

4. RESULTS AND DISCUSSION

The results obtained through various experimental procedures on the research entitled “**Design, develop and evaluate the Smart wearable electronic fabric for monitoring healthcare**” are discussed under the following heads.

- 4.1. Awareness of Smart Wearable kids Health Monitoring System**
- 4.2. Yarn Testing**
- 4.3. Evaluation of the Physical Properties of the Woven Conductive Fabric**
- 4.4. Evaluation of the Mechanical Properties of the Woven Conductive Fabric**
- 4.5. Evaluation of the Absorbency Properties of the Woven Conductive Fabric**
- 4.6. Evaluation of the Physical Properties of the Knitted Conductive Fabric**
- 4.7. Evaluation of the Mechanical Properties of the Knitted Conductive Fabric**
- 4.8. Evaluation of the Absorbency Properties of the Knitted Conductive Fabric**
- 4.9. Electrical Analysis of Conductive Yarns**
- 4.10. Electro-mechanical Analysis of Conductive Textile Fabric**
- 4.11. Evaluation of the Developed Wearable Electronic Band**
- 4.12. Cost analysis for Developed Wearable Electronic Garment**

4.1 Awareness of Smart Wearable kids Health monitoring system

In order to ascertain the awareness of smart textiles- wearable electronics among young mothers, a survey was conducted to know their level of interest and to create aware of them. The findings from the survey are discussed below in Table –V and illustrated in Figures-6 and 7.

Table- V
Details about the Awareness of Smart Wearable kids
Health monitoring system

S.No	Particulars	Factors	Preference in %
1	Difficulty in monitoring the Infant's Health	Yes	92
		No	8
2	Awareness of the Smart Textiles - Wearable Electronics	Yes	56
		No	44
3	Aware of Wearable Electronics to monitor Body temperature	Yes	42
		No	58
4	Smart Wearable Electronics to monitor Heart rate	Yes	39
		No	61
5	Preference in using safe Wearable Electronic garments	Yes	78
		No	22
6	Key features regarding the garment design	1&3	49
		2&3	13
		2&4	10
		1&4	28
7	Preference of communication medium	PC	19
		LCD Display	10
		Mobile	41
		Laptop	30
8	Cost preference	Less Cost	15
		Economical	68
		Don't Matter	17
9	Used before	Used	29
		Not-Used	71
10	Interested in using Wearable Electronics	Yes	64
		No	36

The outcomes of the survey are given in Table V and Figures-6 and 7, which clearly shows that the awareness among the young mothers regarding the smart textiles- wearable electronics. The difficulty in monitoring the infant's body temperature during fever or illness is assessed among young mothers, in that 92% of them facing difficulty to monitor and 8% are not. Regarding the awareness of the Smart Textiles -Wearable Electronics products, 56% of young mothers are aware of Smart Textiles products but not used it except few and 44% of young mothers are totally unaware of it. Forty two percent of young mothers replied that they aware of Wearable Electronics for monitoring body temperature and 58% of them are not aware of it. Among the young mothers,39% of them are aware of the smart textiles that continuously monitors heart beat and 61% of them are unaware of it.

Among the young mothers 78% preferred using a safe Wearable Electronic garment to monitor their infant's body temperature and heart rate. Regarding the preference in selecting the key feature the garment design for Wearable Electronics, 49% of young mothers chosen reusable and washable with removable electronic device. In selecting the preference of communication medium, 41% of young mothers preferred mobile phone as it was a comfortable medium where as 30% of them selected Laptop, 19% preferred PC and 10% chosen LCD Display (Figure-6).

Regarding the cost of the wearable electronics garments 15% of young mothers preferred low cost garment and 68% of them preferred economical while 17% of them did not show any concern (Figure-7). Among the young mothers, 71% had not used any type of wearable electronics where as 29% used some sort of wearable electronics before. Sixty four percent of young mothers were interested in using wearable electronics garments for monitoring infants during sick.

Based on the interaction with the young mothers it could be concluded that there is a need for improved quality of living and finance which has forced young mothers to take up jobs, and walk into offices leaving behind their loved infant in the care of maids or day care centers. 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. Hence it could be concluded that there is a need for wearable electronic garment, especially for persons who find it difficult to express their health problems.

