	28	1400	275	1.81	2
2				53	30	1590	293	1.92	2.5
3				57	33	1881	314	2.15	3

To investigate the effect of fabric structure on its functional behavior, different tests were done including:.

1. Thickness test, this test was carried out according to the ASTM D1777- 96(2011) e1.
2. Weight test, this test was carried out according to the ASTM D3776 / D3776M - 09a.
3. Water Vapor Transmission test, this test was carried out according to the ASTM E96 / E96M – 14.
4. Air Permeability test, this test was carried out according to the ASTM D737 - 04(2012).
5. Thermal Transmittance test, this test was carried out according to the ASTM D:1518- 11a.
6. Bursting Strength test, this test was carried out according to the ASTM D3786 / D3786M – 13.

3. Results and Discussions

3.1. Water Vapor Permeability (%)

Water vapor permeability of a clothing fabric is its ability to transmit vapor from the body. If the moisture resistance is too high to transmit heat by the transport of mass and at the same time the thermal resistance of the textile layers considered by us is high, the stored heat in the body cannot be dissipated and causes an uncomfortable sensation (Guanxiong et al., 1991).

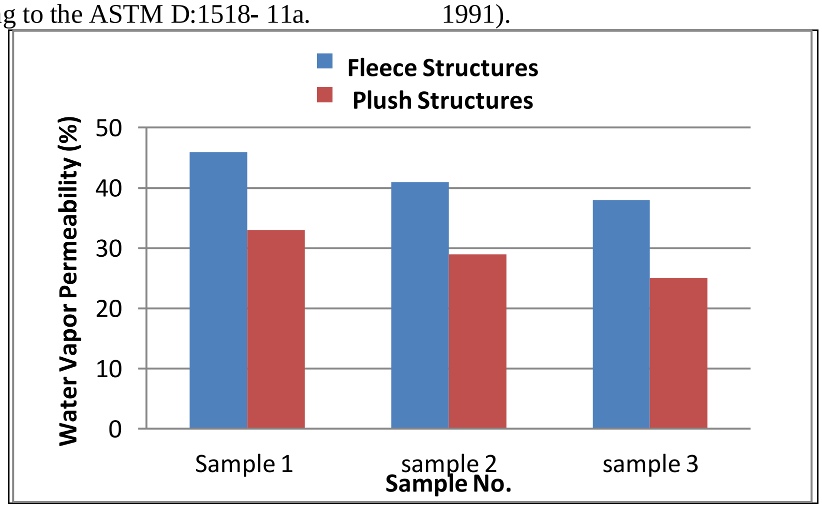


Figure 7. Water Vapor Permeability (%) For Produced Samples

As illustrated in Figure (7), fleece fabrics have higher water vapor permeability than plush fabrics. This is mainly due to the hygroscopic character of fleece fabric which has higher vapor diffusivity. Moreover, the cross-sectional shape of pile fibers in plush structures increases the resistance to vapor flow through the fiber surface, which reduces water vapor permeability. The higher water vapor permeability of fleece fabrics can be attributed to the lower values of fabric mass per square meter, stitches density and fabric thickness, which facilitate the easy passage of the water vapor through the fabrics. The water vapor transmission due to diffusion may also be higher for the blended fabrics (80% polyester-20% cotton) as the moisture regain of blended fiber is higher than that of pure polyester fabrics. Sample No.1 in both structures, presented the higher Water vapor permeability values.

3.2. Air Permeability ($cm^3/cm^2/s$)

As it can be observed in Figure (8), there is a significant influence of the fabric structure on air permeability values (cm3/cm2/s). Both for fleece and plush fabrics, the lower air permeability values were obtained with sample No.3, characterized by higher fabric density and thickness. Sample No.1 in both structures, presented the higher air permeability values.

