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Running functional sport vest and short for e-textile applications

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Abstract. Sports garments with functional properties have become crucial as well as comfort properties since they improve the wearer performance. For this reason, sport vest and short having high elastic recovery with fall detection sensor, were designed and produced by using flat-bed knitting machine. Comfort properties of short and vest were tested with several test instruments and; tensile strength of elastomeric yarn, air permeability, moisture management, drape and objective handle (FAST tests) of garments were achieved. It was proved that short and vest samples have good comfort properties as a functional sport garment. It was also tested that fall-detection sensor can work efficiently by using a mobile phone application.

1. Introduction

There has been a great development in the field of sportswear for the last years. Engineered and well-designed functional sport garments should enable the body to move and not inhibite function/performance.. According to the type of sport and physical activity, functional requirement of sports garment can change. Performance of the player is directly affected by the comfort properties of the sportswear. In high active sportswear like jumping and running, stretch ability and elastic recovery must be supplied to the wearer for movement freedom. In this manner, ergonomic wear comfort becomes crucial for sport garments, especially on their fabric construction and elastomeric properties. In order to design a high active sportswear it is important to choose the suitable type of raw material and construction type of the fabric [1,2].

Polyester and polyamide are the fibres which are mostly utilized in sportswear for their easy care. In addition, elastane is extensively used in sportswear due to its high stretch and recovery properties. When fabric types are compared it can be said that using knitted structures are advantageous than the other structures since flexibility can be adjusted by changing the loop arrangement. Moreover, among the knitted structures it was proved that single jersey type have better wickability than the honeycomb and pique types [1, 3].

In the manufacturing process of sports garments seams are used but they can irritate the skin and prevent the continuous flow of garment surface. Therefore currently, ‘Seamless Garments’ are of great interest in the apparel market. Beyond the seamless technology, other functional performance of the sports garments have become an important issue. The term ‘wearable sensors’ come into prominence

in the sports field since they have both diagnostic and monitoring applications. Textile sensors can be created by addition of the conductive materials such as gold, copper, stainless steel and silver into the traditional textile structures. Among the conductive materials, it can be mentioned that silver has been selected as the mostly utilized one [4-6].

In the light of these information, this study deals with the production of running functional sport vest and short consisting fall detection sensor. Both tensile strength and elongation of the yarn and comfort properties of the produced fabric samples were investigated in detailed. Moreover, studies in order to acquire data from fall detection sensor have been also carried out.

2. Experimental

2.1. Materials

Highly elastic core-shell polyamide yarn obtained by air-mingle method was used. In the core, there is an elastomeric yarn with a yarn count of 150dtex and this core is covered by 3 ply polyamide 6.6 yarn which consists of 44 filaments with the number 13 dtex.

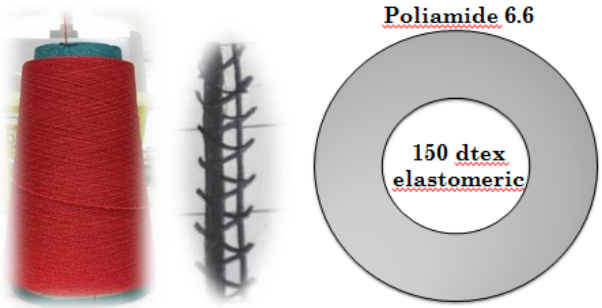


Figure 1. The yarn used to produce sport vest and short

Shima Seiki, 10 gauge flat-bed knitting machine was used in order to produce sport vest and short.

Figure 2. 10 gauge-flat bed knitting machine

Tensile tester was used for testing the strength and elongation of the yarn.Testing equipments to measure drape, air permeability, moisture management, compression, extension and bending r were used for testing the comfort properties of the samples.

Fall-detection sensor was used **to determine** one's motion, direction and orientation in the case of fall. In this study, a fall-detection sensor is attached to the fabric using conductive yarn. For this aim; silver plated nylon yarn is used for sewing fall detection sensor. For fall detection, IMU (Inertial Measurement Unit) is used, which can measure motion, direction and orientation. It has 3-axis accelerometer that can measure acceleration according to gravity, 3-axis magnetometer that can measure the strongest magnetic force is coming from, generally used to detect magnetic north. It also has a 3-axis gyroscope that can measure spin and twist, temperature sensor that can measure the

temperature of the environment. This sensor is placed around waist of short. By using a mobile phone application, IMU works correctly and transfers data to mobile phone by Bluetooth board.