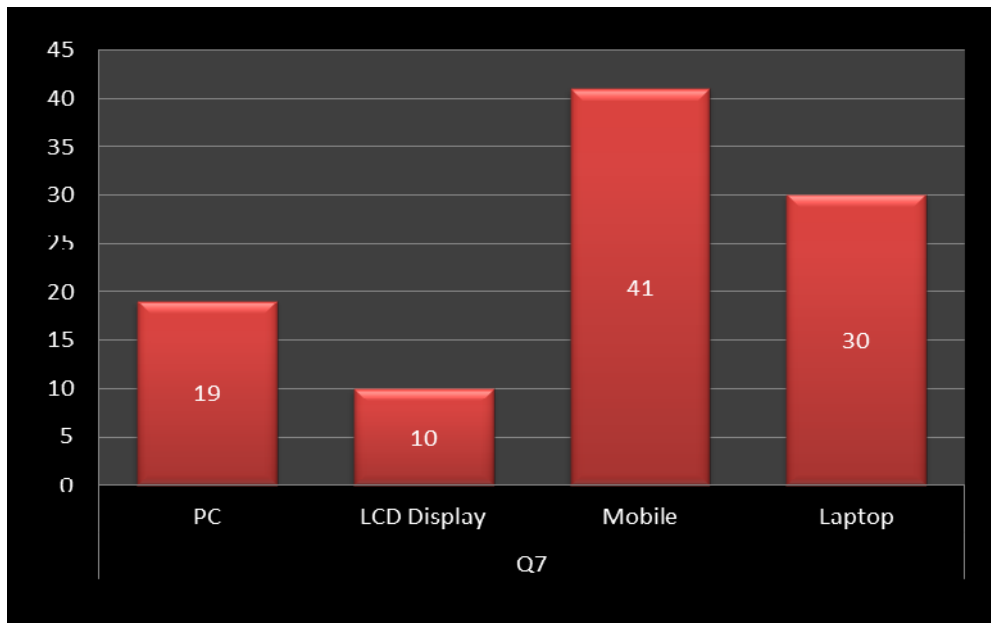


Figure.6
Communication Medium preferred by Mother's

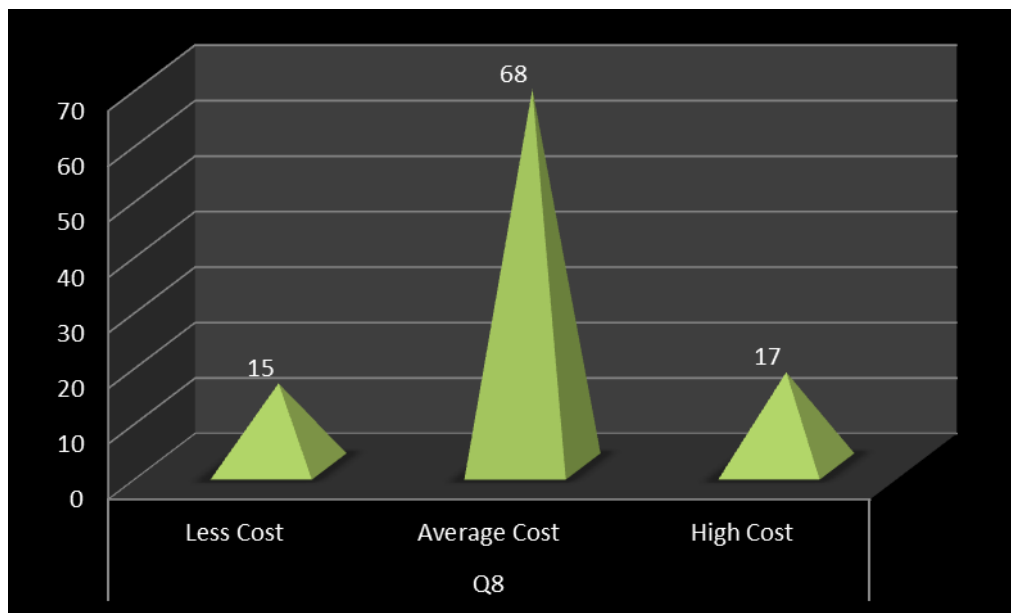


Figure.7
Price preferences for Health Care Monitoring System

4.2 Yarn Testing

4.2.1 Yarn Thickness

The thickness of the conductive yarns selected for the study were calculated using thickness gauge and is tabulated in Table-VI and illustrated in Figure-8.

Table VI
Yarn thickness

S.No	Conductive yarn	Mean Thickness (mm)
1	Copper wire	0.11 to 0.12
2	Aluminium wire	0.332 to 0.353
3	Silver zari thread	0.08 to 0.09

From the Table-VI and Figure-8, it is clear that the thickness of aluminium is high with the range of 0.332 to 0.353mm followed by copper and silver having 0.11 to 0.12mm and 0.08 to 0.09mm respectively. Hence it could be concluded that aluminium yarns were thicker when compared to other selected yarns.

4.2.2 Yarn Elongation

The elongation of the conductive yarn is the important aspect in mechanical analysis which was recorded for each yarn separately by calculating fractured length with standard length of 30cms. The calculated results of elongation percentages of conductive yarns are shown in Table-VII and in Figure-9.

Table VII
Yarn Elongation

S.No	Conductive Yarn	Mean Elongation (cm)	Elongation (%)
1	Copper wire	6.01	20
2	Aluminium wire	6.6	22
3	Silver zari thread	5.4	18

From the Table-VII and Figure-9, it is found that the mean elongation length of aluminium conductive yarn was 6.6 cm which ranks first where as the copper and silver followed with 6.01 cm and 5.4cm respectively. It is also clear that the aluminium

conductive yarn had maximum elongation percentage of 22%, followed by copper and silver as 20% and 18% respectively. Hence it can be concluded that the aluminium had high elongation when compared with other selected yarns.

