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APPLICATIONS OF TECHNICAL EMBROIDERY AND CONDUCTIVE YARNS IN E-TEXTILE DESIGN

E-TEKSTİL TASARIMINDA TEKNİK NAKIŞ UYGULAMALARI VE İLETKEN İPLİKLER

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ABSTRACT

When textile and fashion design approaches are examined, besides aesthetic and creative design studies, it is seen that innovative systematic studies in which technology, engineering, science and art are melted in the same pot stand out. Systematic design approach is considered to be very useful in industrial product design and engineering design and it has been used in scientific design approaches in recent years. Smart textiles, interactive textiles, electronic textiles or soft electronics have become a developing field in the field of textile and fashion design by following systematic design processes and applying technological developments to textile field. As a result, these concepts have been used not only in experimental studies but also in designs that are increasingly applicable to daily life. Researches, which focus on the integration of electronics into textiles, examine the applications of textile production methods such as weaving, knitting, printing, non-woven, embroidery (embroidery) in this field and supervise the design of electronics in accordance with textile structures. For this reason, this research has been developed as a compilation study on embroidery applications developed for use in electronic textile production. In particular, e-textile designs can be applied by embroidering stainless steel yarns and silver-coated polyamide yarns on textile surfaces in accordance with various sensor applications. In these designs, three different methods are seen mostly such as standard embroidery technique, tailored fiber / monofilament placement method (TFP) and sewing technique. In this article, while the usage and applications of embroidery technique in the electronic textiles (e-textiles) were being addressed, properties and usage area of conductive yarn in e-broidery also were discussed.
Keywords: Textile design, Electronic textiles, Conductive yarn, Embroidery

ÖZET

Günümüzde ortaya konan tekstil ve moda tasarımı yaklaşımları incelendiğinde estetik ve yaratıcı tasarım çalışmalarının yanısıra teknoloji, mühendislik, bilim ve sanatın aynı potada eritildiği yenilikçi sistematik çalışmaların öne çıktığı görülmektedir. Sistematik tasarım yaklaşımı endüstriyel ürün tasarımı ve mühendislik tasarımı alanlarında oldukça faydalı görülmekte ve son yıllarda bilimsel tasarım yaklaşımlarında kullanılmaktadır. Tekstil ve moda tasarımı alanında sistematik tasarım süreçlerinin izlenmesi ve teknolojik gelişmelerin tekstil alanına uygulanması ile akıllı tekstiller, interaktif tekstiller, elektronik tekstiller ya da yumuşak elektronikler gelişen bir alan olmuştur. Bunun sonucu olarak bu kavramlar sadece deneysel çalışmalarda değil, giderek günlük hayata uygulanabilir tasarımlarda kullanılmaya başlanmıştır. Konusunu elektronikler tekstillere entegre edilmelerinden alan araştırmalar tekstil üretim yöntemleri olan dokuma, örme, baskı, dokusuz yüzey, nakış (brode) gibi yöntemlerin bu alandaki uygulamalarını incelemekte ve elektroniklerin tekstil yapılarına uygun tasarlanmalarını denetlemektedir. Bu nedenle bu araştırma elektronik tekstil üretiminde kullanılmak üzere geliştirilen nakış uygulamalarını konu

alan bir derleme araştırma olarak geliştirilmiştir. Özellikle paslanmaz çelik içerikli iplikler ile gümüş kaplı poliamid ipliklerin nakış tekniği ile tekstil yüzeylerine çeşitli sensör uygulamaları doğrultusunda işlenmesiyle e-tekstil tasarımları uygulanabilmektedir. Bu tasarımlarda standart nakış tekniği, lif/monofilament yerleştirme yöntemi (TFP) ve dikiş tekniği olarak üç farklı yöntem görülmektedir. Bu makalede elektronik tekstil (e-tekstil) tasarımında kullanılan nakış (brode) tekniğinin uygulamaları ele alınırken, nakış işleminde kullanılan iletken ipliklerin özelliklerine de değinilmiştir.
Anahtar Kelimeler: Tekstil tasarımı, Elektronik tekstil, İletken iplik, Nakış

1. INTRODUCTION

Design is defined as a goal-oriented problem-solving action and an optimal solution of all real needs under certain circumstances (Bayazıt, 2004). It is a complex, often contradictory, nonlinear process. The problem-solving action in its structure reveals pragmatic and situational processes for the designer, because even if the initial conditions of the design problem are explicit, the path through which the design will orient the designer is often ambiguous. Stolterman, McAtee, Royer and Thandapani (2009:11) has expressed this phonemena as "design is more about how we use tools to achieve our goal, rather than how we carry out things flawlessly". With the same approach, the main purpose of the designer is to establish a bond with the consumer by employing art, science, technology and engineering at certain rates. In some cases design benefits by supporting science, technology and innovation, where in other cases it creates an impact on the product produced by the designer by reinforcing art and craft, cultural and social belonging,

