Design/Practical Experience [EEN2020]
Department of Electrical Engineering
Final Report

Academic Year: 2022-23

Semester: Summer Term

Date of Submission of Report: 07-07-2022

1. **Name of the Student:** Mitarth Arora

2. **Roll Number:** B20EE096

3. **Title of the Project:** Understanding the Properties of Conducting Yarns

4. **Project Category:** 4
   Summer Research Project with faculty members within or outside the department

5. Targeted Deliverables:

1. Understanding the properties of conducting yarns;
2. Experimental data collection and their analysis.
3. Exploration of such yarns for wearable sensors and various applications

6. Work Done:

6.1) Understanding the properties of conducting yarns

6.1.1) Introduction

The technical textiles sector has never existed as a single, cohesive industry sector. The boundaries between conventional textiles and other "flexible engineering" materials like paper and plastics, films and membranes, metals, glass, and ceramics are continuously eroding.

Many of the fundamental textile abilities, such as handling textiles and finishing procedures, as well as knowledge of how these interact and function in various combinations, are shared by the majority of participants.

By combining the worlds of electronics and textiles, the discipline of e-fabrics creates unique products that can operate electrically like electronics and physically act like textiles. It incorporates the use of conductive yarns and fibers for power delivery, networking, and communication.

Conductive yarns are important components of E-Textiles because they serve as power supply channels or signal conduits for sensors and actuators.

The conductive qualities of the composite yarn depend on the kind of cover yarns chosen to wrap around the core. One or both of the cover yarns may be conductors. A stretchy conductive yarn should be resilient to repeated stretching and washing.

The conductivity of the composite yarn can be improved by using two conductive components.The ability of stretchy conductive yarn to resist additionally, cyclical straining and washing using two conductive components can increase the conductivity of the composite yarn.

6.1.2) What are conducting yarns?

Conducting yarn is an organic conductive fiber made of stainless steel fiber or other conductive fiber blended with ordinary fiber. It must be conductive and must be machine sewable.

Recent material and processing advances have made it possible to deposit a thin metallic layer on the surface of a thin artificial fiber, resulting in a conductive thread that is strong and flexible enough to be spun into fine yam and woven into cloth.

Moreover, the thread is strong enough to withstand other standard textile processes such as stitching and weaving, Conductive textile yarns, as well as individual conductive threads, on the other hand, are generally not homogeneous.

Some conductive textile yarns consist simply of a bundle of very fine metallic wire, with the voids between the metallic threads making the yam homogeneous. The most promising conductive threads have a strong, flexible, artificial polymer inner core, with one or more outer metallic layers or shells deposited on the exterior surface.

6.1.3) Potential of conducting yarns

Conductive fibers and yarns have drawn considerable attention during the last decade. Generally speaking ,textile materials made of organic polymers are perfect insulators .

Due to weak electrical conductivity electrical load is accumulated on the surface of organic polymers.Therefore, to prevent the accumulation of electrical load, to enhance the possibility of electrical load transfer and to obtain electromagnetic shielding effect, the textile materials are turned into electrically conductors by using different methods.

Conductive yarn is an important component and connector of electronic and intelligent textiles, and with the development of high-performance and low-cost conductive yarns, it has attracted more attention.Smart fabrics and wearable electronics are set to succeed portable electronics as the next milestone in the modern information technology era .

6.1.4) Properties acknowledged and studied

Physical properties:

1. Low weight: The weight of conducting yarn is important when considering its applications and usage. An important property to study. Tex is the unit used in textile industries to measure the density of yarns. It is equal to 1 gram per 1000 meters.
2. Flexibility: Flexibility is the ability to resist permanent deformation under bending, lateral stress and strain. A yarn will be sewn into different patterns .Thus, studying its flexibility property was required.

Electrical properties:

3. Resistance:The resistivity defines the intrinsic nature of the material. The yarns are conductive in nature. Resistance is a magnitude of the conducting nature shown by them. Variance of resistance with length, under stress and with temperature change was studied.
4. Capacitance: Two parallelly weaved conducting yarn can show capacitive behavior which was studied and the change in capacitance under different conditions like in presence of ions was measured and experimented.

Mechanical properties

5. Tensile Strength:A Universal testing machine (UTM) is used to test the mechanical properties (tension, compression etc.) of a given test specimen by exerting tensile, compressive or transverse stresses.
   A specimen of a standard size and shape made of the material is pulled in tension while the load and elongation are continuously (or periodically) monitored. The data thus collected are used to generate stress strain curves. Usually tensile tests are performed under displacement control mode where the moveable end of the grip is made to move at a constant speed. The load and displacement (strain) records are stored at specified intervals of time. Once the sample breaks the machine stops.

6. Thermal Coefficient of resistance:Temperature coefficient of resistance (TCR) is the calculation of a relative change in resistance per degree of temperature change. It is measured in ppm/°C (1ppm = 0.0001%) and is defined as: **TCR = (R2- R1)/ R1(T2- T1)**.The temperature coefficient of resistance for a resistor is determined by measuring the resistances values over an appropriate temperature range. The TCR is calculated as the average slope of the resistance value over this interval.

6.2) Experimental data collection and their analysis (Properties Wise)

6.2.1) Experimental Start with two yarns and their properties

a.) For this experiment we experimented on two varieties of yarns to study their mechanical , electrical and thermal properties.

a.1) First type of yarn is made up of 13μm radius with polyester on the outer layer

a.2) Second type is 20% blended steel which is uniformly mixed up with 80% polyester .

b.) The UTM (Universal Testing Machine) was used to test the yarn breakdown point based on its mechanical properties, as well as its elongation was measured(shown in table below) and breakdown point helped us to understand the extent to which yarns can be stretched while stitching and weaving.

All the data and results corresponding to it are shown below:

Table.1 a)Breakdown point of type 1 yarn (with outer polyester layer) b)Breakdown point of type 2 yarn(blended steel yarn)

a)

Number of strands	**2**
Length	**2.5 cm**
Elonagtion (mm)	Load(Kgf)
0	0
0.1	0.1
0.291	0.3
0.575	0.39
0.591	0.39
0.798	0.39
1.48	0.705
1.779	0.705
1.986	0.795
2.194	0.795
2.5	0.9
2.7	0.6
2.807	0

b)

Number of strands	**2**
Length	**5 cm**
Elongation (mm)	Load(Kgf)
0	0
0.1	0.1
0.277	0.1
0.476	0.188
0.675	0.188
0.978	0.3
1.687	0.293
1.886	0.398
2.189	0.39
2.39	0.5
2.9	0.5
3.1	0.6
3.3	0.6
3.6	0.5
3.79	0

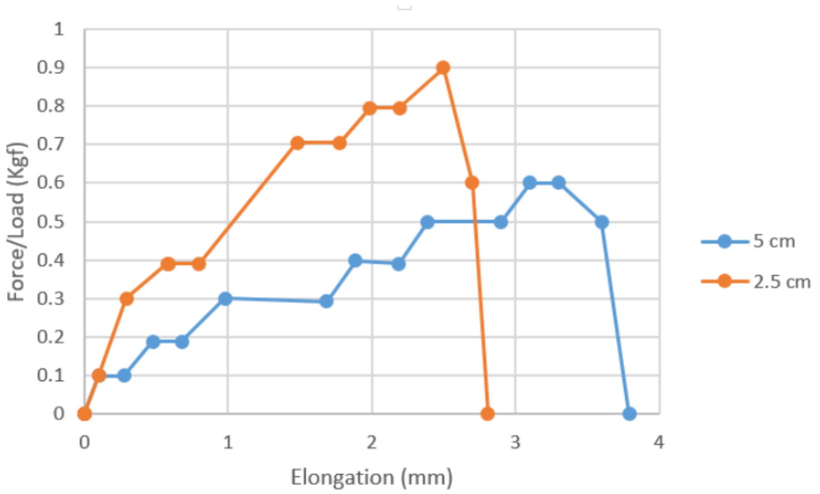


Fig.1 Plot of elongation vs load for the yarn type 1(orange curve) and type 2(blue curve)

c.) The TCR (Temperature Coefficient of Resistance) Machine was used in this experiment to get the Voltage-Current Graph at different temperatures for the blended steel yarn(type 2) to calculate the thermal coefficient of resistance as shown in data below.