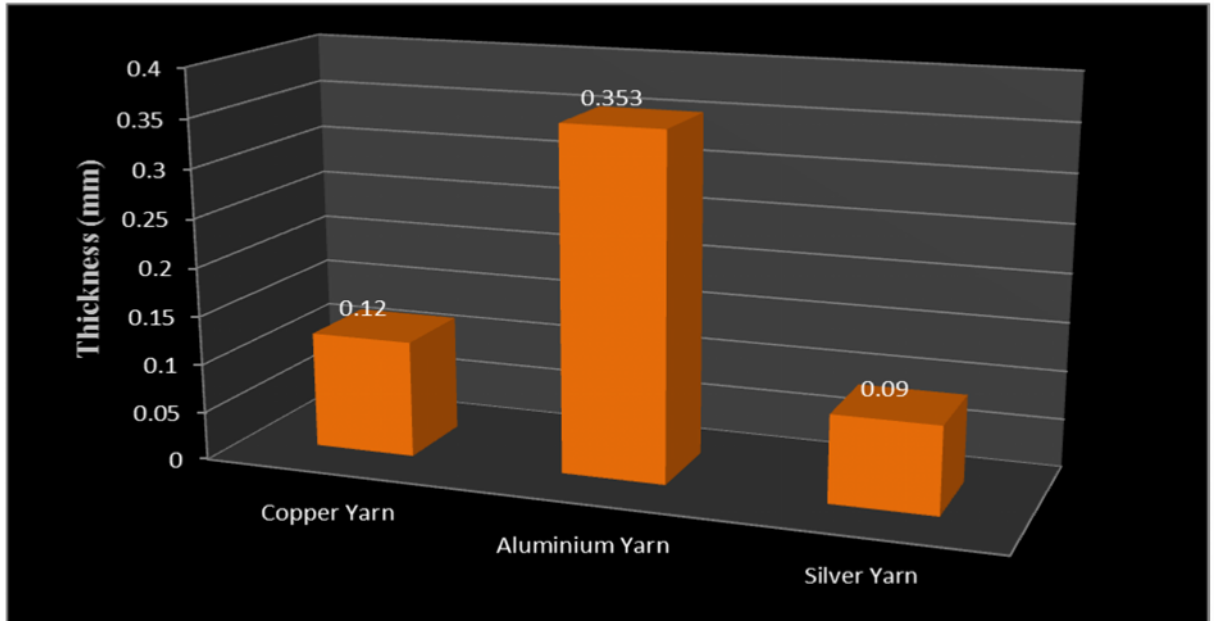


Figure.8
Yarn Thickness

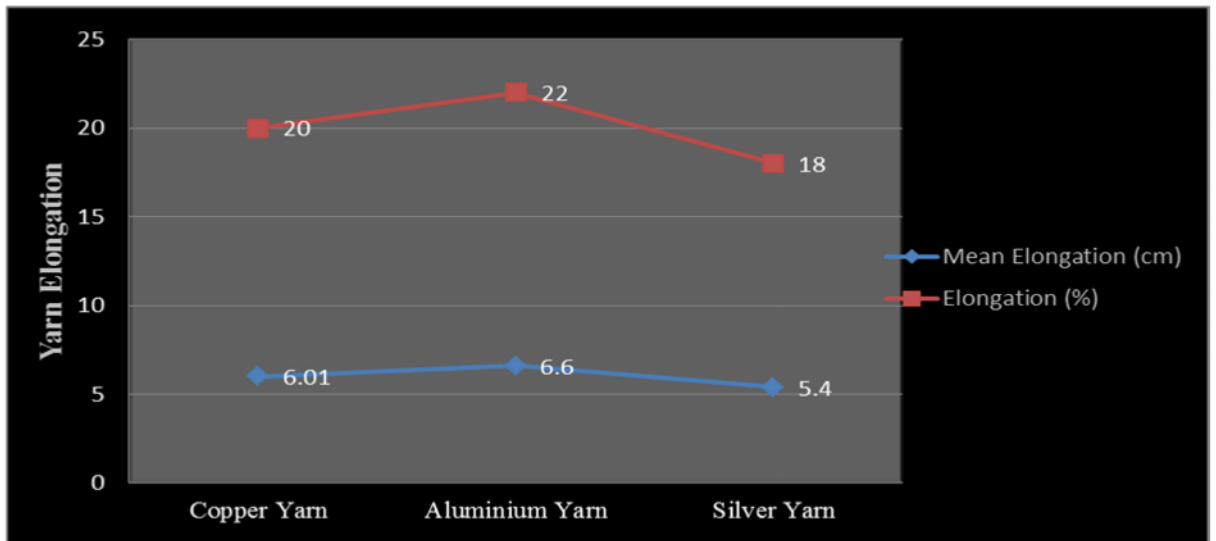


Figure.9
Yarn Elongation

4.3 Evaluation of the Physical Properties of the Woven Conductive Fabric

4.3.1 Fabric Weight

Fabric weight of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are summarized in Table VIII and represented in the Figure 10.

From the Table VIII and Figure 10 it was clear that amongst the aluminium samples with 15 cm of cotton yarns in between the conductive yarn, sample AA showed the highest mean weight as 260.59g. Similarly amongst the 10 cm and 5cm of cotton width yarn samples, AD and AG showed the highest mean weight of 259.66g and 259.49g. On comparing all the aluminium conductive fabrics it is clear that fabrics with 5 cm conductive yarns namely AA, AD and AG showed the highest mean weight. It is clear that increase in the width of conductive yarns increased the weight of the fabric.

With regard to copper conductive woven fabrics when comparing the groups CA, CB, CC (with 15cm of cotton yarns in between the conductive yarn) CD, CE, CF (with 10cm of cotton yarns in between the conductive yarn) and CG, CH ,CI (with 5cm of cotton yarns in between the conductive yarn) it was found that the samples with 5cm conductive yarns in each group namely CA, CD and CG, recorded the highest mean weights of 178.73g, 187.2g and 193.46g respectively. Thus it shows that increase in the width of conductive yarns will effect the weight of the fabric.

Considering the silver conductive woven fabrics, it is evident that the sample SA amongst the 15cm of cotton samples group SA, SB, SC has showed the highest mean weight of 121.83g. Similarly amongst the 10 cm of cotton and 5cm of cotton groups, the samples SD and SG showed highest mean weight of 122.03g and 121.05g. Thus it is clear that the samples SA, SD and SG with 5cm of conductive yarn showed the highest weight. Hence it could be concluded that the increase in width of conductive yarn increased the weight of the fabric and it is clear that the weight of the fabric in directly proportional to the width of the conductive yarns. The result of the fabric weight is statistically proven and all the samples showed significant difference at 1% level. The F values of samples AB and AD are significant at 1% level.

Table- VIII
Fabric Weight of Woven Conductive Fabric

S.No	Samples	Mean (g)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	113.9	-	-	-	-	-
2.	AA	260.59	1.29	128.79	1.73	215.77**	0.77 ^{NS}
3.	AB	173.57	0.52	52.39	19.60	9.60**	8.90***
4.	AC	148	0.30	29.94	1.41	56.56**	0.90 ^{NS}
5.	AD	259.66	1.28	127.97	1.93	198.98**	21.21**
6.	AE	178.57	0.57	56.78	0.80	135.60**	2.41 ^{NS}
7.	AF	148.89	0.31	30.72	1.71	51.83**	0.75 ^{NS}
8.	AG	259.49	1.29	127.82	2.02	192.50**	0.65 ^{NS}
9.	AH	179.67	0.58	57.74	9.11	22.60**	0.33 ^{NS}
10.	AI	148.6	0.30	30.47	5.01	21.22**	0.43 ^{NS}
11.	CA	178.73	0.57	56.92	2.78	67.07**	4.78 ^{NS}
12.	CB	161.18	0.42	41.51	1.81	67.51**	0.89 ^{NS}
13.	CC	132.66	0.17	16.47	1.94	25.53**	1.58 ^{NS}
14.	CD	187.2	0.64	64.35	3.07	69.72**	2.53 ^{NS}
15.	CE	146.64	0.29	28.75	3.02	31.60**	0.54 ^{NS}
16.	CF	134.1	0.18	17.73	2.065	26.28**	1.13 ^{NS}
17.	CG	193.46	0.70	69.85	2.47	90.57**	0.61 ^{NS}
18.	CH	163.88	0.44	43.88	2.13	63.55**	1.58 ^{NS}
19.	CI	136.4	0.20	19.75	2.25	27.52**	0.54 ^{NS}
20.	SA	121.83	0.07	6.96	2.40	9.23**	2.97 ^{NS}
21.	SB	120.28	0.06	5.60	1.57	9.95**	0.30 ^{NS}
22.	SC	120.28	0.06	5.60	1.57	9.95**	0.83 ^{NS}
23.	SD	122.03	0.07	7.14	1.43	13.40**	0.62 ^{NS}
24.	SE	121.5	0.07	6.67	1.97	10.22**	1.23 ^{NS}
25.	SF	117.85	0.03	3.47	2.34	4.66**	0.62 ^{NS}
26.	SG	121.05	0.06	6.28	1.93	9.78**	0.30 ^{NS}
27.	SH	120.24	0.06	5.57	2.29	7.63**	0.30 ^{NS}
28.	SI	114.84	0.09	0.83	2.47	1.05 ^{NS}	0.68 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

