Design & development of smart sportswear integrated with energy harvesting device

[1]Y. Jhanji, [2]S. Khanna & [3]A. Manocha

[1,2,3]Assistant professor, Department of Fashion & Apparel Engineering, TIT&S , Bhiwani

yjhanji@gmail.com

ABSTRACT

Fashion and apparel industry has been witnessing a lot of transitions in past few decades with clothing not merely regarded as an entity for protection and self-adornment but the whole concept has been reformed with inception of smart wearable technologies becoming an integral part of today's fashion parade. Sportswear, is one such highly innovative and functional class of clothing which involves a lot of fiber, yarn and fabric engineering to match the needs of sportsperson. The basic requirement of sportswear is comfort to wearer along with easy mobility. Comfort can be engineered into sports textile by selection of such fiber, yarn and fabric variables that contribute to effective thermal, moisture vapor and liquid moisture transmission through clothing. Furthermore, there has been quest for enhancing the functionality and performance of sportsperson and monitoring their physiological parameters via specifically engineered and designed sportswear.

The present study has been undertaken to integrate the concept of smart wearable technology into sportswear intended for sportsperson indulging in low to dynamic physical activity.

Accordingly, a sportswear assembly comprising solicit-sports panel integrated t-shirt, shorts, wristband and baseball cap have been designed and developed to explore the moisture management properties desirous of sportswear and energy harvesting principle of solar panel (via its integration into sportswear). The moisture transmission properties of different knit structures have been analyzed and based on objective evaluation; the most suitable structure has been selected for design & development of sportswear. The designed sportswear has been incorporated with energy harvesting device and the smart sportswear so developed is subjectively tested and evaluated in real time situations.

Keywords: Sports, moisture transmission, comfort, energy harvesting, solar cell.

1. Introduction

Comfort although a subjective term; is crucial property in textile for clothing. Comfort is related to how an individual feels. There are three main aspects for analyzing comfort of any fabric. The first aspect of comfort is thermal comfort. It is feeling of pleasure or related to how a hot or cold a person feels. Thermal comfort is associated with changes in many physiological and environmental variables like the activity level of the individuals and clothing properties, such as the fabric insulation values and water vapor permeability. Thermal comfort is mostly quantified using physiological parameters though it is a psychological concept. Tactile sensation is second aspect of comfort that is related to interaction of skin with clothing that result from the fabrics in contact with the skin.

The third component of comfort is related to the fit of the garment. A poorly fitted garment, especially too small or too large can interfere mobility and performance, although impact on comfort may not be as great, but it influences the psychological perceptions of the wearer through personal or cultural preferences regarding fit and fashion size trends. Consideration of thermal comfort, sensory skin-feel comfort, comfort due to fit, or the psychological comfort have considerable impact on the individual physical and cognitive performance.

Clothing is considered to be second skin playing a vital role in maintaining thermal balance with environment and keep an individual in comfortable state. It should be the main property of textiles to conserve the heat that body dissipates away, and dissipate heat from body surrounding when body generates it. Moisture management is crucial for thermo-physiological comfort as it involves controlled movement of moisture vapor and liquid perspiration from skin surface to atmosphere through fabric.

Knitting is a process of fabric manufacturing by interlocking series of loops of one or more yarns. Knitted fabrics are used to produce garments that cover every part of human body, in a wide range of garments types from socks, caps, gloves and underwear to upper and lower body garments varying from t-shirts to formal jackets. Figure 1 shows knit and woven structure.