Table.2 Resistance and voltage of the conducting yarn with different current passed at temperature 30 degree celsius

Temperature = 30 °C				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	19.9	19.45	19.675	196.75
200	39.8	40.31	40.055	203.8
300	59.7	60.51	60.105	200.5
400	79.5	72.5	76	158.95
500	99.54	93.33	96.435	204.35
600	99.5	121.2	110.35	139.15
700	140.29	127.75	134.02	236.7
800	151.59	143.16	147.375	133.55
900	160.78	160.54	160.66	132.85
1000	178.77	178.77	178.77	181.1
			Average resitance =	**178.7700000000**
			Resistance from linear regression =	**178**

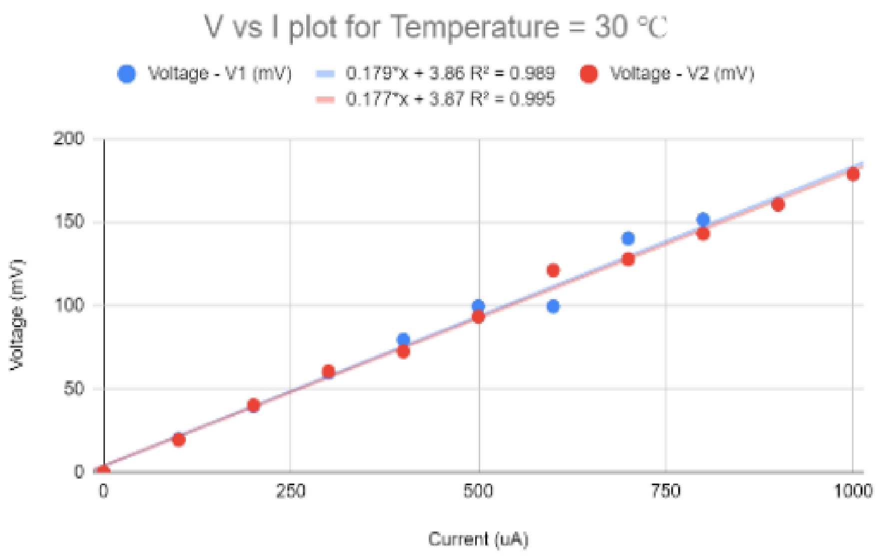


Fig.2 Plotting the voltage-current graph and finding a linear relation using linear regression

Table.3 Resistance and voltage of the conducting yarn with different current passed at temperature 35 degree celsius

Temperature = 35 °C				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	15.62	16	15.81	158.1
200	31.3	32.1	31.7	158.9
300	46.97	47.71	47.34	156.4
400	62.67	63.56	63.115	157.75
500	78.44	79.45	78.945	158.3
600	94.18	95.37	94.775	158.3
700	109.82	111.1	110.46	156.85
800	126.02	126.72	126.37	159.1
900	142.15	142.54	142.345	159.75
1000	158.15	158.15	158.15	158.05
			Average resitance =	158.15
			Resistance from linear regression =	158

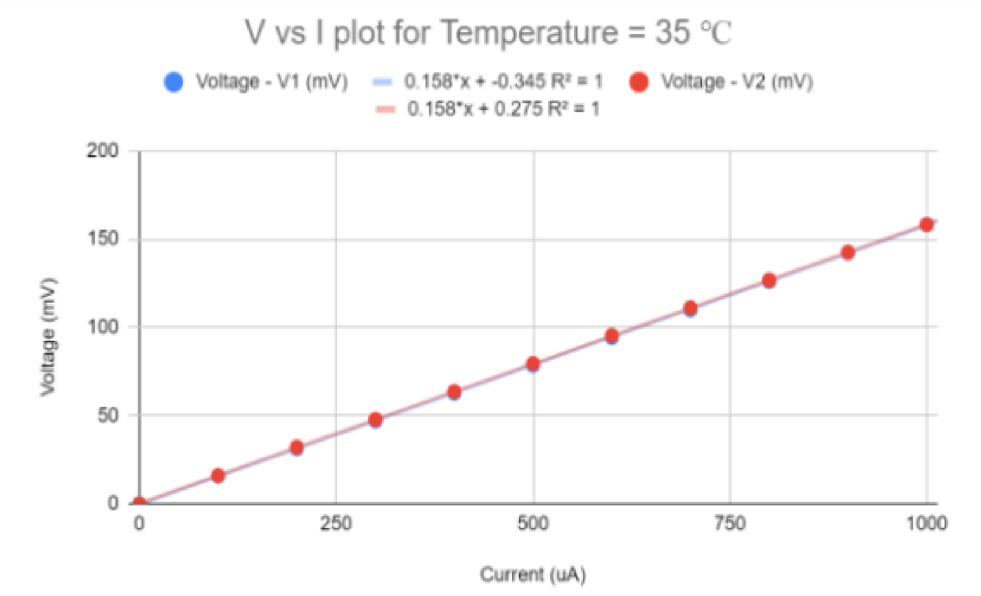


Fig.3 Plotting the voltage-current graph and finding a linear relation using linear regression

Table.4 Resistance and voltage of the conducting yarn with different current passed at temperature 40 degree celsius

Temperature = 40 ℃				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	15.51	16.46	15.985	159.85
200	31.1	32.88	31.99	160.05
300	46.75	49.4	48.075	160.85
400	62.45	65.45	63.95	158.75
500	78.16	81.13	79.645	156.95
600	93.88	97.06	95.47	158.25
700	109.67	113.2	111.435	159.65
800	125.6	129.18	127.39	159.55
900	145.06	145.29	145.175	177.85
1000	161.3	161.3	161.3	161.25
			Average resitance =	161.30
			Resistance from linear regression =	160.5

