Proc. of Int. Conf. on Emerging Trends in Engineering & Technology, IETET

Electro Conductive Knitted Structure: An Over View

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***Abstract*—As the control of the textile complex has shifted further downstream to the consumer, specialized demands has rendered manufacturers to diversify the existing product with suitable modifications in conventional textile structures. Knitting process is an obvious choice for manufacturers due to its flexibility and adaptability in form of tool technique and methodology. Knitted fabrics have been extensively applied in dresses and home accessories due to their ease of manufacturing process, comfort and are most viable option in comparison with woven counterpart. In recent years, with certain structural modifications, the applications of the fabrics knitted have shown remarkable achievement as reinforcement material in forming structural light weight composite materials. Furthermore with innovation in field of conductive and smart textile materials, knitted structure has also played an important role for producing sensors, actuators, heating elements, communication & data transmissions, electromagnetic shielding effectiveness and integrated smart clothing systems.**

An attempt has been made to analyze the research work of different researchers related to conductive knitted structure and their effectiveness in various aforementioned application areas and put forward an overview relevant in present scenario.

***Index Terms*— Knitted structure, conductive textile, sensors, communication & data transmissions, electromagnetic shielding.**

I. INTRODUCTION

Knitted fabrics, due to their properties like shape fitting, softer handle, bulkier nature and high extensibility at low tension is being extensively used for dress materials, are now gaining strong ground in the area of technical textiles. The effective incorporation of conductivity mechanism in a knitted structure has offered an era of enhanced functionality for garment and materials for industrial applications. Conductivity can be introduced via:

--Filling of fibres with carbon black or production of carbon fibres
--Interlacing in the textile structure like metal , steel, or nickel wires or fibres in combination with textile fibre in form of hybrid yarn
--Coating of textiles (fibres or fabrics) with conductive substances
-- Intrinsically conductive polymers (ICP)

The superior conductivities of fabrics containing metal fibres have to compromise by certain parameters like, reduced flexibility, enhanced weight, tailoring & processing problems as well as the increased cost of the end product. Additionally, the aesthetic priorities of textile products are adversely affected by the carbon filling

Grenze ID: 02.IETET.2016.5.47

method. Coating of textile substrates with metal salts usually imposes difficulties in form of the wash resistance of the end product. The metallic and galvanic coatings processes have been also used. [5],[6] It is very challenging to establish a competitive relation between the innovative electro-conductive properties and the fabric properties like comfort, flexibility, durability, wash ability etc.

However with certain structural modifications of knitted structure and conductive yarn architecture by selecting suitable core/ sheath ratio of metallic component and natural/ synthetic yarn as per the required functionality is now being used. For incorporation of conduction properties the analysis of knitted structures, its production mechanism, and various possibilities of conduction mechanism and major areas of applications is discussed below.

A. Knitting Process

Knitting is the process of forming fabric by individual yarn or sets of yarn produced by a loop which is the building unit and interconnecting them by process known as interlooping. The basic principle of knitting is accomplished by drawing the new loop through the previously formed loop. The looping of yarns results in positive binding. It describes the technique of constructing textile structures by forming a continuous length of yarn into columns of vertically intermeshed loops [1]. Knitted structures are sequentially built-up from row after row of intermeshed loops. As knit fabrics are produced on different machines with various conditions to produce different types of fabric, they bear different qualities. [2]

Types of Knitting

Knitting can be divided into two main process called warp and weft knitting. Under weft knitting there are four systems known as single jersey, rib, interlock and purl. Warp knitting have two categories i.e. Tricot and Raschel.

Weft Knitting: - In this type of structure loops made by each thread are formed widthwise in the fabric resembling with pick of weft in weaving process so it is called weft knitting. The horizontal rows of loops produced by the adjacent needles during same knitting cycle is called course. The vertical column of needle loops produced by the same needle knitting at successive knitting cycles is called wale. [3] All the loops in one course are produced from the single supply and loops are formed in successive order one by one. In this system the yarn may be fed so as traverse forward and backward across the fabric called flat knitting or it may be fed continuously in the same direction called circular knitting. Weft knitted fabric is produced simple up and down movement of the needles, which is provided by the profile of a cam system. [4]. Structural representation of different weft knitted structures such as; single jersey, rib and interlock structures are shown in fig, 1, 2, & 3 respectively.