Design feeds on art, engineering, technology and science. Essentially, it comprises over the intersection of art, science, engineering and technology.. Art, for example, is the expression of man's creative abilities and imagination through visual forms such as painting or sculpture that are valued only by their aesthetic coherence. If so, then part of the design is art. Engineering is the use of science and mathematics, economic, social and practical knowledge to solve existing problems in the environment. If so then a big part of engineering is design. Technology is the information that enables the raw material to be converted into useful products by using material, method, tool and device information. If so then one aspect of design is technology. Design knowledge is obtained through observation and experimentation, tested, systemized and collected under general theories, so design also has a scientific aspect. Design manifests creativity with technology, science with truth, function with engineering and aesthetics with art. This also reveals the integrative nature of the design (Fig. 1).

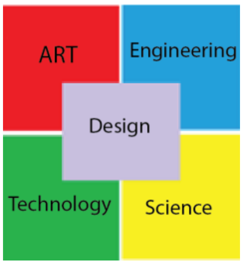

Fig. 1. Integrative Feature of Design

The past 50 years was a period that has witnessed the separation of design from the intuitive and artistic background being supported by approaches and seeking for analytical processes and a methodological basis. As an inevitable consequence of this, positivist perspective has been included in design processes and paradigms of science and engineering studies have been questioned in design intuition. In this manner, design has been re-defined as "the entire activities carried out optimally in the physical solution domain.to satisfy the needs identified in the functional domain." Undoubtedly, the main purpose of all these activities conducted, were just for the product development process.

Mayda and Börklü (2008:14), referring to the systematic approach of Pahl and Beitz during product development process, quotes that the set of needs has to be defined in the first place, followed by a series of activities that resulted in detailed product description and design. Just as explained, Pahl and Beitz, (Pahl, Beitz, Feldhusen & Grote, 2007) proposing the Systematic Design Approach, have attributed the design to the scientific basis and commenced some rules to be followed. The aim was to increase the internal reliability of the design, to ensure that the results were repeatable and to provide good designs by mid-level designers.

The common objects of both scientific and artistic creations are "present object", "mental object" and "object as a completed creation" (Yetişken, 1992:48). As expressed in this statement, design aims to present the message through objects as well. However, the responsibility of the designer continues until the objects are shaped and finished in mind. Undoubtedly one of the completed creations which take place in important areas of human life as a result of this responsibility is textile. Textile is a phenomenon which is developing, revolutionizing and evolving in a very fast and continuous cycle by forming its own discipline. Bye (2010) defines fashion and textile design as a discipline having both fields of application, science and research. According to her, textile design has many common issues and characteristics with the general design discipline of engineering and architecture. In this respect, textile designers need to blend technological issues such as chemistry, fiber physics, knitting, weaving and spinning together with aesthetic qualities such as color, composition, texture and form to produce textiles that satisfy customer demands (Studd, 2002: 36).

Textile design products feed all other sectors from automotive to medical applications, geological textiles to fashion, and there are functionality applications besides textile aesthetic concerns on textile products (Studd, 2002: 36). Though aesthetic and creative production research is less visible topics in terms of financial support when compared to technical textiles using quantitative methods, electronic textile projects, and specialized wearable systems developed for many sporting or apparel businesses are topics that have higher financial support (Bye, 2010: 209). Thus, textile design has shifted its research areas towards the development of high value added technological products. "Smart textiles" is one of the leading technological textiles with high added value. In addition to its traditional use, it has gained some properties such as sensor, light emitting and information reflection by combining with electronic components (Parzer et. al, 2018). They are included in the category of smart textiles, smart materials and electronic textiles with these features.

First-generation e-textiles were designed to fulfill predetermined fictions under limited conditions which resulted in failure when the specified conditions were exceeded. However, with the advent of soft electronics into textiles field, new generation e-textiles have functions that can detect changes in their environment. The concept of "Smart and Interactive Textiles has emerged with the addition of features to perceive and adapt to changes in the environment. When the developments in the electronics industry are examined, it is seen that especially the studies are made on the micro-electronic elements. With the developments in this field, by the integration of micro electronics into yarn and fabric structures and by incorporation into textile production methods such as weaving, knitting and embroidery, an environment has ben established for smart and interactive textiles (Martinez-Estrada, Moradi, Fernández-Garcia ve Gil, 2018; Rathnayake, 2015).