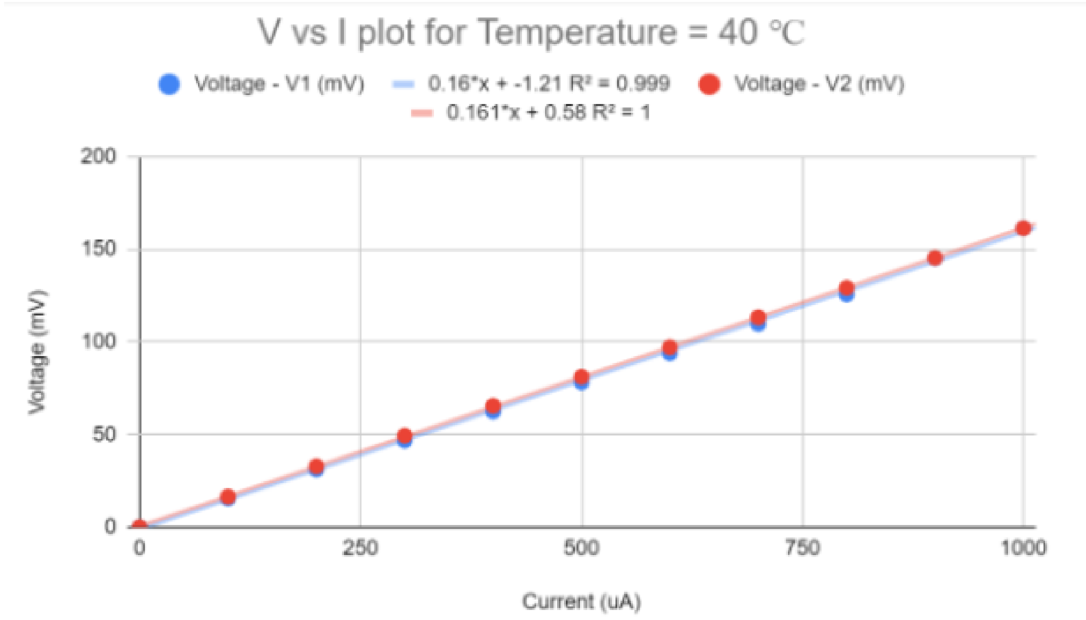


Fig.4 Plotting the voltage-current graph and finding a linear relation using linear regression

Table.5 Resistance and voltage of the conducting yarn with different current passed at temperature 45 degree celsius

Temperature = 45 °C				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	16.68	17.64	17.16	171.6
200	33.38	45.68	39.53	223.7
300	50.1	53.28	51.69	121.6
400	66.8	72.29	69.545	178.55
500	83.48	90.23	86.855	173.1
600	95.46	130.77	113.115	262.6
700	111.07	152.3	131.685	185.7
800	126.82	171.2	149.01	173.25
900	143.45	149.01	146.23	27.8
1000	161.14	161.14	161.14	149.1
			Average resitance =	166.70
			Resistance from linear regression =	169

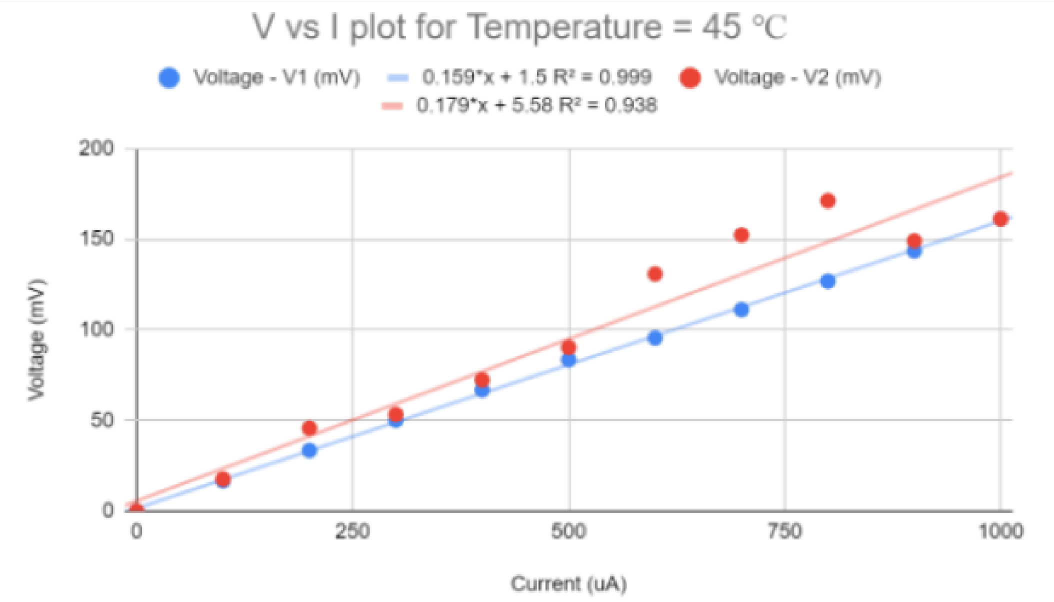


Fig.5 Plotting the voltage-current graph and finding a linear relation using linear regression

Table.6 Resistance and voltage of the conducting yarn with different current passed at temperature 50 degree celsius

Temperature = 50 °C				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	18.79	23.34	21.065	210.65
200	37.59	43.76	40.675	196.1
300	56.41	62.97	59.69	190.15
400	75.11	81.2	78.155	184.65
500	93.84	101	97.42	192.65
600	112.79	120.21	116.5	190.8
700	132.39	139.53	135.96	194.6
800	151.69	158.37	155.03	190.7
900	171.47	174.54	173.005	179.75
1000	191.56	191.56	191.56	185.55
			Average resitance =	191.56
			Resistance from linear regression =	191

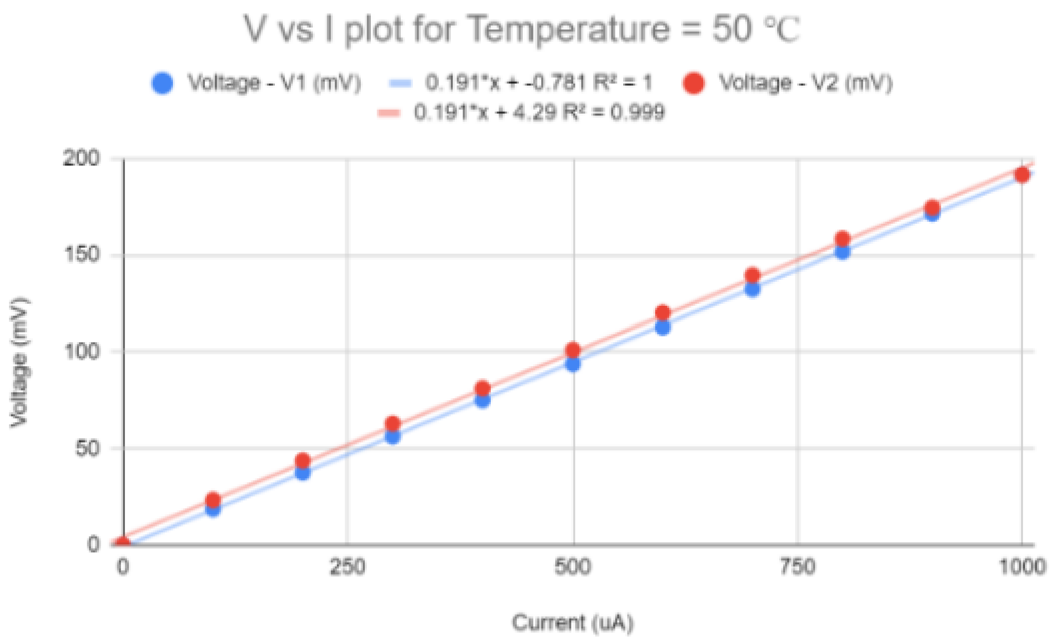


Fig.6 Plotting the voltage-current graph and finding a linear relation using linear regression

Table.7 Resistance and voltage of the conducting yarn with different current passed at temperature 55 degree celsius

