

5. SUMMARY AND CONCLUSION

Textiles has one of the longest histories of all human activities and the history of textiles spans thousands of years with the materials changing from animal skin and leaves in old days to the plethora of yarns and fabrics at present. Also advancements in science and technology has transformed fabrics from the early cave men's interlacements of animals skin's and reeds for protection to men's hi tech interlacements of textured yarns and conductive yarns to develop 'Smart' or 'Intelligent' textiles. The wearable e-textiles became one of the main research avenues in the textile field. The world is becoming more and more "health conscious" and the need for the improvement of the quality of the health care in medicine is necessary. Textile is playing a great role in the development of monitoring systems for health care safety. In electro-textiles, new techniques such as using conductive yarns have been developed to provide an innovative soft textile interfaces that are highly acceptable to the end user in this present world. The wearable e-textiles are still a new field with opportunities to build innovative products that can revolutionize the way that persons interact with their garments. Conductive yarns play a vital role in the production of these types of textiles and garments. They enable the collection, storage and transformation of signals received from one source, may be human body, animals or any object and convert it into digital or luminant forms which could be noted for further action. Any metallic substance which is capable of transforming electrical charges could be used as conductive yarns.

Considering these aspects, designing a smart wearable garments with conductive yarns for transforming electrical charges has been taken up as a research work by the investigator.

The major objectives of the research planned are:-

- ▶ To identify the current scenario of smart textiles and its awareness.
- ▶ To weave fabrics with different conductive yarns and combinations.
- ▶ To prepare knitted fabrics with selected conductive yarns.

- ▶ To evaluate the physical, mechanical, absorbency and conductive properties by standard test methods.
- ▶ To embed appropriate sensor on the above mention fabrics to develop smart wearable electronic fabrics.
- ▶ To evaluate the efficiency of the prepared smart wearable electronic fabrics.

The experimental procedure includes the phases mentioned below: -

Phase I: Survey on awareness of Smart Wearable Kids Health Monitoring System

A survey was planned to be conducted among young mothers to know their level of interest in smart textiles and further to explore awareness in them about wearable kids health monitoring system. Structured survey method was carried out among hundred young mothers with infants. Questionnaires are the most commonly used tool in survey so the investigator framed a questionnaire using a combination of both open ended and close ended questions which included questions related to the awareness on smart textiles and willing of young mothers to use wearable health monitoring systems.

Initially a pilot study was conducted with a group of young mothers to confirm about the clarity of the questions and to analyze the difficulties in answering. After the pilot study corrections and clarifications were made. Later the main survey was carried out for a period of a month. Care was taken to select one hundred young mothers who were educated for the survey. Apart their willingness to take part in the survey was also considered. The questionnaires were given to the mothers when they came to the clinics/hospitals. The duly filled questionnaire was collected from the mothers on the same day after 15 to 30 minutes.

Phase II: Development of Conductive Fabric through different methods of Fabrication process:

Cotton is non-allergic and a preferred fiber for underwear, infants wear and especially for garments worn close to the skin. Considering this the major quality cotton yarn was selected for the study. Silver ranks first in strong electrical conductor list

followed by copper and aluminium and used in electrical components like contacts and circuits for its high conductivity. Therefore, the commercially available copper, aluminum and silver wires were selected as conductive yarns for the study.

To avoid friction and for free flow, without breakage during fabrication, the selected conductive yarns were first twisted with cotton yarns each separately using an automatic twisting machine. Weaving and knitting, being most popular and common method of fabric formation were selected. The twisted conductive yarns were then integrated into textiles by weaving and knitting.

In weaving the twisted conductive yarns namely aluminium, copper and silver yarns were interlaced in the weft direction. Cotton yarn interval was separated into three divided namely 15cm cotton yarn width, 10cm cotton yarn width and 5 cm cotton yarn width. Also the widths of conductive yarns were divided into 5cm, 2cm and 1cm respectively. Finally by combining these different width variations, the investigator produced nine combinations of conductive fabrics using aluminium, copper and silver each separately and one plain cotton fabric. The weaving was carried out in power loom and the nomenclatures for the conductive woven fabrics are given below:

Nomenclature of Woven Fabrics

Conductive yarn	Aluminum			Copper			Silver			Original cotton woven fabric	
	Distance	5 CM	2 CM	1CM	5 CM	2 CM	1CM	5 CM	2 CM		1CM
Cotton distance	15 CM	AA	AB	AC	CA	CB	CC	SA	SB	SC	OW
	10 CM	AD	AE	AF	CD	CE	CF	SD	SE	SF	
	5 CM	AG	AH	AI	CG	CH	CI	SG	SH	SI	