Embroidery as one of the most used surface decoration techniques has become a mass production technique after the Industrial Revolution and its purpose of use has expanded thanks to technological developments to the e-textiles field. Mecnika, Hoerr, Krievins, Jockenhoevel and Gries (2015) indicate that embroidery technique is mostly used in e-textile production. This is because it requires a cheap and easy technique for the application of conductive yarn or tapes and provides flexibility and washability for wearable applications. With this approach, the use and application of embroidery and sewing technique used in electronic textile design is given and the properties of the conductive yarns used are also mentioned in this article.

2. E-TEXTILE DESIGN

In addition to acting as a carrier substrate for e-textiles by adding electronic and conductive components and by printing circuits on fabric, textile materials form (additive) e-textiles itself by producing with conductive materials (constructive) (Fig. 2) (Parzer et al, 2018: 750). Intelligent fabric sensors can be considered as a category of intelligent textiles. E-textiles, equipped with sensing equipment, detect physical and chemical changes such as temperature, pressure, electric current, humidity, pH. Because of the fact that textile materials are in direct contact with the human body, they are considered as an ideal material for sensor design. Electronic textiles are of great interest due to their applications in the field of wearable electronics, portable devices, and especially military and civilian uniforms, health monitoring and portable power supply (Wu, Liu, Zhang, Zhang and Qin, 2017: 697). Wearable electronics are the most efficient textile-based applications of recent years for sensor, and actuator operations (Bonfiglio, 2014:153). Flexible wearable electronics are used as new applications in imaging various physiological properties due to their interaction with the human body (Zhang, Fairbanks ve Andrew, 2017: 1).

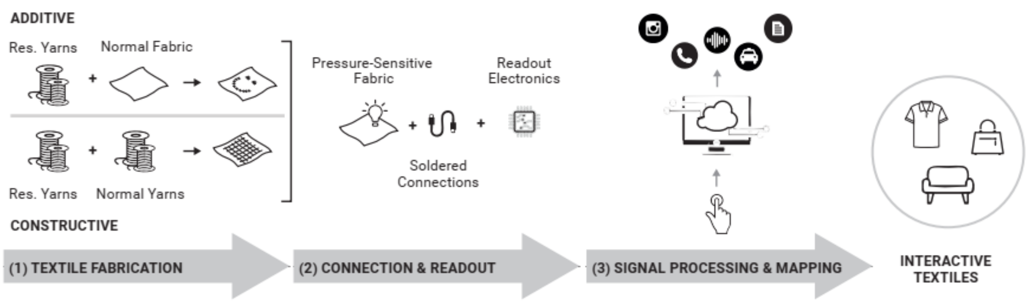

Fig. 2. E-textile Developing Process (Parzer et al, 2018: 750).

Capacitive and resistive sensor approaches in developing the sensing capabilities of e-textiles are the subjects identified by the researchers. Capacitive approaches are based on the principle of separating conductive materials that act as electrodes with a dielectric material. In e-textiles, conductive electrodes can be formed by weaving, knitting, printing and sewing-embroidery methods. Dielectric materials consist of conventional textile materials such as foam and polymer materials. Resistive approaches, on the other hand, are formed by separating textile materials which are generally conductive with semiconductor compressible textiles (Parzer et al, 2018: 746).

Although it attracts attention in various fields, today e-textiles have some disadvantages. These include washability, weight, low flexibility, breathability and comfort. Wires are usually used for cable communication in e-textiles especially used for measuring vital signals in the health field (Rathnayake, 2015). The most important disadvantages of academic studies on e-textile designs can be categorized as mechanical effects, washability, power supply and product development -commercialization. Textile scientist, chemical and physicist, software engineer, electrical and electronics engineer, textile and fashion designers should work together in order to design an e-textile covering these issues.

Fig. 3. First generation e-textile (**a,b**), Second generation e-textile (**c,d**), Third generation e-textile (**e**) [Linz, Kallmayer, Aschenbrenner ve Reichl, 2006, (**a**); Ağaç ve Balkiş, 2018 (**b**); Lee, 2012 (**c**); Bilir ve Gürcüm, 2017 (**d**); Rathnayake, 2015 (**e**)]

Today, the vast majority of accessible e-textiles are developed by integrating electronic components onto them. In the first generation systems, the integration of the electronic devices on the clothes is done by a small pocket (Bonfiglio, 2014:155). Developed in 1999 in collaboration with Philips-Levi's, the jacket is an example of the first generation of work. Ağaç and Balkiş (2018) is an example of the first generation of studies in which the accelerometers are attached to the clothes for the determination of body posture. In the second generation, electrical connections and functions are provided by conductive yarn and fabric structures. Embroidery applied T-shirt developed to measure body vital signals (ECG) is an example of second generation studies. All components used in the integration of sensors in the ballistic vest design study of Bilir and Gürcüm (2017) are at fiber or yarn level. In the third generation e-textile applications, electronic components are developed by fully embedding in the yarn Structure (Rathnayake, 2015: 15). Weaving, knitting, sewing-embroidery and printing techniques come to the fore in third generation applications (Fig.3). (Parzer et al, 2018: 749)

In recent years, fabric / yarn approaches have been included in the classification of wearable devices. The basis of these applications is the development of wearable devices with the addition of very thin plastic sensors to the fabric Structure (Zhang et al, 2017:1). Cherenack, Kinkeldei, Zysset & Troster (2010), while integrating the sensor structure on the polyimide strip into the woven fabric, Mattana et al (2013) used the leds they applied on the strip in the weaving process (Fig. 4).