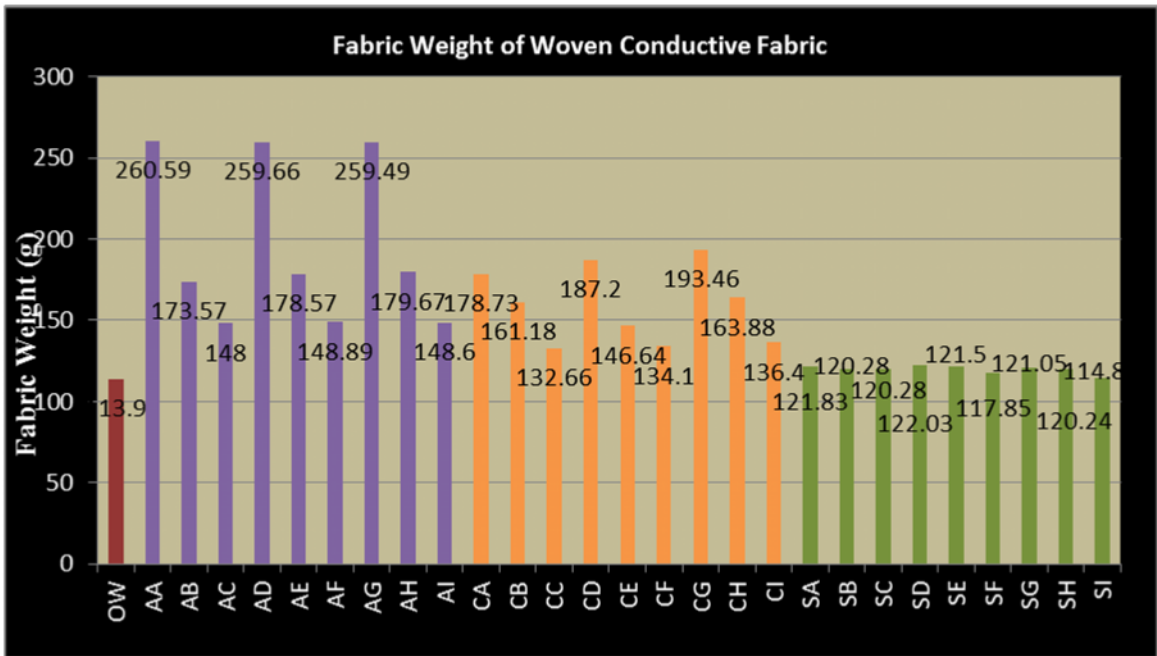


Figure.10

Fabric Weight of Woven Conductive Fabric

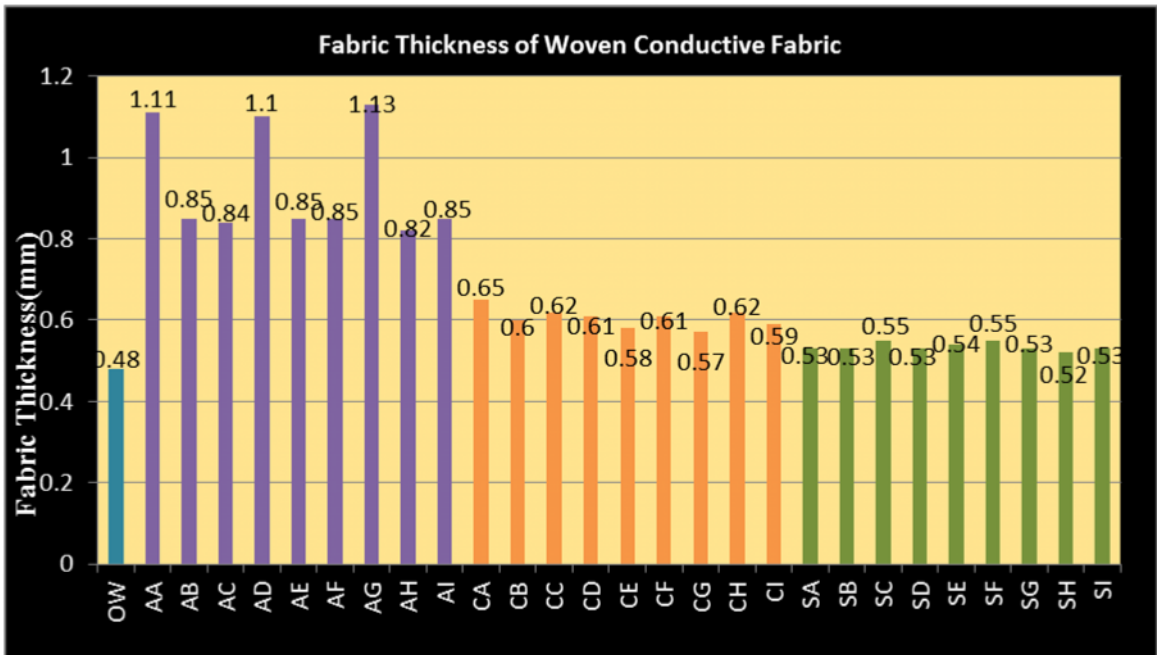


Figure.11

Fabric Thickness of Woven Conductive Fabric

4.3.2 Fabric Thickness

Fabric thickness of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are listed in Table-IX and illustrated in the Figure-11.