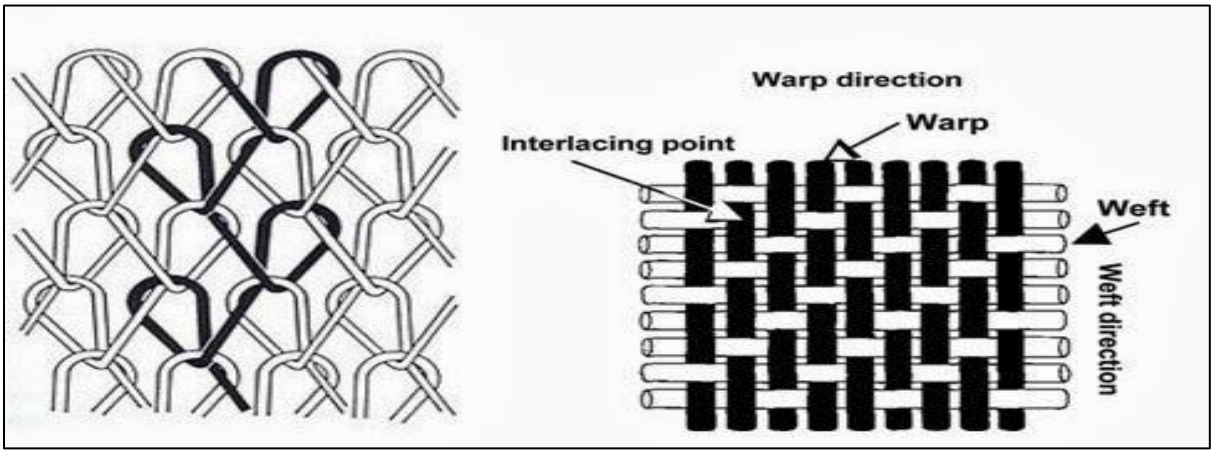


Figure 1-Knit and woven structure

1.1 Requirements of sportswear

Sportswear are generally involved in sweat generating and rigorous activities like jogging, running, cycling etc. therefore sportswear needs to possess the following properties:

- Sportswear garments should be light in weight and dimensionally stable even when wet.
- Outstanding moisture managing properties, which rapidly wick the moisture away from the body.
- Good perspiration fastness and smart and functional design.
- High electrical conductivity along with superior strength and durability.
- Radiation free

Polyester is the single most common fiber used for sportswear and active wear. Other fibers suitable for active wear are polyamide, polypropylene, acrylics and elastanes. Wool and cotton fibers are still finding applications in leisurewear. Synthetic fibers can either be modified during manufacture, e.g. by producing hollow fibers and fibers with irregular cross-section, or be optimally blended with natural fibers to improve their thermo-physiological and sensory properties. Synthetic fibers with improved UV resistance and having anti-microbial properties are also commercially available for use in sportswear.

For most sports the athletes wear a combination of different items of clothing, e.g. sport shoes, pants and shirts. In some sports, protective gear may need to be worn, such as helmets or American football body armor. Yoga clothing should use fabrics with good stretch ability

for easy movement which will likely require the fabric to be of a knitted construction.

Figure 2 - Active & Leisurewear

1.2 Wearable smart textiles

Smart textiles, also known as smart garments, smart clothing, electronic textiles, or smart fabrics, are fabrics that enable digital components such as a battery and a light (including small computers), and electronics to be embedded in them. Figure 3 shows some wearable smart textiles.

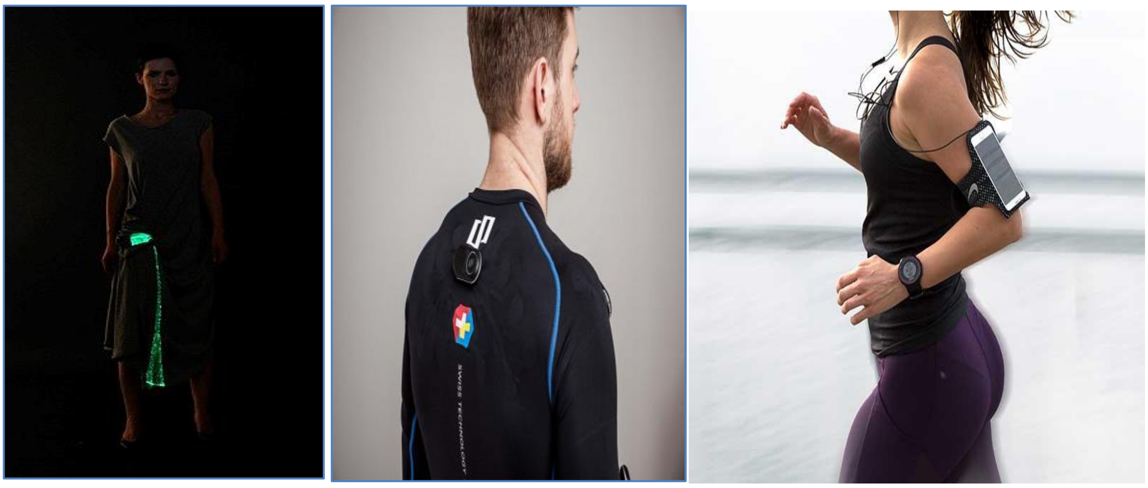
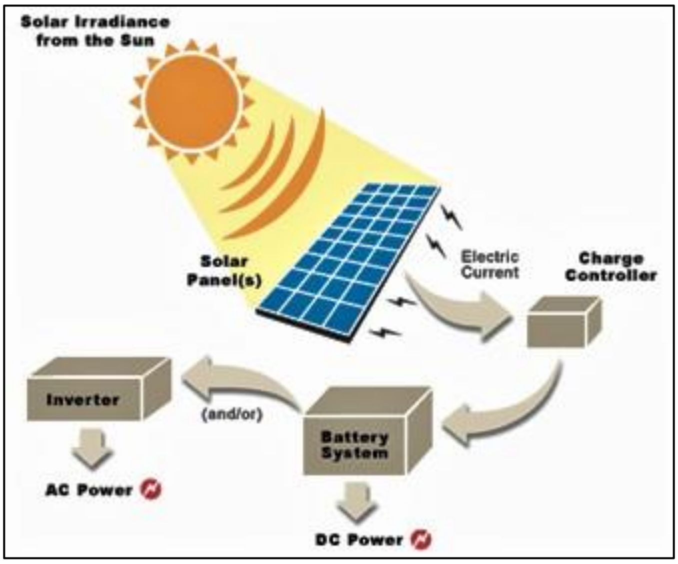