Temperature = 55 °C				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance (Ω)
0	0	0	0	
100	20.24	23.49	21.865	218.65
200	40.49	46.98	43.735	218.7
300	60.78	70.47	65.625	218.9
400	81.01	94	87.505	218.8
500	101.32	117.53	109.425	219.2
600	121.63	132.45	127.04	176.15
700	142.05	148.84	145.445	184.05
800	162.51	169.66	166.085	206.4
900	183.25	190.54	186.895	208.1
1000	211.37	211.27	211.32	244.25
			Average resitance =	211.32
			Resistance from linear regression =	207.5

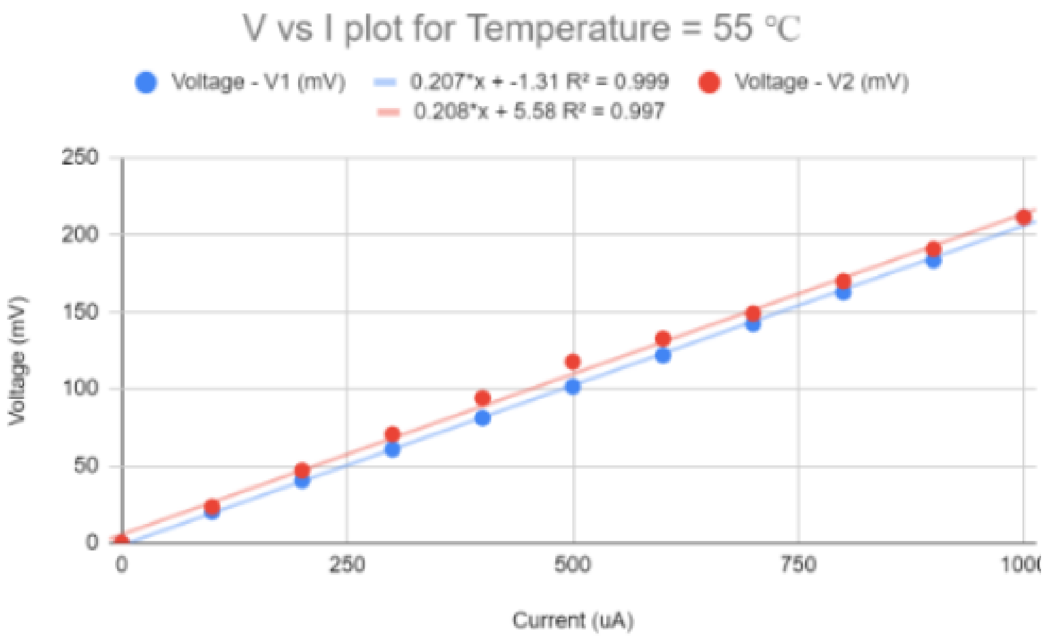


Fig.7 Plotting the voltage-current graph and finding a linear relation using linear regression

Table.8 Resistance and voltage of the conducting yarn with different current passed at temperature 60 degree celsius

Temperature = 60 °C				
Current (uA)	Voltage - V1 (mV)	Voltage - V2 (mV)	Average Voltage (mV)	Resistance Ω)
0	0	0	0	
100	24.42	26.24	25.33	253.3
200	48.77	51.57	50.17	248.4
300	73.17	81.47	77.32	271.5
400	97.75	109.92	103.835	265.15
500	122.25	139.49	130.87	270.35
600	146.97	169.58	158.275	274.05
700	181.55	229.94	205.745	474.7
800	198.3	205.12	201.71	40.35
900	223.87	229.47	226.67	249.6
1000	252.72	252.72	252.72	260.5
			Average resitance =	260.79
			Resistance from linear regression =	257.5

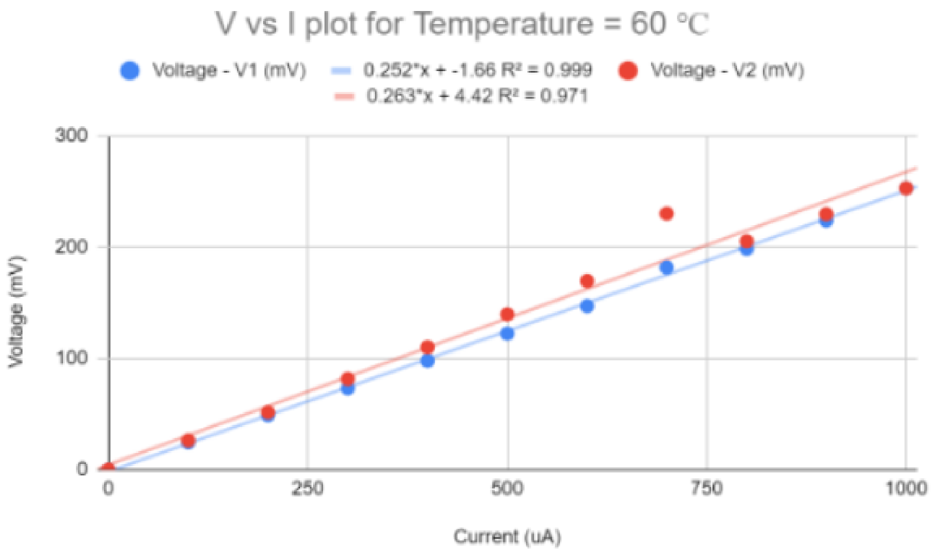


Fig.8 Plotting the voltage-current graph and finding a linear relation using linear regression

d.) Calculated the Thermal coefficient of resistance for the different temperature and the average tcr for the yarn as given out below:

Table.9 Thermal Coefficient of resistance for the blended steel yarn(type 1)

T1(celsius)	T2(celsius)	R1(ohm)	R2(ohm)	TCR(ppm/celsius) X(10
35	40	158	160.5	0.3
40	45	160.5	169	1.05
45	50	169	191	2.6
50	55	191	207.5	1.72
55	60	207.5	257.5	4.8
30	60	178	257.5	1.4
			avg.TCR	1.978333

e.) Now using the Source Meter , we calculated out the values of change in Resistance vs Number of strands over a particular sweep voltage and current for the fixed particular lengths to get an overview of strand based study.

Table.10 Results obtained from testing on source meter

Sl no	Current (uA)	Voltage -1 (V11)	Reverse -1 (V12)	Voltage-2(V21)	Reverse-2 (V22)	Resistance per unit length (Ohm / cm) from V21	Resistance per unit length (Ohm / cm) from V22	Mean
0	0	0	0	0	0			
1	100	1.7	0.6	0.6	0.44	1000	733.3333333	866.6666667
2	200	2	0.8	1.14	0.86	900	700	800
3	300	2.7	1.1	1.32	1.28	300	700	500
4	400	3.2	1.5	1.73	1.51	683.3333333	383.3333333	533.3333333
5	500	3.5	1.9	2.25	1.89	866.6666667	633.3333333	750
6	600	3.4	2.2	2.8	2.29	916.6666667	666.6666667	791.6666667
7	700	3.4	2.6	3.2	2.71	666.6666667	700	683.3333333
8	800	3.4	3	3.7	3.16	833.3333333	750	791.6666667
9	900	3.9	3.5	4	3.63	500	783.3333333	641.6666667
10	1000	4.1	4.1	4.2	4.2	333.3333333	950	641.6666667