Table- IX
Fabric Thickness of Woven Conductive Fabric

S.No	Samples	Mean (mm)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	0.48	-	-	-	-	-
2.	AA	1.11	1.31	131	0.04	41.81**	0.53 ^{NS}
3.	AB	0.85	0.77	77	0.04	25.99**	4.11**
4.	AC	0.84	0.75	75	0.05	24.09**	0.12 ^{NS}
5.	AD	1.10	1.29	129	0.04	52.71**	0.97 ^{NS}
6.	AE	0.85	0.77	77	0.04	27.10**	3.17**
7.	AF	0.85	0.77	77	0.02	36.88**	0.66 ^{NS}
8.	AG	1.13	1.35	135	0.04	45.74**	1.35 ^{NS}
9.	AH	0.82	0.71	71	0.02	43.10**	2.99 ^{NS}
10.	AI	0.85	0.77	77	0.02	43.88**	7.08**
11.	CA	0.65	0.35	35	0.03	13.39**	6.20**
12.	CB	0.6	0.25	25	0.03	11.86**	0.41 ^{NS}
13.	CC	0.62	0.29	29	0.01	18.94**	1.35 ^{NS}
14.	CD	0.61	0.27	27	0.02	13.50**	5.63**
15.	CE	0.58	0.21	21	0.01	13.22**	8.68**
16.	CF	0.61	0.27	27	0.02	13.50**	1.45 ^{NS}
17.	CG	0.57	0.19	19	0.02	11.41**	5.28**
18.	CH	0.62	0.29	29	0.01	18.94**	2.43 ^{NS}
19.	CI	0.59	0.23	23	0.01	15.88**	3.01 ^{NS}
20.	SA	0.53	0.1	10	0.01	6.41**	3.87**
21.	SB	0.53	0.1	10	0.01	6.41**	0.39 ^{NS}
22.	SC	0.55	0.15	15	0.02	8.37**	0.39 ^{NS}
23.	SD	0.53	0.1	10	0.02	6.34**	0.10 ^{NS}
24.	SE	0.54	0.13	13	0.01	7.80**	1.83 ^{NS}
25.	SF	0.55	0.15	15	0.01	10.59**	8.25**
26.	SG	0.53	0.1	10	0.01	6.41**	1.82 ^{NS}
27.	SH	0.52	0.08	8	0.01	5.12**	3.17**
28.	SI	0.53	0.1	10	0.02	6.34**	2.49 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

From the Table IX and Figure.11, it is proven that the thickness of all the samples has increased irrespective of the type of conductive yarn used when compared with plain cotton fabric.

Among the aluminium conductive fabric, it was clear that the sample AA showed maximum mean thickness of 1.11mm in the group AA, AB, AC with 15 cm cotton yarn. Similarly amongst the groups AD, AE, AF with 10cm cotton yarns and AG, AH, AI with 5cm cotton yarns, the samples AD and AG showed highest mean thickness as 1.10mm and 1.13mm respectively. This indicates that the samples AA, AD, AG with 5cm width of conductive yarn recorded maximum thickness. Hence it could be concluded that the thickness of the fabric is directly proportional to the width of the conductive yarn.

With regard to copper conductive woven fabrics all the samples showed increase in thickness when compared with plain cotton fabric. Also it was clearly seen that there is not much variation in thickness amongst the copper conductive samples and the maximum thickness was seen in the samples CA as 0.65 mm. Similarly all the silver conductive woven fabric samples showed maximum gain in thickness of the fabric when compared with the plain cotton fabric and all the samples showed mostly same values. Hence it can be concluded that the difference in width of either conductive yarn or cotton yarn did not effect the thickness of copper conductive fabric and silver conductive fabric. 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.

4.4 Evaluation of the Mechanical Properties of the Woven Conductive Fabric

4.4.1 Fabric Tensile Strength

The tensile strength has been evaluated for all the woven fabric samples in both the warp and weft directions.

4.4.1.1 Fabric Tensile Strength in warp direction

Fabric tensile strength of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are summarized in Table X and represented in the Figure 12.

Table- X
Tensile Strength of Woven Conductive Fabric (warp)

S.No	Samples	Mean (Kg)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1	OW	34.31	-	-	-	-	-
2	AA	39.61	0.15	15	0.01	281.51**	1.44 ^{NS}
3	AB	38.63	0.13	13	0.06	169.88**	2.30 ^{NS}
4	AC	43.08	0.26	26	0.03	425.69**	9.50**
5	AD	43.21	0.26	26	0.06	336.92**	1.15 ^{NS}
6	AE	45.46	0.32	32	0.09	316.64**	.168 ^{NS}
7	AF	41.98	0.22	22	0.02	400.55**	1.90 ^{NS}
8	AG	34.85	0.02	2	0.04	23.99**	1.72 ^{NS}
9	AH	35.75	0.04	4	0.23	18.43**	70.17*
10	AI	38.17	0.11	11	0.07	137.82**	1.10 ^{NS}
11	CA	40.46	0.18	18	0.03	309.09**	.32 ^{NS}
12	CB	39.87	0.16	16	0.07	189.90**	1.71 ^{NS}
13	CC	43.31	0.26	26	0.02	457.69**	.33 ^{NS}
14	CD	42.57	0.24	24	0.07	284.10**	2.65 ^{NS}
15	CE	38.77	0.13	13	0.28	47.98**	.52 ^{NS}
16	CF	39.62	0.15	15	0.08	175.09**	2.84 ^{NS}
17	CG	41.36	0.21	21	0.06	250.30**	.50 ^{NS}
18	CH	36.88	0.07	7	0.04	119.43**	2.50 ^{NS}
19	CI	36.71	0.07	7	0.05	95.87**	.22 ^{NS}
20	SA	36.96	0.08	8	0.06	128.60**	33.50**
21	SB	35.41	0.03	3	0.08	36.27**	.40 ^{NS}
22	SC	38.52	0.12	12	0.02	218.54**	.84 ^{NS}
23	SD	37.68	0.10	10	0.08	111.48**	1.50 ^{NS}
24	SE	35.87	0.05	5	0.02	79.25**	.46 ^{NS}
25	SF	36.44	0.06	6	0.64	9.49**	.67 ^{NS}
26	SG	38.88	0.13	13	0.01	240.86**	2.50 ^{NS}
27	SH	37.21	0.08	8	0.03	143.03**	.56 ^{NS}
28	SI	36.13	0.05	5	0.05	75.09**	.50 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

From the above Table X and Figure 12 it was noted that the fabric tensile strength in warp direction for all the samples of aluminium conductive fabrics showed gain when compared with plain cotton fabric. Also all the samples recorded similar values without much variation when compared in groups as AA,AB,AC with 15cm cotton width yarn, AD, AE, AF with 10cm cotton width yarn and AG, AH, AI with 5cm cotton width yarn. Considering these results it is evident that the difference in width of conductive yarn and width of cotton has affected the tensile strength of the conductive fabrics.