In knitting, the investigator produced conductive knitted fabrics and plain cotton knitted fabric using hand operated knitting machine. The selected conductive yarns namely aluminium, cotton and silver yarns were separately passed through the feeder

from the spools at most care to produce separate conductive knitted fabrics. Also cotton knitted fabric was produced. Totally three conductive fabric and one plain cotton fabric were made by knitting and the nomenclatures for the conductive knitted fabrics is displayed below:

Nomenclature of Knitted Fabrics

S.No	Sample	Fabric
1	OK	Original cotton knitted fabric
2	AK	Aluminum knitted fabric
3	CK	Copper knitted fabric
4	SK	Silver knitted fabric

Finally by weaving, nine combinations of conductive woven plain weave fabrics were made using cotton yarn and conductive yarns namely copper, aluminum and silver thread. Knitting results in one plain cotton fabric and three conductive fabrics. The fabrics produced were evaluated by suitable textile test methods. These results for their physical properties of all the samples were analyzed with the help of statistical tools.

Phase III: Designing of System for Integrating Sensors into Wearable Electronics

The focus of the research is to design a wearable electronic garment for continuous monitoring of healthcare of the infants. Commercially available LM35 body temperature sensor and pulse rate sensor were selected to monitor the vital signs. A block diagram of electronic module was designed for data processing and wireless transmission of the processed data. Then the module was prepared with Arduino Uno microcontroller by coding the necessary program for health care monitoring of vital signs. Bluetooth HC-05 module for wireless communication and lithium ion battery for power supply were selected for the study. Smart phone, the convenient medium for data receiving was selected to display the vital signs to parents and pediatrician.

The investigator designed infant garment jabla with front open with conductive yarns to run across the chest line. The garments were constructed each separately with LM35 sensor and pulse sensor and the electronic module was attached to it suitably. This was tested for its working efficiency.

Phase IV: Product development and Analysis of Wearable Electronics for Monitoring Infants Healthcare

The investigator selected the animal wear study for the research as it was not advisable to directly conduct a wear study on infants. Based on the veterinary doctor advice, the investigator developed an electronic band using the three conductive fabrics each separately with 5cm width, 2cm width and 1cm width of conductive yarns namely aluminium, copper and silver yarns in the center respectively.

The experimental protocol was approved by the Institutional Animal Ethical Committee (IAEC) of the Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamilnadu, India with approval No. AIW: IAEC.2017: TC: 01. Twelve male Albino Wister rats weighing between 150-200g were selected by the investigator and wear study was done accordingly by separating the rats into two groups as controlled and experimental groups. The designed wearable electronic bands were put in order as presented below:

Coding of Wearable Electronic Bands

S.No	Conductive Yarns	Width of Conductive Yarns		
		5 cm width	2 cm width	1 cm width
1	Aluminium	Band AA	Band AB	Band AC
2	Copper	Band CA	Band CB	Band CC
3	Silver	Band SA	Band SB	Band SC

The experimental rats were divided into 3 groups accordingly to wrap around the wearable electronic bands AB, AB, AC respectively (Two rats were wrap with each type of band). At the start, the bands were attached with LM35 temperature sensor to measure the body temperature. It was wrapped on the rats at normal conditions. The full setup of rats with bands was done by putting them in a small cage each separately with the help of veterinary assistant as shown in the Plate-XXXIII to avoid mishappenings of the rats. The

reading for every twenty minutes was noted using the smart phone by the investigator. This was repeated for three times for each day. Later the rats were left free without band to have its normal activities.

Next day fever was induced in the evening for all the experimental rats and from the following morning, the readings of the fever temperature was noted by the investigator in the smart phone at an interval of one hour for twenty minutes continuously. During this period, the actual body temperatures of the rats were also assessed by the veterinary assistant using common medical tool for experimental group of rats. The body temperatures for controlled rats were also noted. Then the mean values were calculated for both the noted readings of experimental rats. This was compared to find the accuracy of the wearable electronic band.

In the same method as started above, the pulse rate sensor was plugged into one set of connecting pins in the conductive yarns to note the heart rate of the experimental group of rats. Then the readings were noted for the heart rate by the investigator at an interval of one hour in the smart phone for twenty minutes continuously. The heart rate for controlled group of rats and experimental rats were also noted by the veterinary assistant using common medical tool. The mean value was calculated. Later both the noted readings of experimental and controlled rats were compared to find the accuracy of the wearable electronic band.