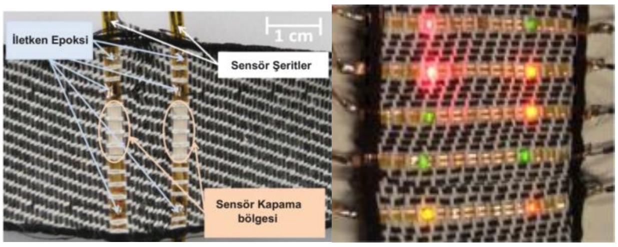

Fig. 4. Sensor stripes entegrated weaving (Cherenack, et al, 2010: 741; Mattana et al, 2013: 3903)

3. CONDUCTIVE YARNS AND USAGE IN ELECTRONIC TEXTILES

Yarns with functional properties such as conductivity are used in weaving, knitting, sewing, and embroidery for e-textile applications. Conductive wires with acceptable current and low resistance values play an important role for smart textiles where lighting application is desired, as the use of high-resistance yarns for sensor and heating works can yield better results. When the production methods of conductive yarns are examined, they can be classified as metal reinforced yarns, conductive polymer applied yarns and yarns coated with conductive material (Cherenack and Pieterson, 2012: 5). Information about the conductive yarns and their application areas in the field of e-textiles is summarized in Table 1.

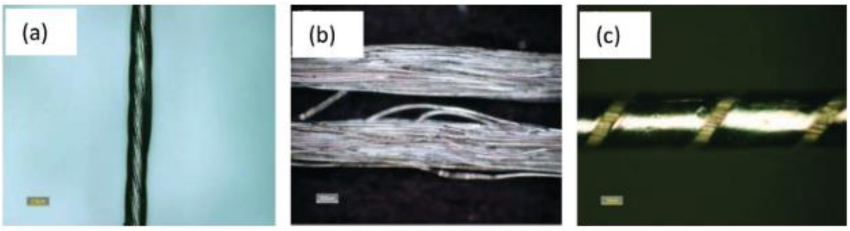

Fig. 5. Different types conductive yarns: (**a**), Ag coated copper wire (**b**) Ag coated Polyamid multiflament yarn and (**c**) metal covered multifilament kevlar yarn (Cherenack and Pieterson, 2012: 5).

Table 1. Conductive Yarns Used in Electronic Textiles and Their Applications

Referance	Yarn structure	Advantage-disadvantege	Field	Technique
Paradiso, Loriga and Taccini, 2005	Stainless steel (SS)/Viskose	-	Sensor	knitting
Linz et al, 2006	Ag coated polyamid yarn (Shieldex)	Easy stitch	ECG sensor and circuit conductor line	Embroidery
Huang, Tang and Shen, 2006	Carbon coated yarn	Knitting and Weaving application	Sensor	Knitting
Gilliland, Komor, Starner and Zeagler, 2010	Ag coated polyamid yarn (Shieldex)	-	E-textile sample book	Embroidery
Mitchell, Coyle, O'Connor, Diamond and Ward, 2010	Bekinox 100% SS 2-ply yarn	-	Pulse sensor	Knitting
Zhang and Tao, 2012	SS fiber addition yarn	-	Pressure map	Embroidery
Özkaya, 2014	NE 20/1+NE 20/2 and 0.035 mm SS wire	Low conducivity	Electromagnetic shielding	Knitting
Shanbeh and Emadi, 2015	SS fiber/ polyester	High streching	Sensor	Weaving
Saenz-Cogollo, Pau, Fraboni ve Bonfiglio, 2016	Ag coated polyamid yarn (Shieldex)	-	Pressure map	Embroidery