Similarly from the table it is clearly seen that all the samples of copper conductive woven fabrics and silver conductive woven fabrics showed increase in tensile strength in warp direction when compared with plain cotton fabric. Comparable results were reported by Takamatsu et al., (2016) that the selection of metal core cotton yarns and metal wires in conductive fabric production was a better choice in attaining higher tensile strength.

With regard to copper conductive woven fabrics, the maximum mean strength was seen in the sample CC as 43.31 kg and the least strength gain was noted in the sample AG. Thus it clearly proves that the integration of conductive yarn increases the tensile strength of the fabric. The result was statistically proven that all the samples showed significant difference at 1% level. The F values are significant for the samples AC, AH and SA.

4.4.1.2 Fabric Tensile Strength in weft direction

Fabric tensile strength of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are presented in Table XI and illustrated in the Figure-13.

Table XI and Figure-13 clearly depicts that there is an increase in the conductive fabric for tensile strength in the weft direction when compared with plain cotton fabric. This proves that the integration of conductive yarn increased the strength of the fabric.

Table-XI
Tensile Strength of Woven Conductive Fabric (Weft)

S.No	Samples	Mean (Kg)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1	OW	26.17	-	-	-	-	-
2	AA	51.36	0.96	96	0.03	944.98**	.96 ^{NS}
3	AB	46.82	0.79	79	0.05	703.14**	1.10 ^{NS}
4	AC	33.94	0.30	30	0.04	285.58**	2.05 ^{NS}
5	AD	51.98	0.99	99	0.02	1020.82**	.245 ^{NS}
6	AE	44.27	0.69	69	0.05	606.09**	.70 ^{NS}
7	AF	34.15	0.30	30	0.08	217.72**	.70 ^{NS}
8	AG	51.45	0.97	97	0.06	821.62**	1.17 ^{NS}
9	AH	41.04	0.57	57	0.05	514.07**	.25 ^{NS}
10	AI	35.78	0.37	37	0.18	155.05**	.96 ^{NS}
11	CA	42.19	0.61	61	0.07	479.70**	2.50 ^{NS}
12	CB	35.16	0.34	34	0.07	275.78**	.81 ^{NS}
13	CC	32	0.22	22	0.07	174.00**	66.90*
14	CD	43.54	0.66	66	0.08	485.09**	2.69 ^{NS}
15	CE	34.86	0.33	33	0.05	296.84**	3.03 ^{NS}
16	CF	31.98	0.22	22	0.02	227.29**	20104.50*
17	CG	42.81	0.64	64	1.60	33.77**	.51 ^{NS}
18	CH	35.86	0.37	37	0.04	346.38**	.70 ^{NS}
19	CI	31.87	0.22	22	0.04	203.31**	2.07 ^{NS}
20	SA	30.7	0.17	17	0.08	125.89**	.50 ^{NS}
21	SB	29.31	0.12	12	0.07	92.83**	.50 ^{NS}
22	SC	28.63	0.09	9	0.08	67.98**	1.55 ^{NS}
23	SD	30.63	0.17	17	0.10	108.63**	2.17 ^{NS}
24	SE	28.82	0.10	10	0.02	103.75**	1.50 ^{NS}
25	SF	26.47	0.01	1	0.09	6.97**	.76 ^{NS}
26	SG	26.8	0.02	2	0.06	19.04**	2.17 ^{NS}
27	SH	29.15	0.11	11	0.03	109.77**	.59 ^{NS}
28	SI	27.73	0.06	6	0.05	52.44**	4001.50*

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

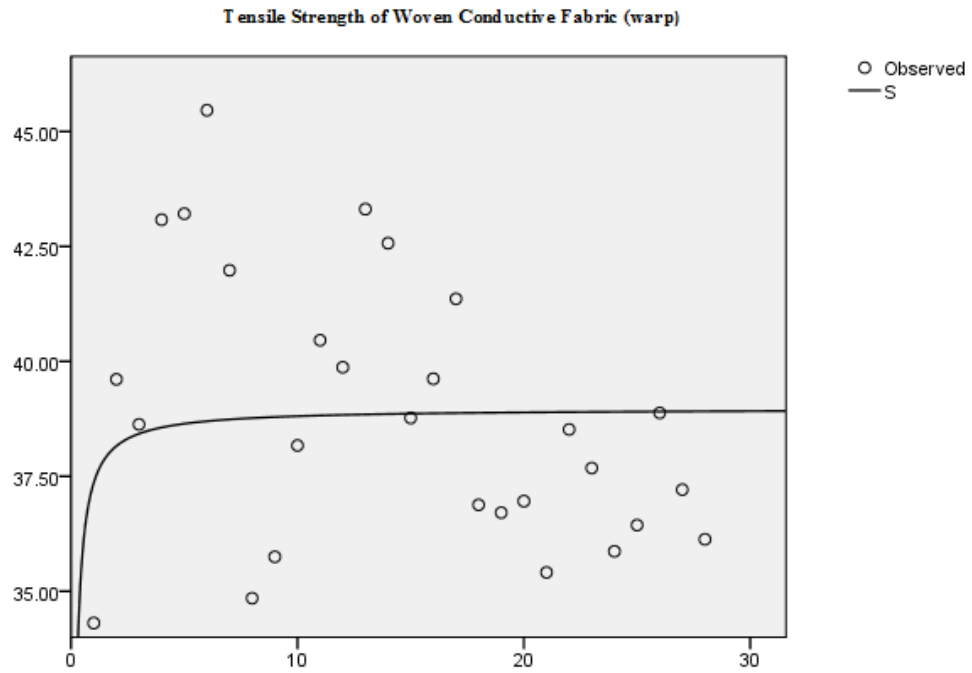


Figure.12
Tensile Strength of Woven Conductive Fabric (warp)