2.2. Method

By using highly elastic core-shell polyamide yarn, 5 samples of sport vest and short were produced via 10 gauge flat-bed knitting machine. For the bottom edge of the samples, 1x1 rib and for the whole part of them, single jersey knitting structures were selected.

Figure 3. Samples of seamless sport vest and short

After the production of the samples, fall-detection sensor was sewn on the surface of the fabric via silver yarn. For the vest product, the sensor can be sewn on the shoulders of the vest or in the middle of the waist of the vest. For the short it should be sewn on the waist or on bottom of the leg. The sensor sends data to a server, then applies machine learning algorithm on the data. The data can be executed and interpreted by a mobile phone application.

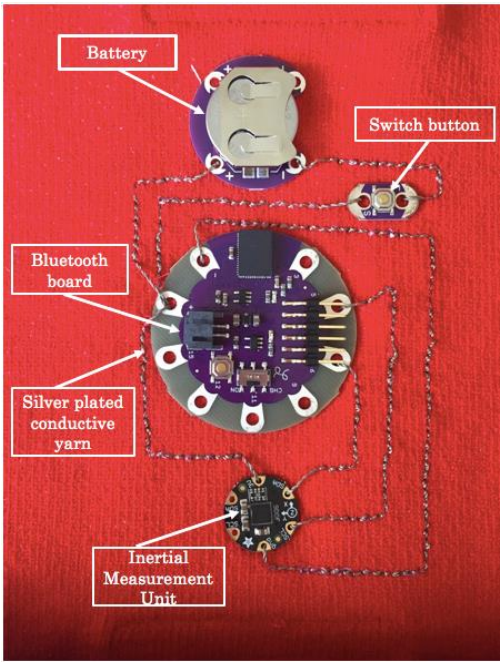


Figure 4. Fall-detection sensor on the fabric

3. Testing of functional sport vest and short

In order to evaluate comfort propertiesof the samples, equipments for measuring drape , air permability, moisture management, compression, bending and extension were used.

3.1. Tensile strength and elongation of yarn

Tensile test was applied according to BS EN ISO 2062: 1995, with initial length of 100 mm. Yarn has very high elasticity and test results shows that extension of yarn is over 400%. Tensile test results of 10 specimens are shown in Figure 5.

	Tenacity at Break (Standard) (cN/tex)	Load at Break (Standard) (cN)	Extension at Break (Standard) (mm)	Tensile strain at Break (Standard) (%)	Modulus (Automatic) (gf/tex)
1	12.37	841.47	400.64	400.64	8.88
2	12.34	838.94	400.38	400.38	5.53
3	10.53	716.30	400.70	400.70	6.11
4	9.33	634.33	400.83	400.83	0.51
5	11.09	754.19	400.83	400.83	5.75
6	11.59	788.45	400.97	400.97	9.29
7	11.65	792.44	400.42	400.42	9.45
8	13.05	887.40	400.69	400.69	8.05
9	11.62	790.37	400.97	400.97	9.15
10	10.86	738.66	401.47	401.47	6.79
Mean	11.44	778.26	400.79	400.79	6.95
Standard Deviation	1.06	72.07	0.31	0.31	2.73
Coefficient of Variation	9.26	9.26	0.08	0.08	39.34

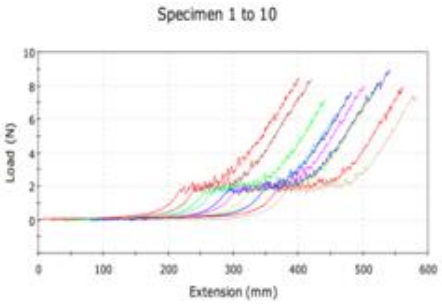


Figure 5. Tensile properties of yarn

As seen from the results, elongation of yarn was found over 400 %, which is highly suitable for a compression garment as it leads to better stretch fabric.

3.2. Drape test

The drape of the fabric was also evaluated by using drape tester. For the front of the vest, the drape was 14.34 % and for the back of the vest it was 26.78 %. For the front of the short, the drape was 23.69 % and for the back of the short it was 26.01 %. Difference between front and back of the fabric is caused by crimpy structure of knitted fabrics.

3.3. Air permeability test

The air permeability of the fabric was determined by SDL ATLAS M021A test device, BS 5636:1990 test standard was used, 200 Pa air is passed through the fabric and test area is 20 cm2. All results are demonstrated on Table 1.