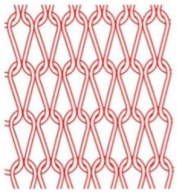

Figure 1 Single Jersey

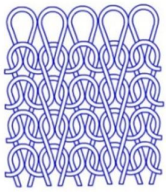

Figure 2 Rib

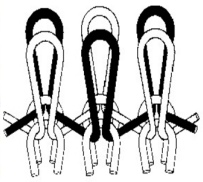

Figure 3 Interlock

Warp Knitting:- Warp knitting is the method of making a fabric in which the loops made from each thread are formed along the length of fabric. It is characterized by the fact that each warp thread is fed almost in line with the direction in which fabric is produced. In warp knitting a number of yarns aligned longitudinally are linked with each other as shown in fig. 4. [2] All yarns from one or several yarn beams are presented to all the needles simultaneously and each of these yarns is connected with its neighboring one by a lapping movement. The loops in a row are obtained simultaneously by a collective needle movement. Loops in warp knitted structures are made of two parts. The first one is the loop itself, which is formed by the yarn being wrapped around the needle and drawn through the previous loop. This part is called overlap, which is due to lateral movement of the guide bars on the hook side of the needle. This movement is normally restricted to one needle space. The second part is the length of yarn connecting the loops, which is called an under lap. Under lap is the lateral movement of the guide bar made on the side of the needle remote from the hook. When the overlap and the next under lap are made in the same direction an open lap is produced. If the

overlap and the following under lap are in opposition, a closed lap is formed. The closed lap is mostly used and is heavier more compact, opaque and less extensible as compared to open laps. [2],[4]

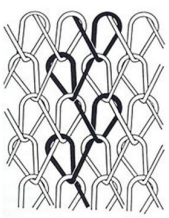

Figure 4 Warp Knitted structure

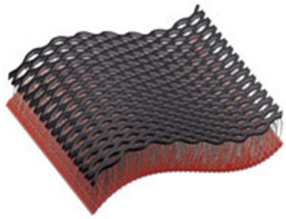

Figure 5 Knitted Spacer Fabric

II. An Over View Of Conducting Materials & Techniques

Various conductive materials and techniques have been used on the textile substrate. The material in form of metallic fibre/ yarn, hybrid & commingled yarns, conductive polymer etc is being applied. Different methods like melt spinning, wet spinning, electrochemical processing etc have been reported for the production of conductive fibres. Conductive polymer composites produced by melt spinning process of thermoplastic polymers like polyethylene or polystyrene with carbon nano tubes, metal powders and carbon black etc, has low conductivity level. [7] If concentration of conductive material is increased the mechanical properties of composite material will decrease. In order to enhance electro mechanical properties an attempt has been successfully adopted to transform the textile fibres or yarn into electrically conductive fibres/yarns. This approach is based on the principle to use commercially available textile fibres like polyester, nylon, cotton, viscose etc in order to use their good mechanical properties. The conduction properties can be incorporated either by metallic filaments in the yarns or by coating them with conductive materials. Metallic coatings can be applied by electro less plating, vacuum deposition, sputtering carbonizing and filling methods. Sometimes the metallic content by this approach is found inconvenient in comfort and processing of specifically designed cloths. [7] The coating of textile fibres with intrinsically conductive polymers like poly aniline, polypyrrole, polythiophene etc. will overcome the aforementioned difficulties.
Depending on the type & application of conductive materials different methods are used to achieve conductivity on a textile substrate is summarized as follows:

- Pure metal yarn in form of multifilament
- Carbon & E- glass fibres
- Twisted metal wire around the textile based yarns.
- Hybrid & commingled yarns with core/ sheath composition of metallic fibres/ textile yarns
- Incorporating inherently conductive polymers.
- Coating with conductive materials
- Conductive ink- It is a traditional printing ink containing added metallic content like copper, silver, gold and nickel.

III. Conduction Phenomenon Of Knitted Structures

With the increase of stretching and distortion, the resistance of conductive knitted fabrics reduced correspondingly and when stretching achieved certain degree, the electric conductivity of fabrics achieved a relatively stable state. The conduction phenomenon of knitted fabric is based on hypothesis i.e. the unit length of conductive fibre resistance is invariable, and is not affected by the stretching and distortion in certain stretching range. When the fabrics are drawn, the transfer of various loops are consistent, i.e. the yarn in the loop transfer from the arc part to the pole part and the loop length is invariable, the resistances of the arc part and the pole part change with the changes of length, so the network resistances of the whole fabrics will correspondingly change. [3]
The rib texture is collocated by the transverse line of the face loop and the transverse line of the reversed loop alternately. The sinking arc linking the face loop and the reversed loop sustains large bending and torsions, and the loop transverse lines on each face are adjoined each other. In comparison with plain single jersey, rib structures will have larger flexibility when transverse stretching happens. [5]

Spacer fabrics are three-dimensional knitted structures. These structures are characterized by three layer assembly as shown in fig. 5. The face and back are knitted separately, but at the same time, these two layers are interconnected by third layer sandwiched in between them. [2] For incorporating conductivity in spacer fabric, face & back layers are knitted with either metallic hybrid yarns or by coating these layers by intrinsically conducting polymers like poly aniline, polypyrrole, polythiophene etc. [7] .The interconnecting middle layer may have monofilament yarns of polyamide, polyester, and viscose or could be natural fibers, such as cotton. (Figure 3). They can be produced on warp knitting machines, flat knitting machines, and circular weft knitting machines. The properties of conductive spacer fabrics can be engineered to suit the specific end product such as sensors, electromagnetic shielding fabric, heating pads etc. by manipulating the yarns and structures used in the three different and independent elements: face, back, and middle layer