Figure 3 - Wearable smart textiles

1.3 Energy harvesting devices & working of Solar panel

Energy harvesting ,also known as power harvesting or ambient power is the process by which energy is derived from external sources e.g., solar power, thermal energy, wind energy, salinity gradients, and kinetic energy, also known as ambient energy, captured, and stored for small, wireless autonomous devices, like those used in wearable electronics and wireless sensor networks. Energy harvesters provide a very small amount of power for low-energy electronics. Energy harvesting devices converting ambient energy into electrical energy have attracted much interest in both the military and commercial sectors. The application is in wearable electronics, where energy harvesting devices can power or recharge cellphones, mobile computers, radio communication equipment, etc. Solar panels are those devices which are used to absorb the sun's rays and convert them into electricity or heat. A solar panel is actually a collection of solar (or photovoltaic) cells, which can be used to generate electricity through photovoltaic effect. These cells are arranged in a grid-like pattern on the surface of solar panels. When the sunlight falls over the solar panel the energy is absorbed in the form of photons and further converted to electric current by the p-n junction diode present in the solar panel. This electric current is then either stored in batteries in the DC power or converted into AC power using the inverters [Figure 4]. Also, the battery system can be connected to the external USB port in order to transfer the electricity to charge



mobiles, torches, power banks etc.

Figure 4- Working of solar panel

1.5 Applications of solar power in apparels

The solar power is now being considered as the future for the generation of electricity due to rapid exhaustion of the fossil fuels. Also, solar power has emerged as an economic, sustainable and eco-friendly option to the textile, fashion and apparel industry. From the rooftop solar power plants in the textile industries providing large amount of electricity to the garments and accessories using the solar power for various decorative, smart and protective features. Figure 5 shows application area of solar panel in apparels and accessories.

Figure 5 - Application areas of solar panel in apparels and accessories

2. Materials & Methods

2.1 Materials

Different knit structures of cotton single jersey and polyester interlock mesh knit structure were used for the study. The fabrics were procured from Vardhman Polytex Ltd., Ludhiana for the study. The details of the fabrics procured have been provided in Table1:

Table 1- Details of fabric samples & plan for development of sportswear

Sample code	Fibre composition	Design aspects	Level of physical activity	c) End products
SJ_B	PET/C	Wristband	Static/low	Wristband
IW	100% PET	Zonal garment integrated with solar panel	Dynamic/high	T-shirt, shorts & cap
IN	100% PET		Dynamic/high	T-shirt, shorts & cap
IB	PET/C		Dynamic/high	T-shirt, shorts & cap

Note: Iw- Interlock White fabric, I_B- Interlock Black fabric, I_N- Interlock Neon fabric, SJ_B- Single Jersey fabric

The solar panel integrated in the designed apparels was procured from Manohar Electronics, Bhiwani. A range of trims and notions like velcro, snap fasteners & elastic were used.