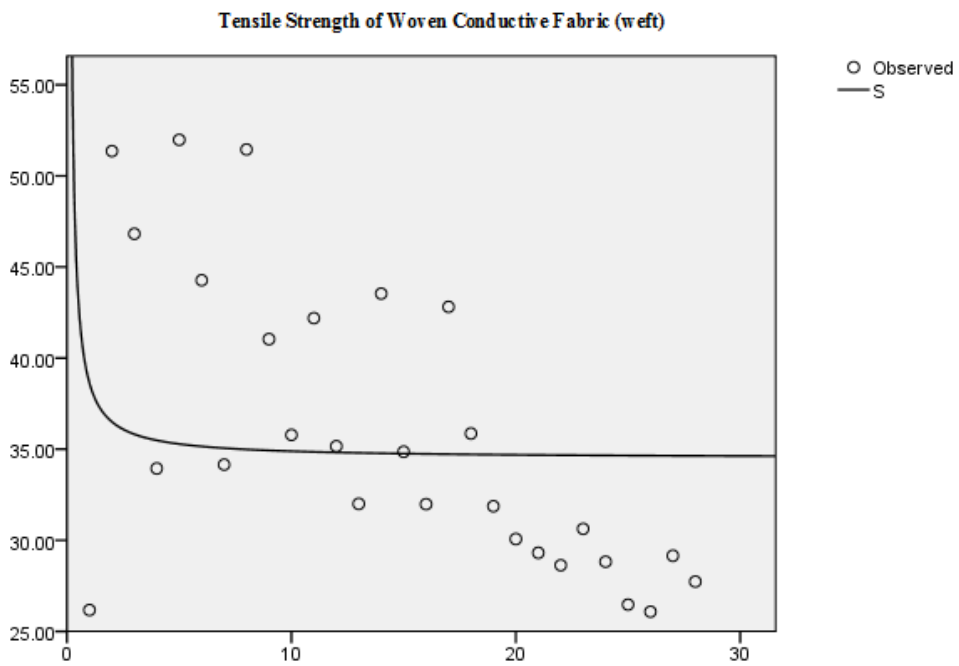


Figure.13
Tensile Strength of Woven Conductive Fabric (weft)

On comparing the samples of aluminium conductive fabric, the sample AA showed highest strength amongst the group AA, AB, AC with 15cm cotton width yarn as 51.36kg. Also amongst the group AD, AE, AF with 10cm cotton width yarn and AG, AH, AI with 5 cm cotton width yarn, the samples AD and AG showed highest mean strength as 51.98 kg and 51.45kg respectively. Thus it is clearly shows that the samples AA, AD, AG with 5cm of conductive yarn scored the highest mean value for weft direction tensile strength.

Similarly for copper conductive fabric, the sample CA amongst the group CA, CB, CC with 15cm cotton width yarn showed high tensile strength in weft direction as 42.19kg. Also amongst the groups CD, CE, CF with 10 cm cotton width yarn and CG, CH, CI with 5cm cotton width yarn, the samples CD and CG showed high tensile strength in weft direction as 43.54kg and 42.80kg respectively. Therefore it is clearly noted that the maximum tensile strength is seen in the samples CA, CD, CG with width of 5cm conductive yarn. These results are same as the results reported by Kumar and Vigneshwaran (2010), the higher tensile strength is obtained with the increased number of yarns used in the fabric. Hence it was conducted that the difference in width of conductive yarn affects the strength of conductive fabric.

With regard to silver conductive fabric, all the samples showed increase in tensile strength in weft direction when compared with plain cotton fabric. From the table it is clear that all samples showed similar values and the sample SA had the highest mean weft tensile strength as 30.7kg. On statistical analysis, all the samples are significant at 1% level and the F values of the samples CC, CF and SI showed 1% level significance.

4.4.2 Fabric Elongation

The fabric elongation has been evaluated for all the woven fabric samples in both the warp and weft directions.

4.4.2.1 Fabric Elongation in warp direction

Fabric elongation of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are tabulated in Table-XII and illustrated in the Figure-14.

Table-XII
Fabric elongation of Woven Conductive Fabric (Warp)

S.No	Samples	Mean (%)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	13.08	-	-	-	-	-
2.	AA	18.69	0.43	43	0.05	-309.34**	4.97**
3.	AB	20.18	0.54	54	0.02	-841.96**	1.82 ^{NS}
4.	AC	16.85	0.29	29	0.03	-306.69**	3.19***
5.	AD	19.73	0.51	51	0.02	-788.59**	8.54**
6.	AE	20.28	0.55	55	0.01	-985.90**	1.89 ^{NS}
7.	AF	18.98	0.45	45	0.01	-807.89**	.35 ^{NS}
8.	AG	21.12	0.62	62	0.01	-1019.26**	.83 ^{NS}
9.	AH	19.33	0.48	48	3.17	-7.24**	1.15 ^{NS}
10.	AI	20.13	0.54	54	0.01	1008.29**	.77 ^{NS}
11.	CA	19.59	0.50	50	0.01	840.44**	.14 ^{NS}
12.	CB	17.43	0.33	33	0.02	504.66**	.65 ^{NS}
13.	CC	16.8	0.28	28	0.01	499.09**	.20 ^{NS}
14.	CD	20.15	0.54	54	0.04	517.47**	.01 ^{NS}
15.	CE	17.63	0.35	35	0.03	384.55**	1.46 ^{NS}
16.	CF	19.68	0.51	51	0.01	836.70**	7.22**
17.	CG	21.3	0.63	63	0.07	370.09**	4.42***
18.	CH	20.44	0.56	56	0.01	1007.81**	2.58 ^{NS}
19.	CI	18.73	0.43	43	0.03	493.43**	2.58 ^{NS}
20.	SA	14.81	0.13	13	0.02	196.16**	.01 ^{NS}
21.	SB	13.98	0.07	7	3.16	0.10 ^{NS}	.10 ^{NS}
22.	SC	14.97	0.15	15	0.02	217.44**	.09 ^{NS}
23.	SD	14.14	0.08	8	0.01	155.17**	.85 ^{NS}
24.	SE	13.73	0.05	5	0.02	74.77**	8.54**
25.	SF	13.87	0.06	6	0.09	27.04**	1.17 ^{NS}
26.	SG	14.57	0.11	11	0.01	218.11**	.49 ^{NS}
27.	SH	14.3	0.09	9	0.03	107.46**	4.75**
28.	SI	14.28	0.09	9	0.02	146.97**	2.31 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