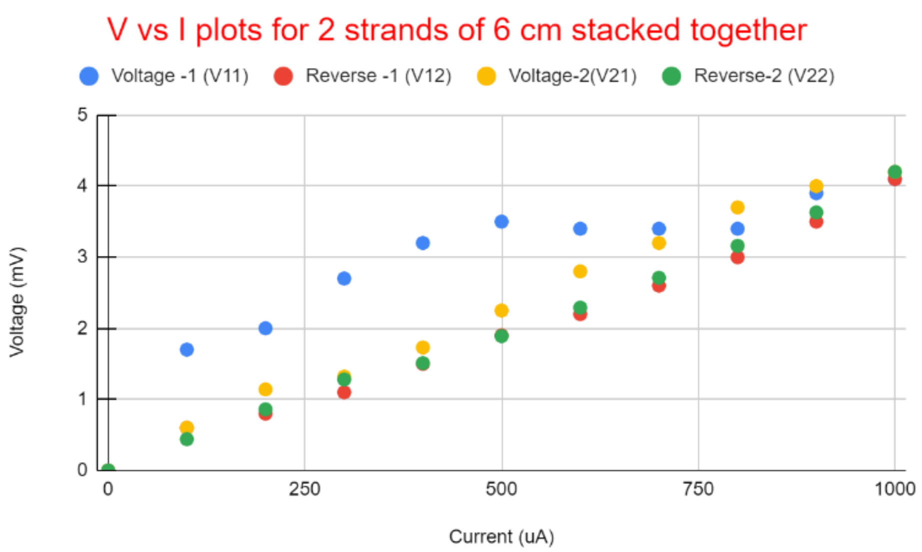


Fig.9Plotting the voltage-current graph of the results obtained from source meter f.) We proceeded on the experimental set-up shown below to calculate the Resistance vs Weight to see how the increase of load is impacting our resistance of the conducting wire.

Table.11 Change in resistance with the weight applied

weight	resistance(10^3 ohm)
11	1030
22.9	736.25
34.8	705.64
46.7	439.29
58.6	405.4
70.5	368.43
82.4	349.73
94.3	343.84
106.2	367.78
118.1	353.21
130	394.65
141.9	405.1
153.8	412.08

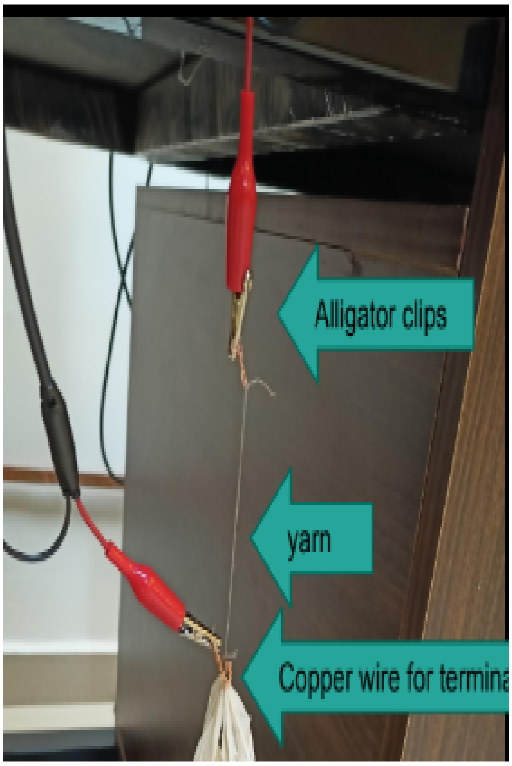


Fig.10 The setup for the experiment

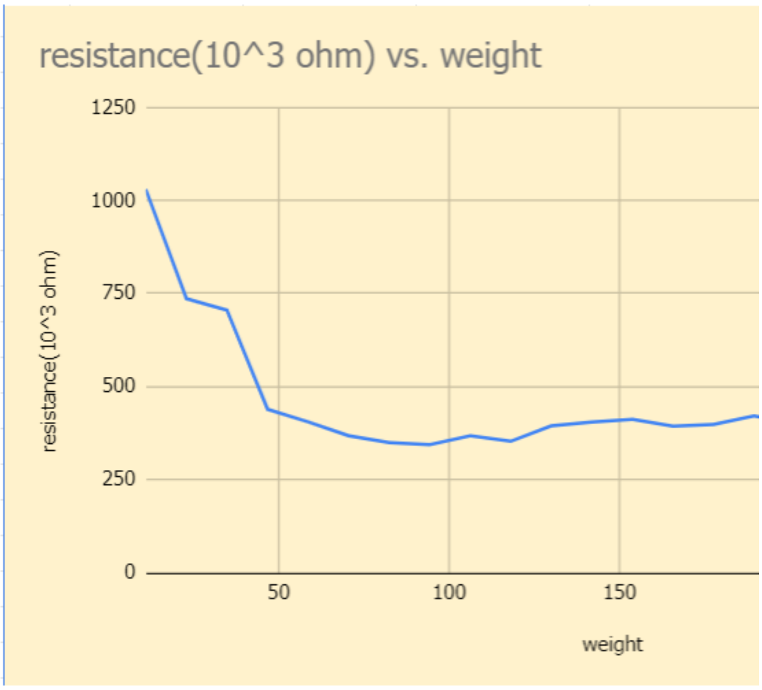


Fig.11 Plot of resistance vs. weight

g.) After working on the two types of yarn , we started working on the woven elastic based band of yarns which are woven in the particular fashion to know more about their characteristic properties such as resistance , conductance and many other applications based properties , we also observed all of these knots and weaving patterns under the compound microscope at 10x and 100x as and whenever required.