The trims and notions were procured from Vinod General Store, Bhiwani for apparel and accessory designing. The trims and notions used in the project were- elastics, used in shorts and wristbands for good fit and firmer grip; buttons, for holding the wires of solar panel arrangement; velcros, to firmly hold down the solar panels at their proper position and angle of inclination and also to make the arrangement detachable; piping, used for covering the wires in order to resemble them with the design aspects of the whole garment; interlining, used in the cap for the firmer shape retention.

2.2 Methods

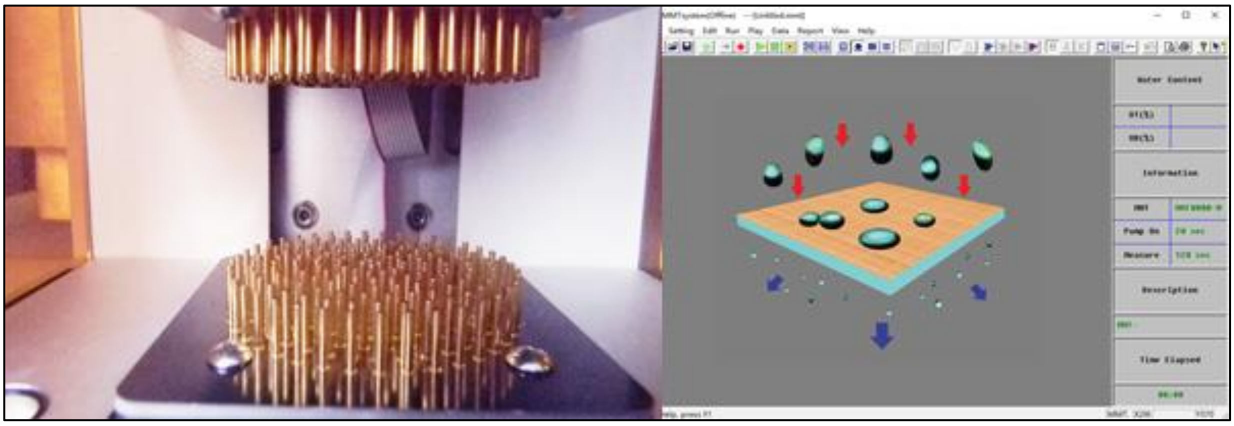
The procured materials were evaluated for their physical and moisture management properties to assess their suitability as sportswear textiles. The prepared fabric samples were evaluated for their fiber content to determine the content or ingredient of provided fabric.

Aerial density of samples was determined according to ASTM D-1059. The thickness of fabrics was determined using fabric thickness gauge. CPI and WPI were measured using the magnifying glass. Moisture management properties of developed knit samples were determined on moisture management tester (MMT) (SDL Atlas, Hong Kong) (AATCC Test method 195-2009) Figure 6 shows moisture management tester & top and bottom sensors of moisture management tester.

Figure 6- Top and bottom sensors of moisture management tester

3. Results & Discussion

Different moisture management indices were obtained for top (next to skin) and bottom (outer layer) for the four test samples under consideration. Analysis of water content vs time curve, finger print of moisture management properties are shown in Figures 7-9. It was observed that interlock mesh structures (I_W & I_N) composed of 100% polyester were moisture management fabric as indicated by their fingerprints. Overall moisture management was



observed to be highest for I_W and lowest for single jersey structure. I_W fabric was observed to be quick drying and wicking fabric with lower absorption rate in top (next to skin) layer and higher absorption rate in bottom (outer layer) which is prerequisite for wickable sportswear design. I_N although moisture management fabric has lower value of AOTI & OMMC as compared to I_W. Moreover, the I_N fabric exhibited lower spreading speed and absorption rate in bottom layer compared to I_W indicating that fabric would be slow drying and wickless liquid moisture compared to I_W.

I_B although interlock mesh structure exhibited inferior moisture management properties compared to its interlock counterpart with lower value of OMMC as compared to I_W and I_N.

Wetting of the surface is essential to propagate wicking to outer layer. Hence, such a structure won't be very effective in transferring liquid to outerlayer as wetting of inner layer takes place gradually.