The process for monitoring temperature and heart rate was repeated for three days alternatively, where in on the 1st, 3rd and 5th days the rats temperature and heart rate was noted at normal condition. On the 2nd, 4th and 6th days the temperature and heart rate was noted after inducing of fever. After the study, rats were tested to assess its health condition with the help of veterinary assistant and then were sent to the rehabilitation center.

Salient Findings of the Study

- ❖ The outcomes of the survey showed 92% of young mothers facing difficulty in monitoring body temperature and heart rate for their infants. Also 56% of young mothers were aware of Smart electronic wearable fabric products but not used it except for a few and 44% of young mothers are totally unaware of it.
- ❖ Seventy eight per cent of young mothers preferred using a safe wearable electronic garment to monitor their infant's body temperature and heart rate. Majority of mothers selected reusable electronic garment and preferred to remove electronic modules while washing.
- ❖ In the choice of communication medium, 41% of young mothers preferred mobile/smart phone as it was a comfortable and convenient device to handle. Regarding the cost preference, 68% of young mothers preferred economical garment. Sixty four percent of young mothers were interested in using wearable electronics garments for home-use in monitoring infants.

The survey on awareness of smart wearable health monitoring garment among young mothers shows increased curiosity, interest in smart textiles and preference for safe wireless monitor for their infant's healthcare and awareness in wearable electronics.

Yarn Test

- ❖ Aluminum conductive yarns had highest thickness which ranged between 0.332 to 0.353mm followed by copper and silver having 0.11 to 0.12mm and 0.08 to 0.09mm respectively. An aluminum yarn was thicker when compared to other selected yarns. Aluminum had the maximum elongation of 6.6 cm which is 22% in elongation percentage, followed by copper and silver as 20% and 18% respectively.

Woven Fabric

- ❖ Amongst the aluminium conductive woven fabric samples, AA, AD and AG samples with 5 cm conductive yarns showed the highest weight and the maximum weight was seen in sample AA as 260.59g. With regard to copper conductive

woven fabrics, when compared in groups based on cotton yarn width variation it was found that the samples CA, CD and CG with 5cm conductive yarns in each the highest mean weights as 178.73g, 187.2g and 193.46g respectively. Similarly for silver conductive woven fabrics, the samples SA, SD and SG with 5cm of conductive yarn showed the highest weight. The F values of samples AB and AD showed significant at 1% level and all the samples showed significance in t-test.

- ❖ Fabric thickness of all the samples increased irrespective of the type of conductive yarn used when compared with plain cotton fabric. Among the aluminium conductive woven fabric, the sample AG showed highest mean thickness as 1.13mm. Among the copper conductive woven fabrics all the samples showed similar increase in thickness without much variation and the maximum thickness was seen in the samples CA as 0.65 mm. Similarly all the silver conductive woven fabric samples showed maximum increase in thickness. On statistical analysis, all the samples showed significant of 1% level. The F value is significant for samples AA, AE, AI, CA, CD, CE, CG, SA, SF and SH.
- ❖ Fabric tensile strength in warp direction for all the samples of aluminium woven conductive fabrics, copper conductive woven fabrics and silver conductive woven fabrics showed increase in tensile strength in warp direction when compared with plain cotton fabric. As a whole, the maximum tensile strength was seen in the sample CC as 43.31 kg and the least tensile strength was noted in the sample AG as 34.85 kg. The result is statistically proven to the significant difference at 1% level for all the samples. The F values is significant for the samples AC, AH and SA.
- ❖ All the samples of aluminium, copper and silver conductive woven fabric showed maximum increase in fabric tensile strength in weft direction when compared with plain cotton fabric. The difference in width of conductive yarn influenced the tensile strength of conductive fabric and the maximum strength was seen in the sample AD as 51.98 kg.
- ❖ The elongation property of all the samples of aluminium, copper and silver conductive woven fabric showed similar increase in strength when compared with

plain cotton fabric in warp direction. On statistical analysis, all the samples showed 1% level significance except the sample SB. The F values of the samples AA, AC, AD, CF, CG, SE and SH showed 1% level significance.