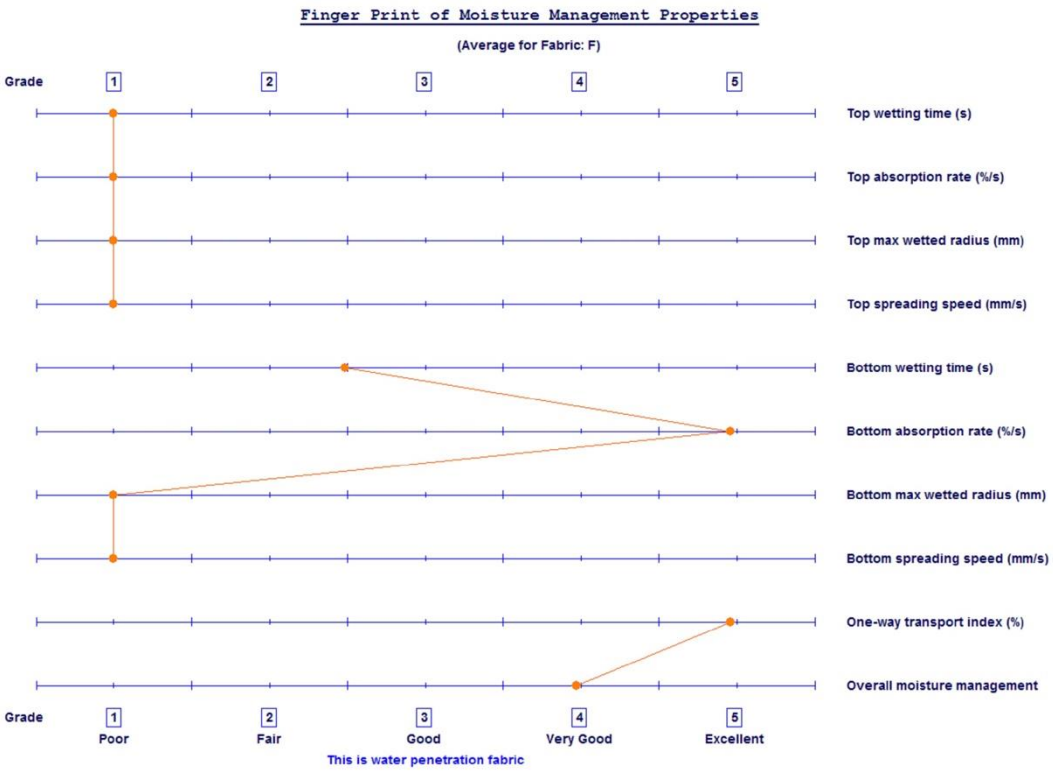
Table 1. Air permeability test results

Short Sample No	**Air Permeability values (l/m2/s)**	**Short Sample No**	**Air Permeability values (l/m2/s)**
1	240	1	259
2	238	2	293
3	314	3	263
4	294	4	269
5	303	5	277
6	244	6	260
7	258	7	297
8	221	8	274
Average	264	Average	274

3.4. Moisture management test (MMT)

Moisture Management test was performed by SDL ATLAS M290 MMT test device according to AATCC-195 test standard. Three samples of vest and short were used for this test. Figure 6 shows finger print of moisture management properties. For vest and short samples, overall moisture management is very good for the fabric (4/5) and one-way water transport index is excellent. The wetting and absorption properties of the sample is medium to fast. Thus, this fabric can be used in the applications where moisture transport is beneficial.