IV. Applications of Conductive Knitted Structures

A. Sensors

Good flexibility and stretching property of the knitted fabrics make the sensors to fit measuring the large stretching stress, offering extensive application range. The fabric texture, loop transfer, contact resistance and good extensibility of the conductive knitted fabrics are the factors to impact the resistance of the fabrics and thereby contributing to differential conductivity when knitted structure is incorporated with conductive material. Various kinds of textile based sensors are developed like tilt sensors, stretch sensors, stroke sensors, pressure sensors, bend sensors etc. Based on knitting technology stretch sensors, bend sensors and pressure sensors are well designed for various functional applications. [6] Stretch sensors can be made from the simplest single jersey, rib, purl and interlock structures by using conducting yarn. These sensors are predominantly used for sensing and monitoring body parameters like heart rate, respiration, blood pressure. Bend sensors are also used in form of aforementioned knitted structures and are significantly used to detect various body movements specifically at joint areas. Pressure sensors are commonly used as switches, monitor vital signs, muscle activities and development of interactive textile. Normally pressure sensors are designed on 3D knitted structures called spacer fabric. [7]

B. Smart Clothing

Knitted fabric is an obvious choice for the electro conductive functional application. The ease of operation in incorporation of conductive materials and economical viable process are some of the paramount phenomenon. Smart conductive T shirts can be transformed to function like computer or other analog devices to monitor heart beat rate, ECG, temperature or many other health related issues. Furthermore these smart dresses can be equipped with sensors, integrated with small micro strip antenna, and actuators in order to facilitate transmitting or receiving data from or to wearer's end to other sources. Now with the help of other accessories like MP3, soft switches, conductive networking knitted clothing can be used for communication and entertainment purposes.[7]

C. Heating Applications

The conductivity phenomenon in knitted structures provided a scope of heating pads, battery operated heating garments. Electro conductive property incorporated with suitable configuration of conductive and insulating yarn in both warp and weft knitted structures have capability for producing various substrates for heating applications.

D. Electromagnetic shielding

The rapid growth of electronic devices in communication, computations and automation on one hand has elevated our standard of living but on other has created a serious thrill for our health in form of electromagnetic interference problem, as system operates in our close proximity. Apart from human body the electronic equipments are also adversely affected from these unwanted electromagnetic wave emission. [8] The approach to shield these electromagnetic waves is called electromagnetic shielding. When these waves falls on the surface of shielding material the shielding material works on basic three principles i.e. reflection, absorption and multiple reflection of electromagnetic wave, thereby protecting the electronic device or human body from the adverse consequences of EMI emissions. EMI shielding material with woven or knitted structures must have a conductive surface. Hence any of the conductive medium discussed above can be in

incorporated in a knitted structure to provide efficient shielding capabilities form destructive electromagnetic radiations.[8]

V. CONCLUSIONS

Knitted fabric is well established for fulfilling the house hold requirements for the garment and fashion world. The ease of manufacturing, shape fitting capabilities, bulkiness associated with permeable structures and highly comfortable to the wearer, is some of the properties associated with knitted fabric. In present scenario of advancement, knitting technology, which has been focus of attention for fashion designers, has also gained attention for the multidisciplinary engineers and scientist. The evolution of electro conductive knitted structures describes the convergence of electronics and textile into fabric which is able to sense, compute, communicate and actuate, has remarkably transformed traditional conceptual aspects. Developments of sensors, micro antennas, heating elements, smart clothing etc are some of the application areas which have enhanced the functionality in field of communication system, entertainment, military intelligence and health monitoring system. Furthermore application of knitted structure has offered a scope for protective mechanism by achieving capabilities of electromagnetic shielding effectiveness.

REFERENCES

[1] Elfadil M. M. A. Elkarsany, Amel A. Magboul, Effect of Yarn Input Tension on Knitted Fabric, International Interdisciplinary Research Journal, {Bi-Monthly}, ISSN2249-9598, Volume-IV, Issue-I, Jan-Feb 2014.

[2] D. J Spencer, Knitting Technology (Woodhead Publishing Limited, Cambridge, 2001).

[3] P. L. Chen, R. L. Barker, G. W. Smith and B. Scruggs, Handle of Weft Knit Fabrics, Textile Research Journal, 62 (4), pp. 200- 211, 1992.

[4] D. B. Ajgaonkar, Knitting Technology (Universal Publishing Corporation, Mumbai, 1998).

[5] Meoli, D. & May-Plymlee, T. 2002, "Interactive electronic textile development: a review of technologies", *Journal of Textile Apparel, Technology Management*, vol. 2, no. 2, pp. 1–12.

[6] Tang, S. & Stylios, G. 2006, "An overview of smart technologies for clothing design and engineering", *International Journal of Clothing Science and Technology*, vol. 18, no. 2, pp. 108–128.

[7] Gotipamul G.L., Ingole K.S.,& Deka A.B, "Conductive yarns: agreat scope in technical textile" Colourage May 2015, pp.44-56.

[8] Perumalraj R. "Studies on conductive textile materials for electromagnetic shielding" Ph.D Thesis August 2009.