Table 1. Conductive Yarns Used in Electronic Textiles and Their Applications

Referance	Yarn structure	Advantage-disadvantege	Field	Technique
Roh, 2017	Metal composite yarn and Ag coated polyamid yarn	Easy stitch and high conductivity	Touch sensor	Embroidery
Greenspan, Hall, Cao and Lobo, 2018	Ag coated polyamid yarn and SS wire yarn	High resistive	Strain sensor	Embroidery
Martinez-Estrada et al, 2018	Shildex 117/17 dtex Ag coated polyamid yarn	Easy stitch	Moisture sensor	Embroidery
Chen, Ukkonen and Virkki, 2018	Shieldex Ag coated polyamid yarn 110f34 dtex 2ply	Easy stitch	Antenna	Embroidery
Jiang et al, 2018	SS and Ag coated polyamid yarn	Resistant to water and low acidic solutions	Antenna	Embroidery
Eryuruk, Bahadir and Kalaoglu, 2018	SS yarn	-	Heat panel	Embroidery
Briedis, Valisevkis, Ziemele and Abele 2019	Ag coated yarns: Elitex, Weixing, Madeira. SS yarn: Thermotech	high conductivity	Sensor	Embroidery
Ankhili et al, 2019	Shieldex, Madeira	-	ECG electrot	Embroidery

4. TECHNICAL EMBROIDERY APPLICATIONS IN ELECTRONIC TEXTILES

Technical embroidery using conductive yarns has been a very effective method in the development of textile-based electronic circuits. Because it provides free circuit design compared to weaving, knitting and printing techniques. Thanks to computer-aided embroidery technique, electronic circuits can easily be processed on fabric. In addition to all these advantages, it also facilitates the connection between the electronic circuit and other components (Roh, 2018:163). Tailored fiber placement (TFP) and embroidery techniques are the most commonly used techniques in technical embroidery applications (Fig. 6). This method ensures orientation of a fiber or cord on the ground material in all directions, creation of three-dimensional structures and offers vast opportunities in structureand shape design. In embroidery technique, surface formation is ensured by combining conductive upper yarn and dielectric lower yarn (Mecnika et al, 2015: 56).

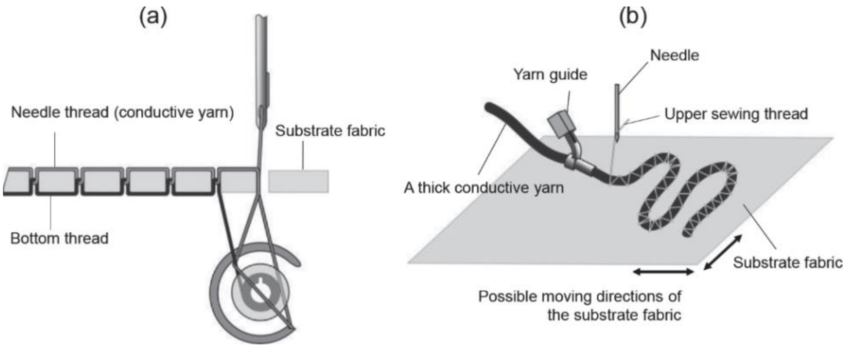

Fig. 6. Embroidery technique (**a**) tailored fibre/wire placement (**b**) (Roh, 2018:163)

Technical embroidery applications are concentrated in the fields of automotive textiles, medical textiles and e-textiles as well (Mecnika et al, 2015: 57). Since conductive materials are often used in the embroidery processes studied in these fields, this process is referred to as electronic embroidery (e-broidery). In recent research projects, textile antennas and magnetic resonance sensors are implemented using e-embroidery technique (Jiang et al, 2018; Kiourti, Lee ve Volakis, 2016; Osman, Abd Rahim, Samsuri, Salim ve Ali, 2011; Virkki, Chen, Bjorninen ve Ukkonen, 2017; Wang, Zhang, Bayram ve Volakis, 2012).

Martinez-Estrada et al, (2018) developed a moisture sensor with embroidery technique in their studies. For this purpose, 140/17 dtex nylon yarn coated with 99% purity silver was used and cotton fabric was preferred as the substrate. Impedance were measured in the climatic test chamber in order to measure the sensitivity of the developed sensor, 25-65% relative humidity at 20 ºC. In addition, measurement variants and washing test performances of the embroidery sensor are examined. According to the results of the measurements, it was found that the developed sensor can be useful in the field of wearable applications for moisture measurement (Fig. 7).

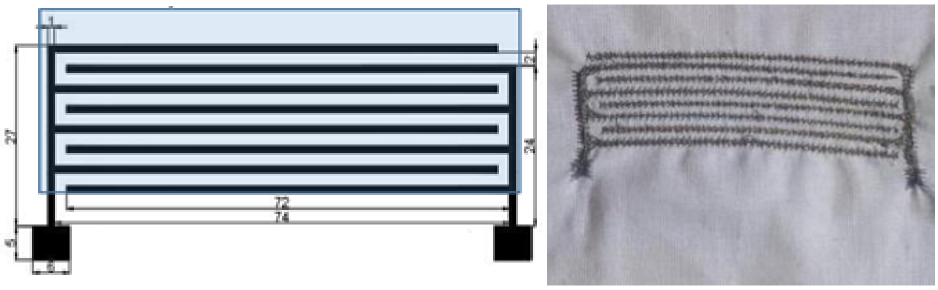

Fig. 7. Capacitive Embroidery Moisture Sensor (Martinez-Estrada et al, 2018: 2)