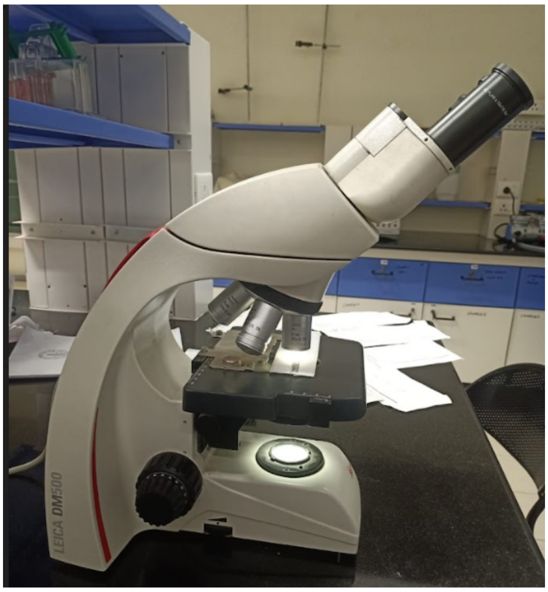


Fig.12 compound microscope used for observations

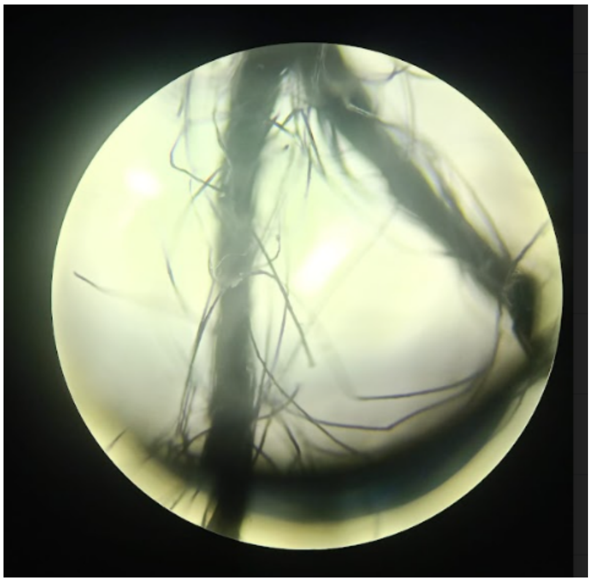


Fig.13 Weaving pattern

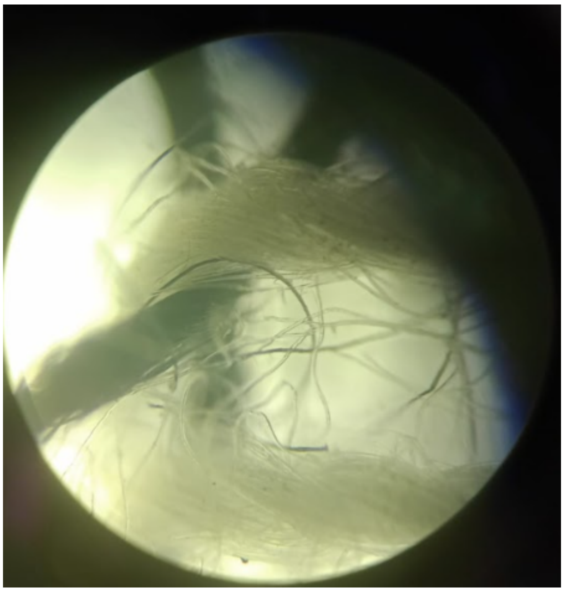


Fig. 14 Junction of conducting yarn and normal yarn under microscope

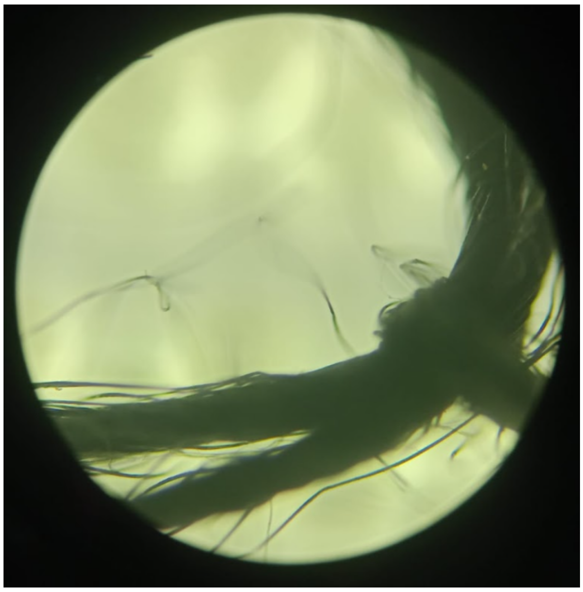
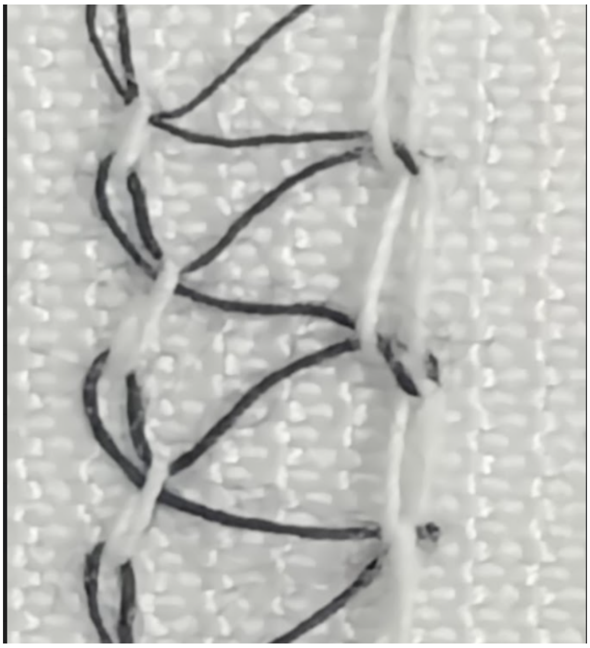
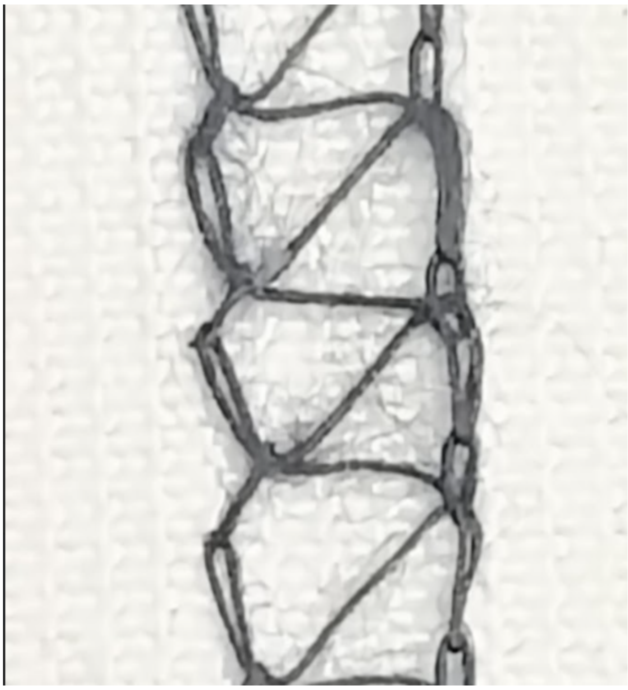