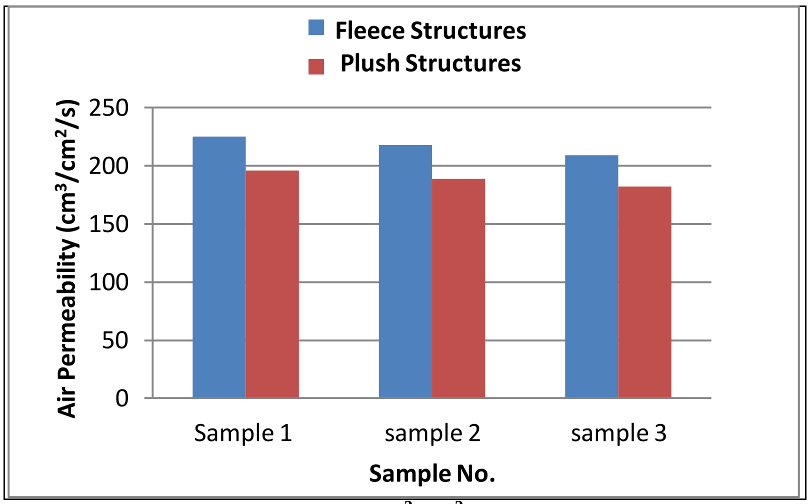


Figure 8. Air Permeability ($cm^3/cm^2/s$) For Produced Samples

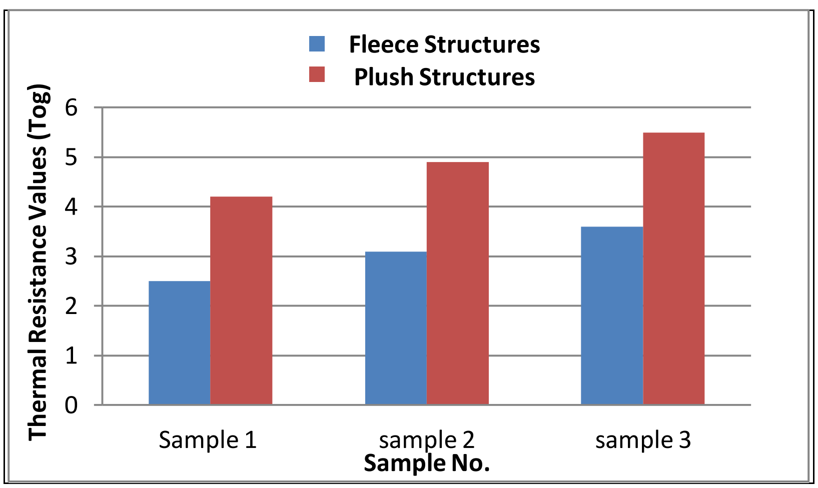


Figure 9. Thermal Resistance (Tog) For Produced Samples

In the fleece structure this behavior is mainly due to stitches density, lower thickness of fabrics and to fibers' geometry. While in the plush structures, due to their surface characteristic. The higher loop of the pile in plush structures increases the resistance to air flow, which results in lower air permeability.

3.3. Thermal Properties (Tog)

All plush fabrics have higher thermal conductivity than fleece fabrics, as shown in Figure (9). This behavior is in a great extent influenced by the yarn characteristics, but also by the fabric structure. Both for fleece and plush fabrics, Sample

No.1 has the lowest thermal conductivity and Sample No.3 the highest thermal conductivity. This is most probably due not only to thickness, but also to fiber conductivity (100% polyester for plush structures while 80% polyester & 20% cotton for fleece structures).

Yarn characteristics play a significant role on thermal absorptivity. Moreover, the results revealed that the surface characteristics of the fabric also have a great influence on the warm feeling. . The pile surface in plush structures provides space for air pockets between the yarns. Because it is moisture-resistant, it can keep wearers warm even under extreme weather conditions.

Bursting Strength (Kg.f/cm^2)

The bursting strength of knitted fabric is extremely important in many ways. The fabric should have sufficient strength against forces acting upon it during dying, finishing and use. Knit, tuck and miss loops can be combined to produce different designed knit fabrics (Ertugrul and Ucar, 2000).

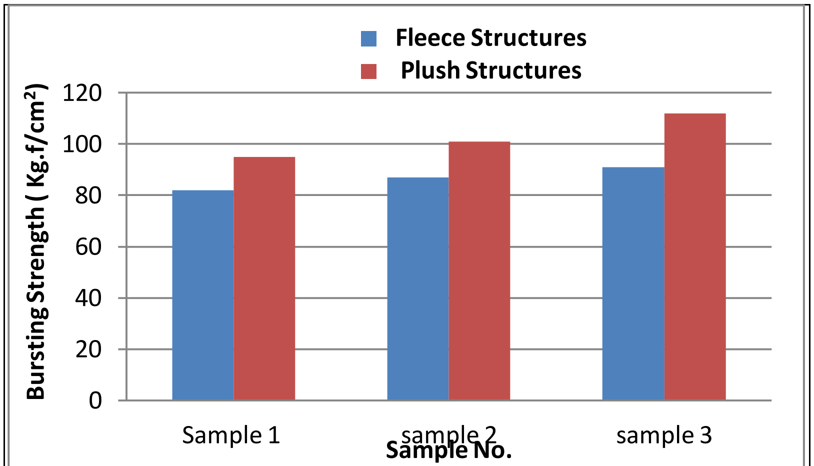


Figure 10. Bursting Strength (Kg.f/cm^2) For Produced Samples

As illustrated in Figure (10), The results for bursting strength revealed that the effect of knit structure is highly significant in produced fabrics. Fleece fabrics have weaker bursting strength performance compared with plush fabrics due to the tuck and miss loop in these structures. That higher tuck loop presence decreases the bursting strength; Miss loop also reduces the bursting strength but bursting strength of miss loop containing derivatives is higher than tuck loop containing derivatives. The structures with the higher thickness (Sample No.3) have the higher bursting strength properties for both fleece and plush fabrics. This is most probably due not only to thickness, but also to stitches density.

Conclusions

In this paper, the design of typical winter outerwear fabrics were discussed. All results indicate that, these fabrics are used to provide insulation / protection against loss of body temperature, according to the requirements imposed by climate / temperature conditions. The insulation capacity of winter outerwear fabrics depends on two factors;

1. The thermal resistance of garments (Tog), where the higher the Tog rating, the better the insulation. It has to be noted that the Tog does not depend only on the weight or the raw material, but also on the fiber quality, the type of knitting structure, and pile raising.

2. The air permeability of the material, where low air permeability will ensure protection from draughts, while inherent breathe ability allows evacuation of body perspiration. The structural characteristics of knitted fabrics, i.e. pile length, structure compactness and structure type, have an important influence on the air permeability of a knitted fabric.

It has been proven that different pile knitting structures have different functional and mechanical properties. Therefore, in order to achieve the ideal winter outerwear clothing, it is necessary to consider the end use of the garment while selecting the fabrics. According to the results plush structures, due to their high thermal insulation values and bursting strength properties, could be preferred for winter garments in order to protect from cold. On the other hand, fleece structures should be chosen for active outerwear clothing for better moisture management properties and air permeability. The previous findings are an important tool in the design of a typical winter outerwear product tailored to the different requirements.

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