Roh (2017), in the study, aims to develop touch sensors with embroidery technique. In this study, metal composite yarns and silver coated nylon yarns were used as conductive yarns. Metal composite yarns are used in circuit design and connection lines, while high resistance silver yarns are used to create the sensor pattern (Fig.8)

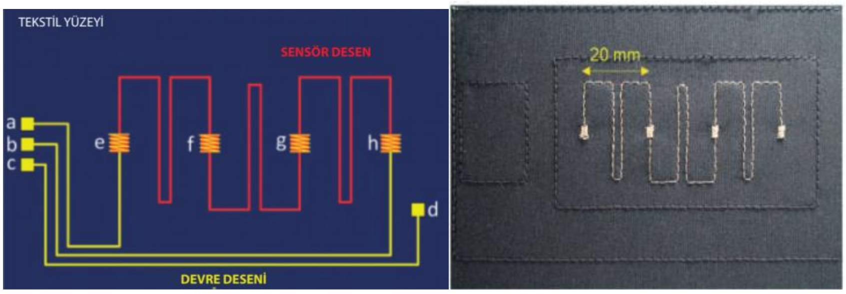

Fig 8. Touch Sensor Design with Embroidery Technique (Roh, 2017:1448)

Zhang and Tao (2012) used the stitch technique to develop a pressure mapping sensor. In the study, conductive yarns were used as sensing elements and the sensing mechanism is based on the resistance difference between the two conductive yarns. Conductive yarn structure used contains 275 fiber stainless steel. Another important step applied in this study is to cover the junction points of conductive yarns with silicone material. Thus, the resistance change caused by pressure is optimized. Composing of lightweight and flexible materials of the product developed in the study allows using in the field of wearable electronics (Fig. 9).

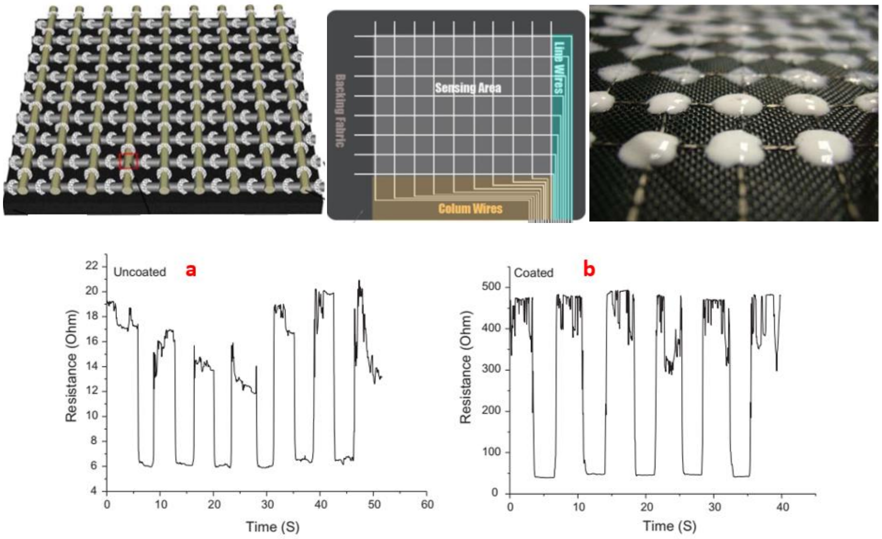

Fig. 9. Uncoated (**a**) coated (**b**) sensors (Zhang and Tao, 2012: 1152,1156)

Greenspan et al (2018) performed a textile-based sewing sensor to measure human movements. In this study, silver coated conductive yarns and stainless steel yarns were used. In order to determine the best sewing geometry, 4 different sewing geometries were studied. and two different sensor lengths were used. As a result of the experiments, the resistance value increased as the stretch ratio increased. As a result of the stretch test, the best results were obtained by using yarn 1, zigzag stitching and 90/10% polyester / elastane fabric (Fig. 10).