Single jersey fabric (SJ_B) exhibited the lowest OMMC. The results obtained shows that the structure shows higher absorption & spreading speed in next to skin layer (as indicated by AR_t and SS_t), thus making structure suitable for low physical activity or for static conditions in summers.

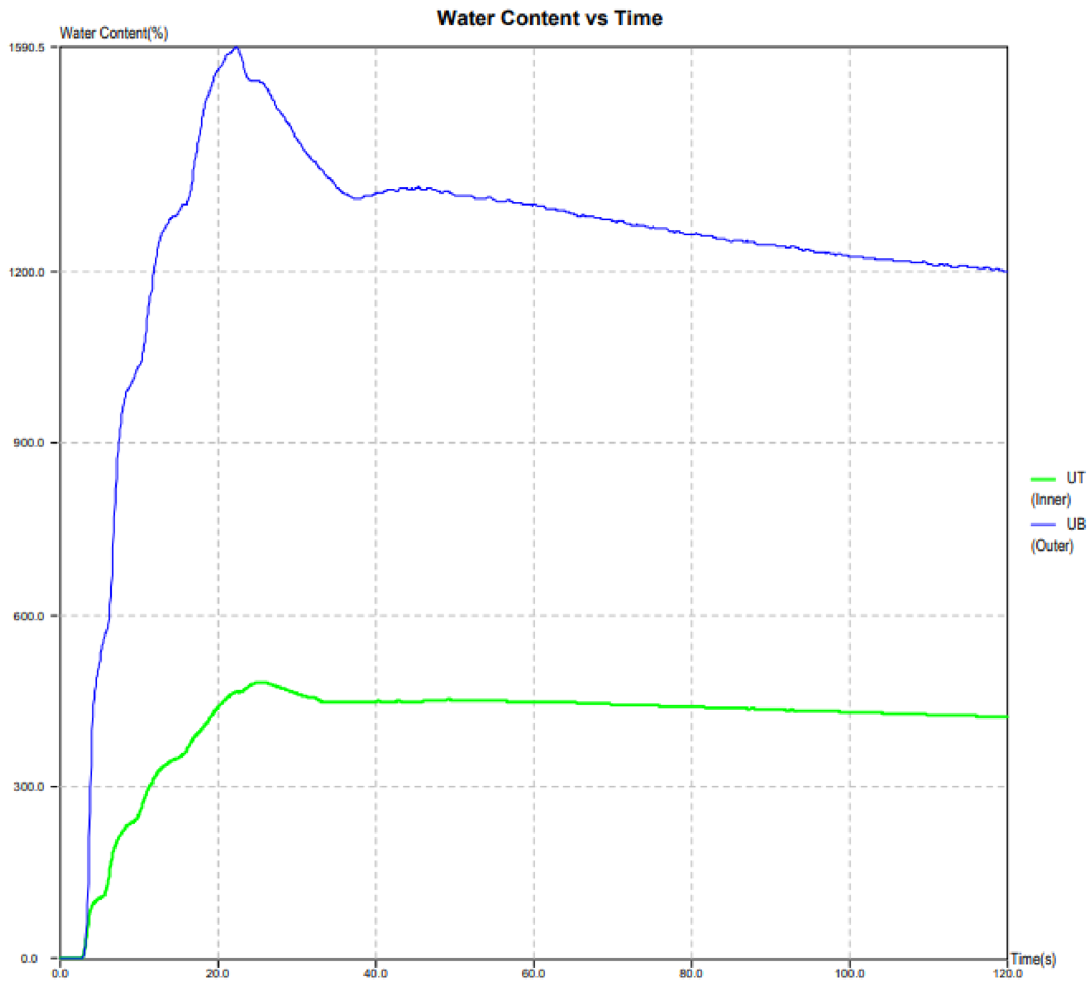


Figure 7 - Water content vs time curves for Iw fabric

(Iw- 100% P, Interlock mesh)