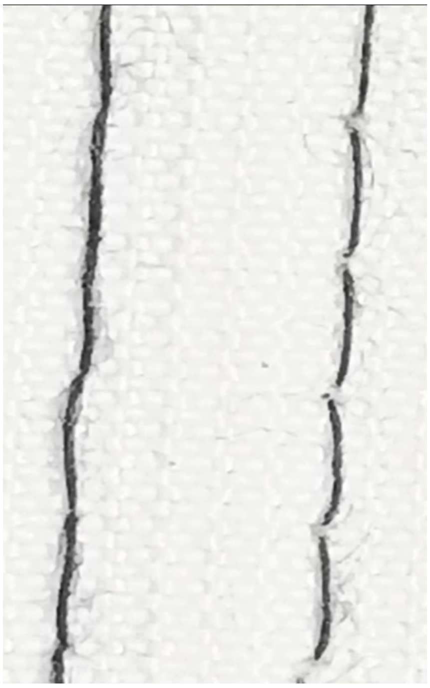
Fig.15 Knot between the yarn

Weaving patterns of different samples

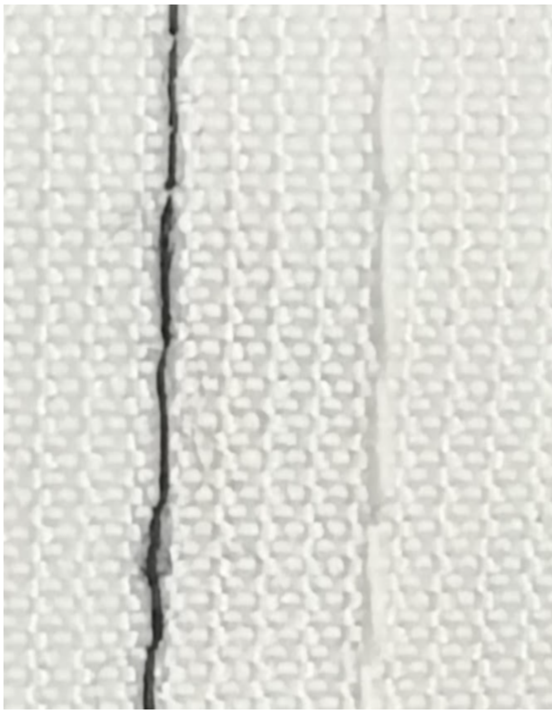


Type A - Weaving Pattern

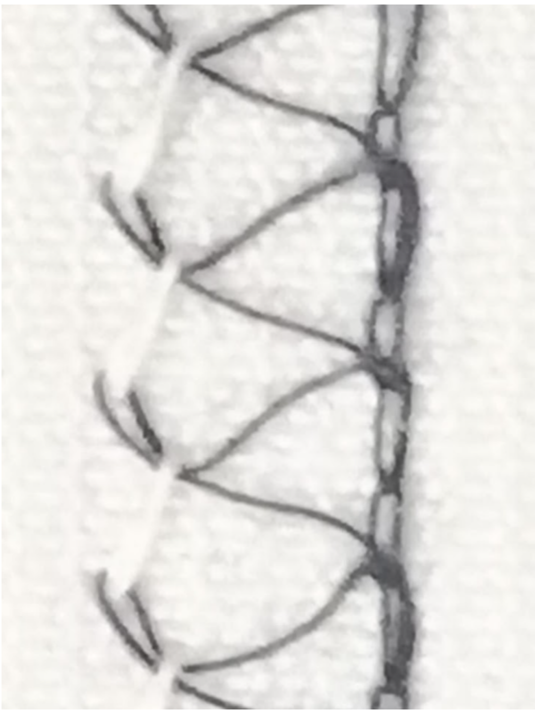




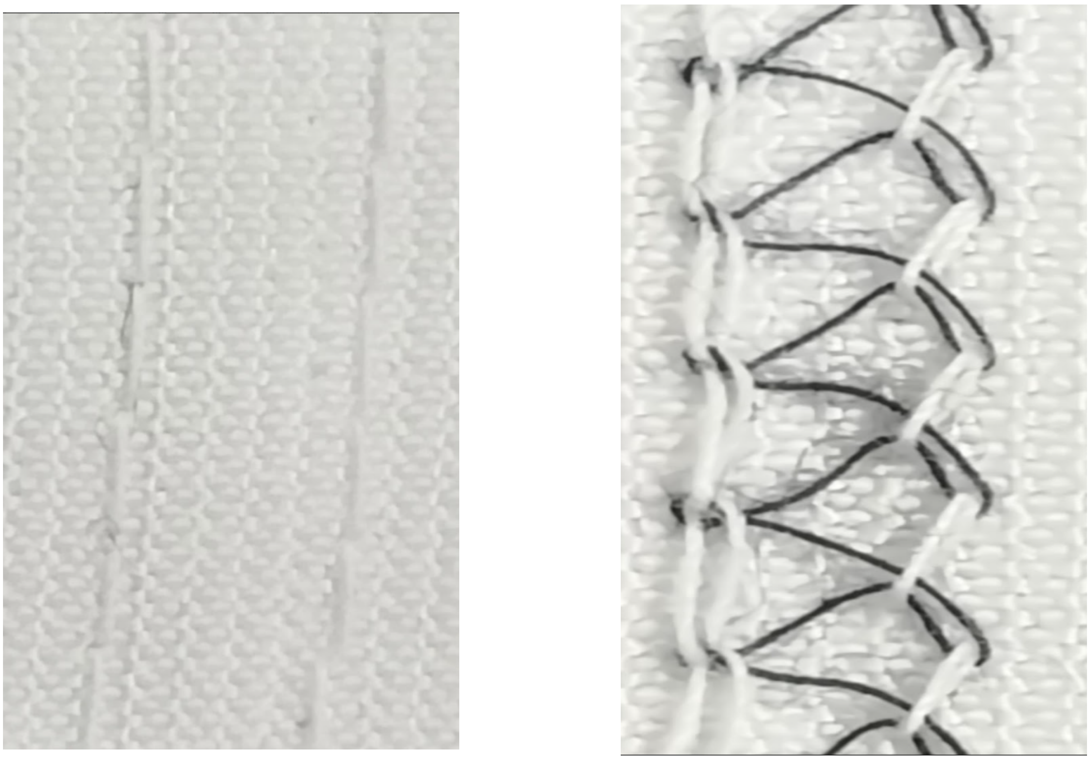
Type B - Weaving Pattern

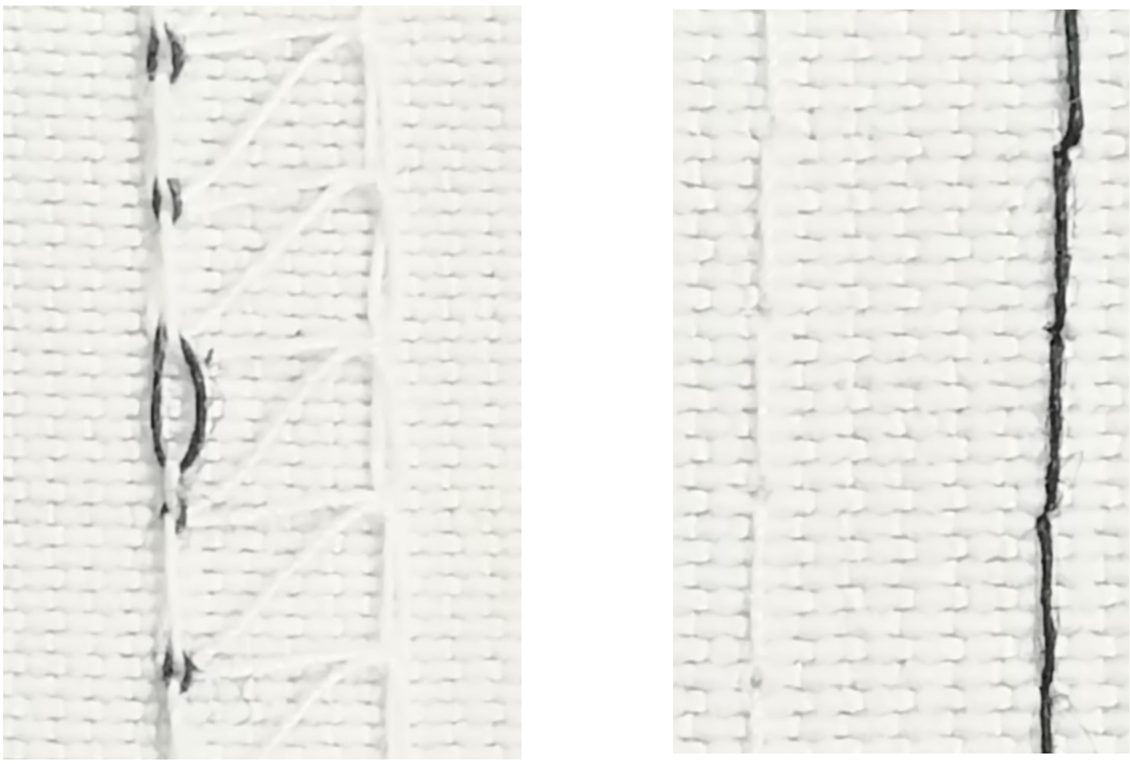
Type C - Weaving Pattern



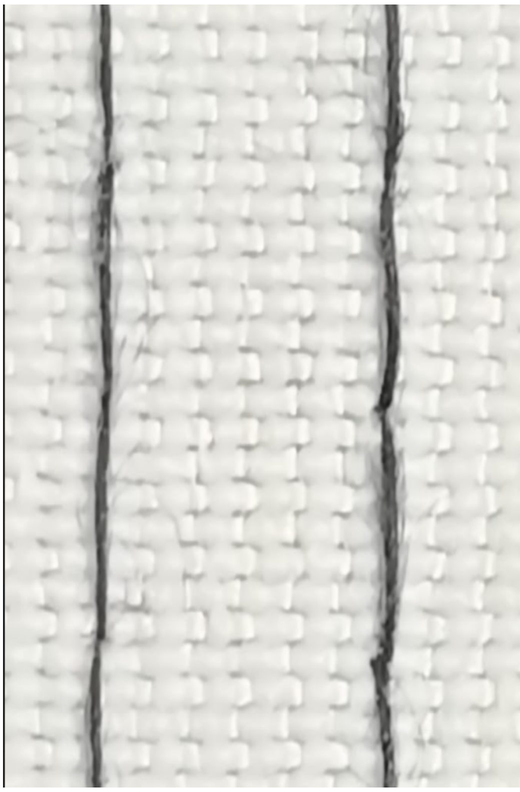

Type D - Weaving Pattern



<u>Type E - Weaving Pattern</u>



<u>Type F - Weaving Pattern</u>



Type G - Weaving Pattern

Elastic used for A-E

Elastic used for F-G

h.) studied the change in capacitance of the sample with two yarns weaved parallely to each other on using dielectric as ionic solutions.

The plot below shows the three cases:

a) In presence of no dielectric
b) Capacitance change in presence of deionised water
c) Capacitance change in presence of ionic (NaCl) solution

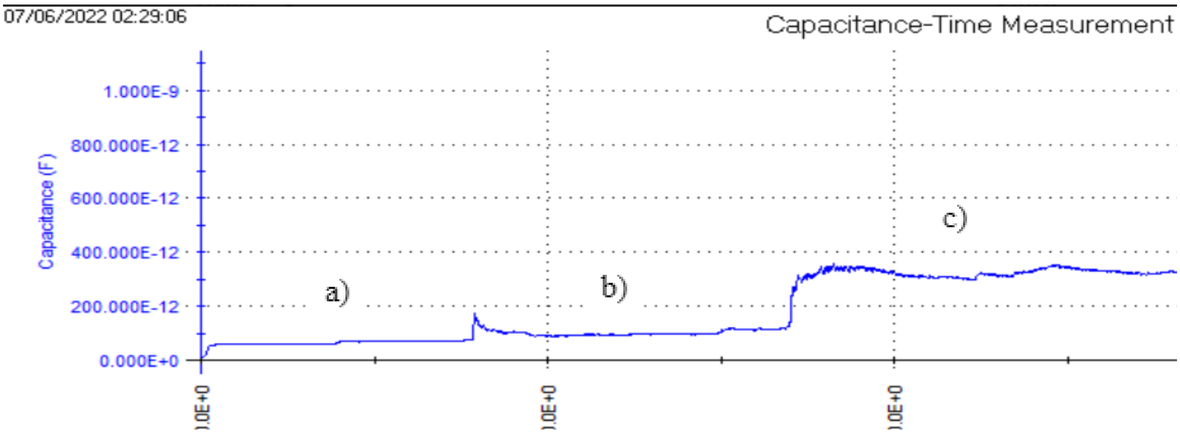


Fig.16 Plot of capacitance vs. time gradually as the dielectric is changed between two parallely weaved conducting yarns

6.3) Applications of these Conducting Yarns

1. The sudden peak and change in capacitance of the two parallely weaved conducting yarn in presence of ions can be utilized to make sensors which can be used in underwater workstations. The ocean water is saline and thus has many ions. In case of leakage , the ionic saline ocean water will come in contact with the sensor made of conducting yarn and this can be detected.
2. Conducting yarns can be used in designing heating wearable textile structures. In this a simple adjustable regulator circuit can be designed in order to provide the requested current.
3. Conductive yarns have been woven to form large electrodes which can measure biopotentials, sense strain.
4. Optimization of the electro conductive yarns distribution in flexible wearable dielectric structure- The temperature influences the electrical resistance and are in direct proportionality with resistance. We can conclude that an increase of parameters thickness and temperature can generate an increase in electrical conductivity.
5. Textile electrodes for body function measurement.
6. Conducting Yarns can be used for the application in the Med Tech industry where the patients are in the high need of getting sensor based Diapers so as to prevent bed sores and other serious medical issues.
7. Conducting yarns can be used as sensors to detect if a person is sweating profusely in case when one gets a heart attack.