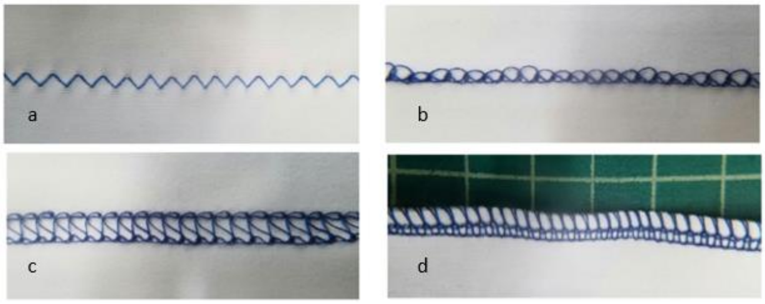

Fig.10. Stitching types for strecth sensor; zig-zag stitch (**a**), Chain stitch (**b**), bottom cover stitch (**c**), overedge stitch (**d**). (Greenspan et al, 2018:3)

Saenz-Cogollo et al (2016) aimed to develop a mat-like pressure mapping system based on a single layer textile sensor and intended to be used in home environments for monitoring the physical condition of persons with limited mobility. For this purpose, silver coated conductive yarns were sewn orthogonally by sewing technique and PEDOT: PSS (poly (3,4-ethylenedioxythiophene): poly (styrene sulfonate) liquid dispersion was applied to the intersection points of the yarns. When the data obtained in the study were compared with the results of commercial products, it was found that the textile based pressure sensor could be used in the field of health applications (Fig. 11).

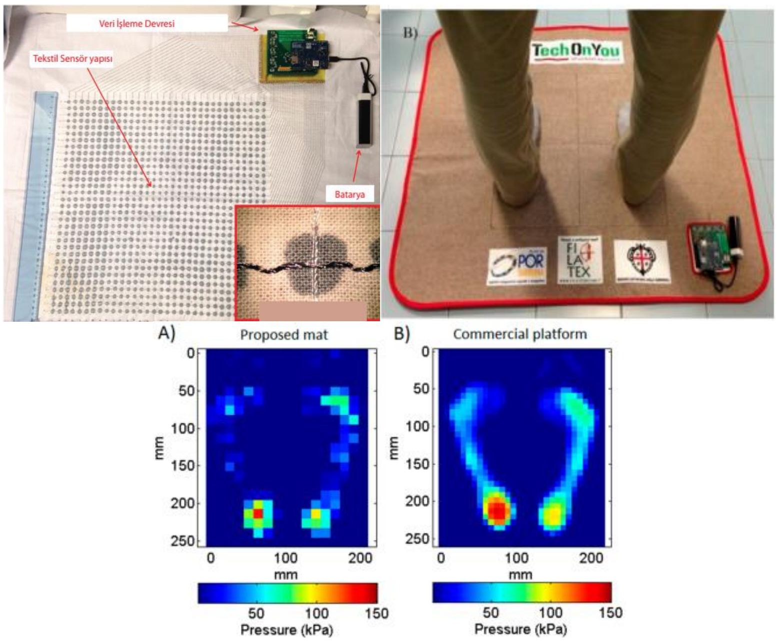

Fig 11. Commerical Pressure Map and Textile Based Pressure Sensor Test Results (Saenz-Cogollo et al, 2016:5)

Linz et al (2006) in their study, designed a prototype T-shirt that can measure ECG signals. the circuit and processor designed for the processing of ECG signals were applied with sewing technique in this study. ECG electrodes and circuit conduction paths are constructed thorugh emboridery technique using silver-coated conductive yarns. The transmission paths between the electrodes and the circuit are formed using the zig-zag stitch for maximum flexibility (Fig. 12).

Fig. 12. ECG Sensor T-shirt (Linz et al, 2006)

Gilliland et al (2010) created an e-textile sample book by preparing e-textile samples that could serve multiple purposes. In the study, while using silver coated conductive yarns, they determined the diameters of the yarns. According to this; unlike fine yarns, the using of thick yarns provides a low resistance values, it has caused mechanical problems on working of the sewing machine (Fig. 13).

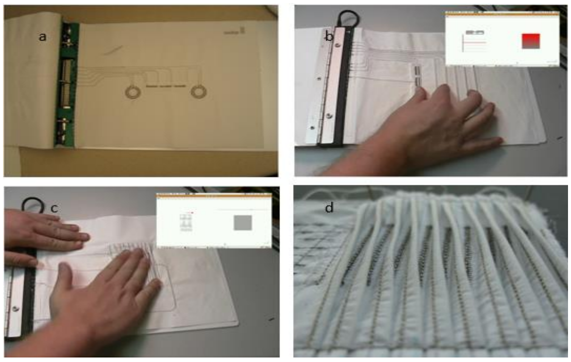

Fig. 13. E-tekxtile Sample Book, Rocker Switch (**a**), Menu (**b**), Elektronic Pleat (**c**), Detailed Pleat (**d**) (Gilliland et al, 2010)

Briedis et al (2019) have evaluated the electrical performance of conductive yarns used for the integration of electronic components and sensor applications in e-textile designs as a result of washing tests of different sewing applications. In this study, silver coated yarns (elitex, weixing and madeira) and stainless steel micro-fiber (thermotech) yarns were examined (Fig. 14). Among all yarns, thermotech yarn has the best conductivity after washing, while among the silver-coated yarns, the best result is observed in elitex yarn.