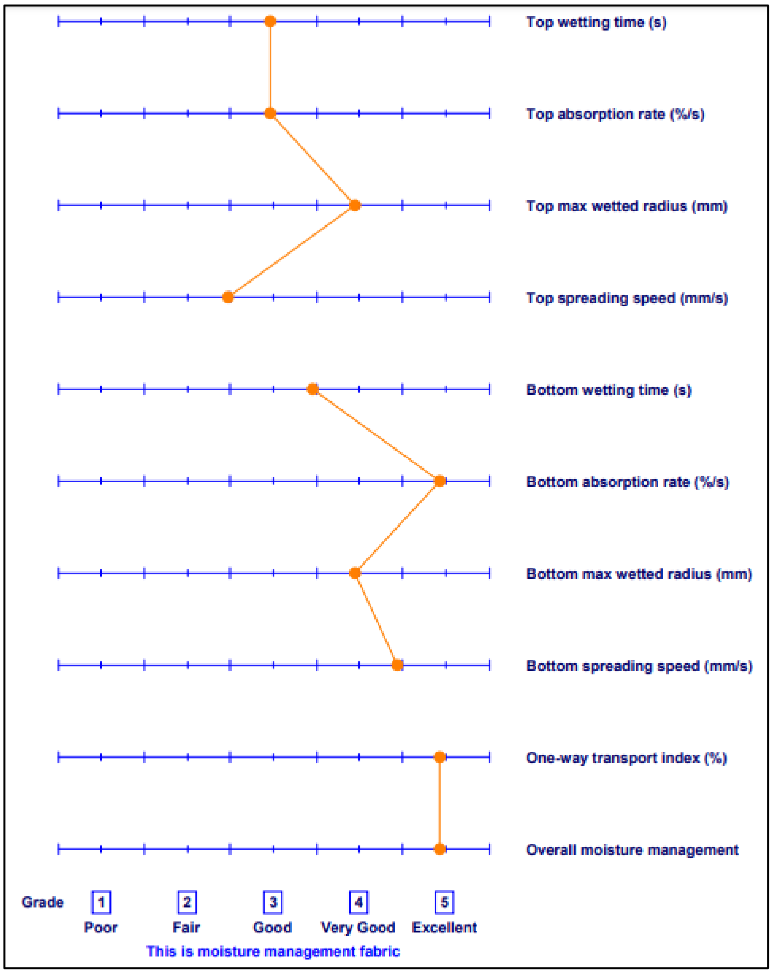


Figure 8 – Fingerprint of moisture management properties of Iw fabric

(Iw- 100% P, Interlock mesh)

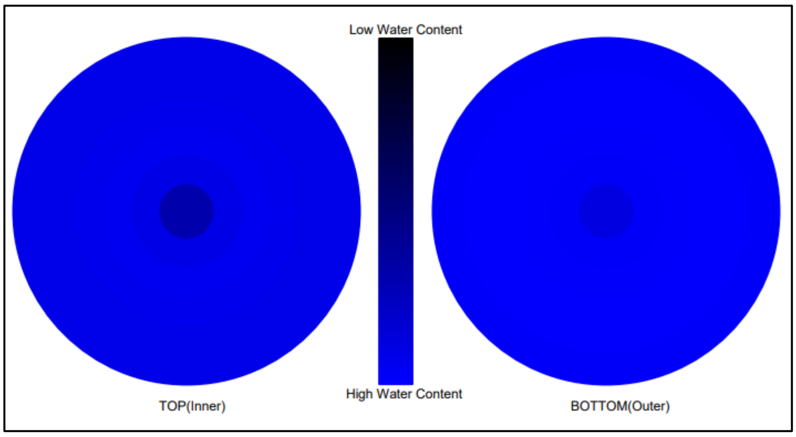


Figure 9 - Water location vs time plot for Iw fabric

The results for moisture management properties indicated that Interlock mesh structure (I_W) exhibited excellent moisture management properties. Moreover, the above stated fabric exhibited highest one way transport capability suggesting that structure is capable to keep wearer skin dry with sweat readily transferring from next to skin to outer layer.

Results of the study prompted the usage of this knit structure (I_W) for designing of sportswear intended for high level of physical activity.

I_B fabric ranked second compared to I_W as far as moisture management properties are concerned. Therefore, the two mesh structures were predominantly used for designing of sportswear.

3.1 Designing

Solirt- the solar sports T-shirt complimented with a pair of shorts, baseball cap and wrist bands were developed using the above mentioned fabrics that exhibited the moisture management properties suitable for sportswear design.