- ❖ Fabric elongation for all the samples of aluminium, copper and silver conductive woven fabric showed maximum increase in weft direction when compared with plain cotton fabric. The maximum mean elongation was seen in the sample AE as 10.33% among aluminium conductive woven fabrics, by the sample CI as 10.65% among copper conductive woven fabrics and in the sample SB as 9.88% among silver conductive woven fabrics.
- ❖ The integration of conductive yarns into the fabric structure showed highest abrasion strength in warp direction due to the influence of thickness of conductive yarn in the fabric. The result of the abrasion resistance is statistically proven and the samples showed 1% level significance except the sample SF. The F values of samples AG and SF are significant at 1% level.
- ❖ Fabric abrasion strength of all the samples of aluminium, copper and silver conductive woven fabric showed increase in resistance in weft direction when compared with plain cotton fabric. The maximum number of cycles was noted in the sample AE as 1606 and the least number of cycles was seen in the sample SF as 59.
- ❖ In bursting strength of aluminium conductive woven fabric, the samples with 5cm of conductive yarn observed increase in strength when compared with plain cotton fabric and the maximum strength was noted in the sample AG as 10 kgs/sq cm. The samples of copper conductive woven fabric with 1cm conductive yarns scored the highest bursting strength and the maximum was noted in the samples CC and CI both as 5.9kgs/sq.cm respectively.
- ❖ The samples of aluminium conductive woven fabrics and copper conductive woven fabrics with one cm conductive yarn showed better absorbency in wicking and all the samples of silver conductive woven fabrics took similar time to wick.

- ❖ On comparing all the three conductive fabrics, the aluminium conductive woven fabrics samples showed minimum time to sink. The weight of conductive yarn influences the sinking capacity of the fabric.
- ❖ The aluminium conductive woven fabrics showed less time to absorb a drop of water completely when compared with all the three conductive woven fabrics. The thickness of conductive yarn is responsible for compactness in fabric structure that decides the water absorbency.

Knitted Fabric

- ❖ The aluminium conductive knitted fabric noted the highest weight as 293.9 g when comparing all the three conductive fabrics with plain knitted fabric. On statistical analysis all the knitted samples showed significance at 1% level.
- ❖ The integration of conductive yarn increases the thickness of the fabric and the maximum thickness seen in aluminium conductive knitted fabric as 1.71mm and the samples are significant at 1% level.
- ❖ The thickness of conductive yarn influence the abrasion resistance of the fabric and the maximum number of cycles to abrade was seen in aluminium conductive knitted fabric as 294. The samples are significant at 1% level on statistical analysis.
- ❖ The highest bursting strength was seen in silverconductive knitted fabric as 11.81 Kgs/sq.cm when compared with all the three conductive fabrics.
- ❖ The presence of conductive yarns reduces the water absorbency property of the fabric when compared with the plain cotton knitted fabric.
- ❖ The electrical resistance of silver was negligible that is high in electrical conductivity when compared with copper and aluminum with the resistance of 376.4 mΩ/Mtr and 1719.2 mΩ/Mtr accordingly. Therefore, the three conductive yarns were suitable for wearable electronics as transmission lines.
- ❖ The aluminum interlaced conductive fabric is high in surface resistance when comparing to all other conductive fabrics namely copper and silver. The surface resistance increases with increased in width of conductive yarn in the fabric.

- ❖ The efficiency of smart wearable electronic band was proved to be effective by rat wear study. The actual temperature readings were in par with reading shown in the smart phone. Hence it is clear that the smart wearable electronic band is capable of monitoring the temperature and heart rate of the rat.
- ❖ The cost of silver wearable electronic garment is Rs.245 which is the highest price among the three wearable electronic garments followed by copper and aluminium wearable electronic garment as Rs.161 and Rs.128 respectively. Also when comparing the cost of wearable electronic bands, the aluminium wearable electronic band costs less as Rs.26. Hence it is proven that the aluminium wearable electronic garment and band are cost effective

CONCLUSION

Health is considered as the most important aspect in every ones life. If one can able to check and monitor variations in the vital signs with the use wearable electronics, then the possibility of misleading will be reduced. Today women are forced to take up employment for their family income even after few months of delivery, leaving back their lovable young ones at home or day care centres. This innovative development of wearable electronic garment will be able to satisfies the requirements of young mothers by easy and effective method of monitoring. The wearable e-textiles are still a new field for creative products with more opportunities that can revolutionize the way of interaction between persons.

SCOPE FOR FUTURE WORK

- Researches related to incorporation of more sensors for monitoring many of the vital signs and even fit alert systems to inticate the emergency conditions can be carried out.
- Commercialisation of wearable garments with newly developed conductive yarns are possible
- Designed wearable electronic band can be modified for other animals to monitor their health and

- Possibilities of using the knitted conductive fabrics could studied.

LIMITATIONS OF THE STUDY

- Due to time limitation wear study of the designed infant garments could not be carried out.
- Knitted conductive fabric could not be constructed into wearable electronic garment and band due to its fabric properties.