(a) Vest



(b) Short

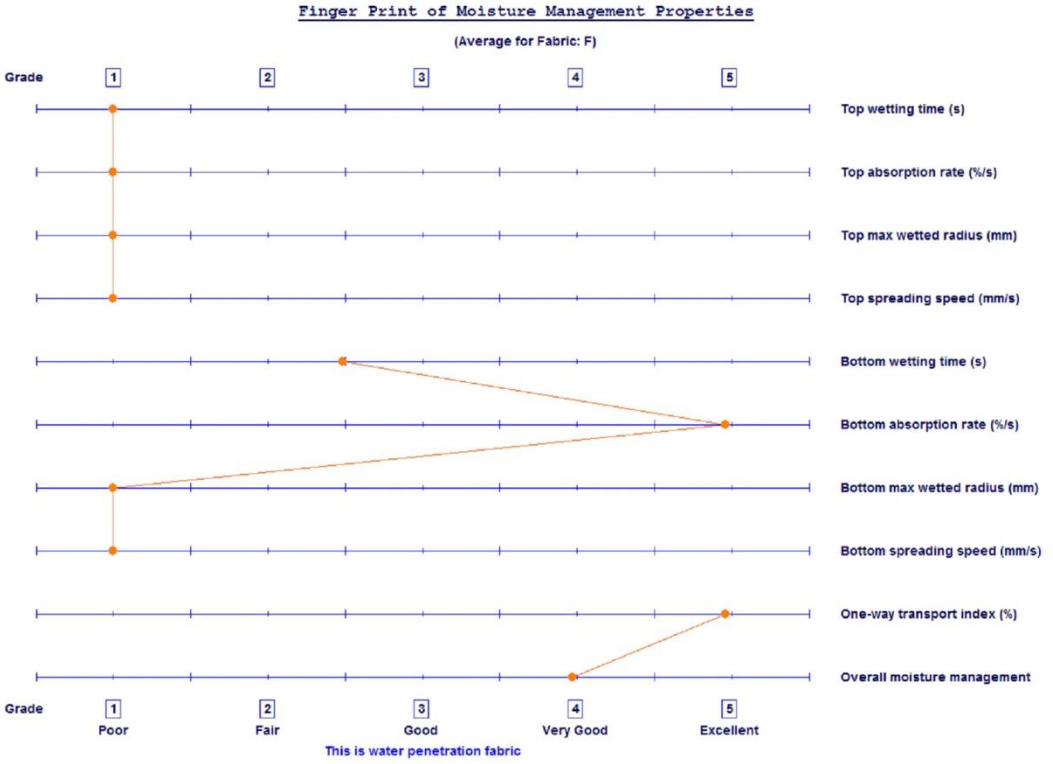


Figure 6. Finger Print of Moisture Management Properties of Vest (a) and Short (b)

3.5. FAST tests

Fast is a simple system of fabric objective measurement for assessing aspects of the appearance, handle and performance properties of fabrics. FAST or Fabric Assurance by Simple Testing consists of the following instruments and a test method: FAST-1 Compression meter, FAST-2 Bending meter and FAST-3 Extension meter.

3.5.1. Compression meter. A compression meter, which is also called as FAST (Fabric Assurance by Simple Testing)-1, is used for measuring thickness of the fabric between two predetermined loads. First the fabric is measured under a load of 2 g/cm^2 and then again under a load of 100 g/cm^2. The fabric thickness is measured on a 10 cm^2 area at two different pressures, firstly at 2 gf/cm^2 and then at 100 gf/cm^2 using the apparatus. This gives a measure of the thickness of the surface layer which is defined as the difference between these two values. The fabric is considered to consist of an incompressible core and a compressible surface.

Five samples were performed in this test. The thickness results are shown on Table 2.

Table 2. Average fabric thickness results in FAST-1

Vest Thickness	Short Thickness
0,449 mm	0,534 mm

3.5.2. Bending Meter. A bending meter (FAST-2) is used to measure the stiffness or flexibility of a fabric. If the fabric stiff, it bends slowly and if the fabric is flexible, it bends quickly. The bending rigidity, which is related to the perceived stiffness, is calculated from the bending length and mass per unit area. The average test results show that stiffness of the fabric is medium and 8,732 µNm for short and 12,965 µNm for vest.

3.5.3. Extension Meter. FAST-3 is an extension meter which measures the amount that a fabric will stretch under three fixed loadings (5 g/cm, 20 g/cm and 100 g/cm). The system is simulating the kind of deformation, the fabric is likely to undergo during garment manufacture. The extensibility of the fabric can be measured at any angle to the warp (or weft) threads. The fabric extensibility is very high, and 10,2948 mm2 for short and 16.405 mm2 for vest. This level of extension is based on the elasticity of knitting yarn.

4. Conclusion

In this study, functional sport short and vest were designed and produced with a special polyamide yarn which has highly elastomeric structure. A flat bed knitting machine was used and whole garments were knitted. Garments have perfect fitting to body. Comfort properties of short and vest were tested with several test instruments and; tensile strength of elastomeric yarn, air permeability, moisture management, drape and objective handle (FAST tests) of garments were achieved. Moisture management and FAST test results showed that short and vest samples have good comfort properties as a functional sport garment.

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