The design inspiration was taken from sportsperson who give precedence to comfort over aesthetic appeal. Accordingly, the design was proposed which reflected functionality rather than aesthetic appeal thereby minimal use of surface embellishment of designed and developed apparels and accessories. Furthermore, design proposed zonal garment with zones to distinguish profusely sweating and low sweating areas of garment. Mood board and story board were designed for the sportswear to be developed. Mood board and story board are shown in Figure 10 (a&b).

Designing phase was followed by pattern making. Flat pattern making i.e. drafting was employed for the same. A standard size chart was referred for the sizes and patterns of L size were made. Garment assembly designed for sportswear includes t-shirts, shorts, baseball cap and wristbands as shown in Figure 11.

3.2 Solar Panel Integration

It was intended to further enhance the functionality of designed sportswear. Henceforth, solar panels were integrated in **Solirt** t-shirt which served as energy harvesting device and could assist the sportsperson to charge their gardget, specifically a mobile while on the move or involved in any activity. The Solirt is shown in Figure 12.

Figure 10 (a) Moodboard (b) Storyboard

(a) (b)

(c) (d)

Figure 11 (a) T-shirt (b) Shorts (c) Wrist band (d) Baseball cap

Figure 12- Solar panel integrated t-shirt

4. Conclusions

- Interlock mesh (100% polyester) structures were the most suitable knit structures for sportswear design and development owing to their excellent liquid moisture transmission properties.
- Interlock mesh structures exhibited highest highest one way transport capability and wicking property compared to their counterparts indicating that such structure would be suitable in transmitting liquid sweat to outer layer effectively, thereby keeping next to skin layer dry.
- The subjective evaluation of designed and developed sportswear by sportsperson involved in dynamic physical activity revealed that sportsperson found the combination of sports wear and accessories functionally as well as aesthically appealing. However, the subjects suggested to reduce the cumbersome solar panel attachments.

References:

1. Li, Y., “The science of clothing comfort”, Textile progress, 1(2), 31(2001).
2. Kothari, V. K., “Quality control: Fabric comfort”, Indian Ins. of Tech., Delhi, India, 2000.
3. Jhanji, Yamini & Gupta, Deepti & Kothari, V. (2017). Moisture management and wicking properties of polyester- cotton plated knits. Indian Journal of Fibre and Textile Research. 42. 183-188.
4. Jhanji, Yamini & Kothari, V & Gupta, Deepti. (2015). Liquid transfer properties and drying behavior of plated knitted fabrics with varying fibre types. Indian Journal of Fibre and Textile Research. 40. 162-169.
5. Jhanji, Yamini & Gupta, Deepti & Kothari, V. (2014). Moisture management properties of plated knit structures with varying fiber types. The Journal of The Textile Institute. 106. 1-11. 10.1080/00405000.2014.934044.
6. Saville, B. P., “Physical testing of textiles”, Woodhead Publishing Ltd., 1999.
7. Zhang, P., Watanabe, Y., Kim, S. H., Tokura, H. and Gong, R. H., Thermoregulatory responses to different moisture-transfer rates of clothing materials during exercise, J. Text. Inst., 92 (1), 372-378 (2001).
8. Sudarshan Guruacharya and Ekram Hossain, “Self-Sustainability of Energy Harvesting Systems: Concept, Analysis, and Design”, Department of Electrical and Computer Engineering, University of Manitoba, Canada.
9. Morton, D. H. and Harley, J. W. S., “Physical properties of textile fibers”, New York, 1993.
10. Pause, B., “Measuring the water vapor permeability of coated fabrics and laminates”, J. of Coated Fabrics, 25(4), 311-320 (1996).
11. Kar F,Fan J,Yu W & Wan X,Fibers and Polymers,8(2007), 537.
12. Romeli D, Barigozzi G, Esposito S, Rosace Z & Salesi G, Polymtest , doi ; 10.1016/j.polymertesting .2013.05.011.
13. SportsTech: Revolutionary Fabrics, Fashion and Design Book by Marie O'Mahony and Sarah E. Braddock
14. Nuray U & TurgutY, Fibers & Textiles in eastern Europe,12(2004),147.
15. Voelker C, Hoffmann S, Kornadt O, Arens E, Zhang H & Huizenge C, Paper presented at the eleventh International IBPSA Conference,2009.