Fig. 14. Stitch Types for Washing Test (Briedis et al, 2019)

Ankhili et al (2019) aimed to develop textile electrodes using the embroidery technique for the purpose of electrocardiography imaging (Fig. 15). In this study, two different conductive yarns of shieldex and madeira were sewn using ZSK embroidery machine. Conductive yarns were coated with dielectric yarns and thermoplastic polyurethane (TPU) to increase the washing resistance of the developed textile electrodes. As a result of the washing tests, shieldex yarn was damaged more than madeira yarn. In addition, the protection process with ordinary yarns on the conductive yarn showed better results than the TPU coating.

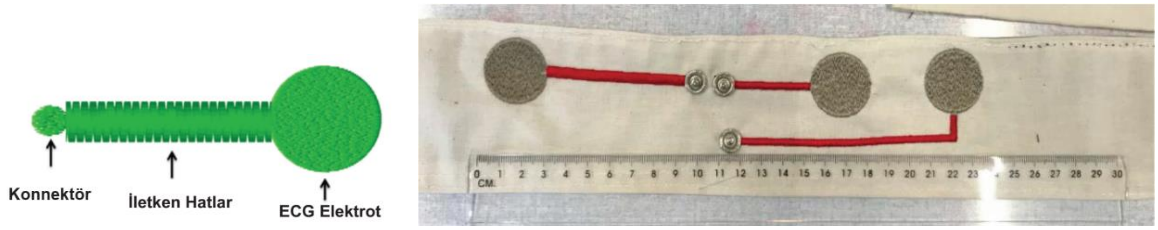

Fig. 15. Embroidery Electrocardiography Electrot (Ankhili et al, 2019)

In addition to academic studies, there are commercially developed products. Illuminated led textile products developed by the e-broidery ® brand of Forster Rohner AG are among the commercial products. In order to increase the usability of conductive yarns in embroidery machines, ZSK (Germany) made some changes in embroidery machines and made it possible to apply technical embroidery (Fig. 16).

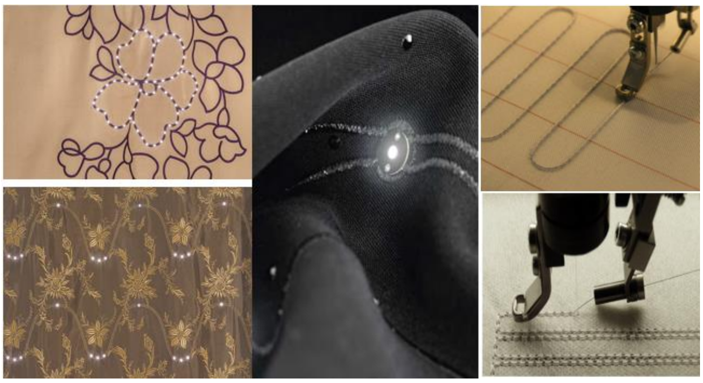

Fig. 16. E-broidery Led Textile Applications, Froster Rohner AG (left), ZSK Technical Broidery Systems (right)

5. RESULTS

In textile design, which is one of the areas where functional and aesthetic concerns are seen the most, positive sciences should be used in addition to creativity in order to reveal a useful product design. While the concept of aesthetics is based on creativity, functionality is demonstrated by the coordination of technology, science and engineering. The systematic design approach has played an important role in the development of textile-based sensors to meet the needs of e-textile design.

There are many research projects and various approaches in textile based sensor design and application. Embroidery technique is one of the prominent approaches with the advantages of sensor design in various geometries and various material possibilities. Embroidery technique, which was used only in the past to create decorative textile products, is an effective method in developing functional products today. Computer-aided manufacturing and developments in textile materials are of great importance in ensuring this functionality. The use of computer-aided embroidery systems which provide flexible patterning, especially in e-textile applications and conductive yarns, has led to the transfer of electronic circuits onto the fabric. Particularly stainless steel yarns and silver coated nylon yarns have been used in the development of various sensors. These sensors are especially used for monitoring physical, chemical and biochemical parameters. In addition to applications requiring high conductivity, heating panels has been developed by using yarns with high conductivity resistance.

In addition to R & D focused studies, it is seen that embroidery-based products have started to take place in the field of innovative textile design. Therefore, embroidery technique was not only effective for applied research but also for transferring technology to industry. Therefore, in this research, textile production methods which are used during the integration of electronics into textiles and especially the applications of embroidery and sewing in this field have been examined and the researches that stainless steel content yarns and silver coated polyamide yarns are used in embroidery technique for textile sensor applications have been compiled.

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