6.4) Acknowledgement and Bibliography:

I want to thank and acknowledge the following links and papers that have helped me to gain some knowledge for this report. Without the assistance of Dr. Ajay Agarwal sir, this report would have been an indefinite task for me.

I have listed all links from which educational pictures and data were used. In case of missing links, I would like to thank the owner and promise to abide by the fact that educational content is in fair use without violating the copyright rules.

https://www.tandfonline.com/doi/abs/10.1080/00405000.2012.664867

http://en.wikipedia.org/wiki/Smart_textiles.

http://www.mottcorp.com Fiber metal, The high-flow, low-pressure drop Alternative.

www.aksteel.com 304/304L stainless steel.

https://www.researchgate.net/publication/261056091_Applications_of_electrically_conductive_yarns_in_technical_textiles

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https://www.sciencedirect.com/topics/engineering/conductive-yarn

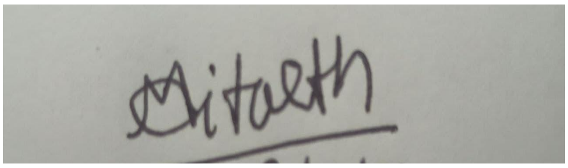
https://www.mdpi.com/1996-1944/15/1/272/htm

https://www.technicaltextile.net/articles/conductive-yarns-and-their-use-in-technical-textiles-3739

https://www.hilarispublisher.com/open-access/study-on-different-techniques-of-fabricating-conductive-fabrics-fordeveloping-wearable-electronics-garments-2165-8064-1000212.pdf

Declaration: I declare that no part of this report is copied from other sources. All the references are properly cited in this report.

The project was conducted and performed in a group of four.
Team Members:
1.Sargam(B20EE057)
2.Mitarth Arora(B20EE096)
3.Kunj Golwala(B20ME040)
4.Bhavya Manish Sharma(B20EE013)
Therefore, the report contents(tables and figures) submitted by all the team members are the same.



Signature of the Student

Signature of the Supervisor

<u>Supervisor's Recommendation for the Evaluation</u>

Please tick any one of the following

1. The work done is satisfactory, and sufficient time has been spent by the student. The submission by the student should be evaluated in this term.
2. The work is not complete. Continuity Grade should be given to the student. The student would need to be evaluated in the next semester for the same Design Project with me.
3. The work is not satisfactory. There is no need for evaluation. The students should look for another Design Credit Project for the next semester.
4. [Other Comment, if 1-3 are not valid] ____________________________________

Signature of the Supervisor

END OF THE REPORT