Table XII and Figure-14 furnished the result of fabric elongation percentage in warp direction. When comparing the samples of aluminium conductive woven fabric with plain cotton fabric (OW), all the samples showed increase in elongation percentage. Also all the samples recorded similar values without much variation when compared in groups as AA, AB, AC (with 15cm cotton width yarns), AD, AE, AF (with 10cm cotton width yarns) and AG, AH, AI (with 5cm cotton width yarns). These results it clearly shows that the presence of conductive yarns increased the elongation percentage in the conductive fabrics and the difference in width of conductive yarns with cotton yarns has no effect on the mean elongation values of the samples.

With regard to copper conductive fabrics, it is noted that the elongation percentage in warp direction for all the samples increased when compared to plain cotton fabric (OW). Also when compared in groups as CA, CB, CC (with 15cm cotton width yarns) CD, CE, CF (with 10cm cotton width yarns) and CG, CH, CI (with 5cm cotton width yarns), all the samples showed similar values for mean elongation percentage. Similarly for silver conductive fabrics, all the samples recorded an increase in mean elongation and showed similar values among the samples.

Hence it could be concluded that the integration of conductive yarns resulted in increase of elongation percentage of the conductive fabrics and the difference in width of conductive yarns with cotton yarns has no effect on the mean elongation of all the samples. In general the insertion of the conductive yarn has increased the stability which in turn proves better load bearing of all the fabrics irrespective of the type of conductive yarns used. 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.

4.4.2.2 Fabric Elongation in weft direction

Fabric elongation of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are tabulated in Table XIII and illustrated in the Figure- 15.

From the Table XIII and Figure- 15, it is clear that all the aluminium conductive fabric samples showed similar values with minute variation in mean elongation in weft direction when compared as groups AA, AB, AC (with 15cm cotton width yarns), AD, AE, AF (with 10cm cotton width yarns) and AG, AH, AI (with 5cm cotton width yarns). On comparing the conductive fabric with plain cotton fabric (OW), all the samples recorded increase in elongation except AA, AC, AH and the sample AE showed maximum mean elongation as 10.33%. Thus it reveals that the integration of conductive yarn influence the elongation percentage of the fabric.

Similarly copper conductive fabric samples showed increase in the elongation in weft direction when compared with the plain cotton fabric. The maximum mean elongation was noted in the sample CI as 10.65% and also all the samples recorded similar values in elongation when compared in groups as CA, CB, CC (with 15cm cotton width yarns), CD, CE, CF (with 10cm cotton width yarns) and CG, CH, CI (with 5cm cotton width yarns). Thus it proves that the presences of conductive yarns increase the elongation of the fabric in weft direction.

With regard to silver conductive fabrics, the samples SA, SB, SC, SD and SF showed increase in elongation in weft direction when compared with the plain cotton fabric and the maximum mean elongation was noted in the sample SB as 9.88% in weft direction. The study by Allen et al., (2018) reports that the strips of conductive fabrics were able to elongate more and bear more load than standard fabric proving excellent stretchability of conductive fabrics in both warp and weft direction.

Therefore, it was concluded that the integration of conductive yarns in the fabric influence the elongation in weft direction. On statistical analysis, all the showed 1% level significance except the sample SC. The F values of the samples of AH, CC, CF, SB and SC showed 1% level significance.

Table-XIII
Fabric elongation of Woven Conductive Fabric (Weft)

S.No	Samples	Mean (%)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	9.52	-	-	-	-	-
2.	AA	9.13	-0.04	-4	0.01	61.66**	.86 ^{NS}
3.	AB	9.63	0.01	1	0.02	13.95**	1.53 ^{NS}
4.	AC	8.98	-0.06	-6	0.01	79.05**	.77 ^{NS}
5.	AD	9.73	0.02	2	0.02	1294.35**	2.15 ^{NS}
6.	AE	10.33	0.09	9	0.01	1614.00**	.11 ^{NS}
7.	AF	10.1	0.06	6	0.01	1419.00**	.25 ^{NS}
8.	AG	9.78	0.03	3	0.01	1588.40**	3.50 ^{NS}
9.	AH	9.14	-0.04	-4	0.01	1471.50**	33.98**
10.	AI	9.56	0.00	0	0.01	1677.59**	2.17 ^{NS}
11.	CA	10.1	0.06	6	0.02	1408.55**	1.75 ^{NS}
12.	CB	10.54	0.11	11	0.02	1051.68**	1.04 ^{NS}
13.	CC	10.61	0.11	11	0.05	401.34**	6.50***
14.	CD	10.33	0.09	9	0.04	797.25**	.63 ^{NS}
15.	CE	10.1	0.06	6	0.03	708.27**	.10 ^{NS}
16.	CF	10.28	0.08	8	0.95	32.98**	26.11**
17.	CG	10.7	0.12	12	0.07	535.21**	1.82 ^{NS}
18.	CH	10.13	0.06	6	0.01	1638.00**	.19 ^{NS}
19.	CI	10.65	0.12	12	0.03	833.08**	1.78 ^{NS}
20.	SA	9.79	0.03	3	0.01	42.69**	3.02 ^{NS}
21.	SB	9.88	0.04	4	0.01	60.37**	23.78**
22.	SC	9.51	0.00	0	0.01	1.17 ^{NS}	6.50***
23.	SD	9.71	0.02	2	0.01	31.86**	2.20 ^{NS}
24.	SE	9.32	-0.02	-2	0.01	33.54**	.98 ^{NS}
25.	SF	9.57	0.01	1	0.01	7.50**	.08 ^{NS}
26.	SG	8.71	-0.09	-9	0.01	135.84**	1.30 ^{NS}
27.	SH	8.98	-0.06	-6	0.01	87.86**	1.79 ^{NS}
28.	SI	9.13	-0.04	-4	0.42	8.92**	.78 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

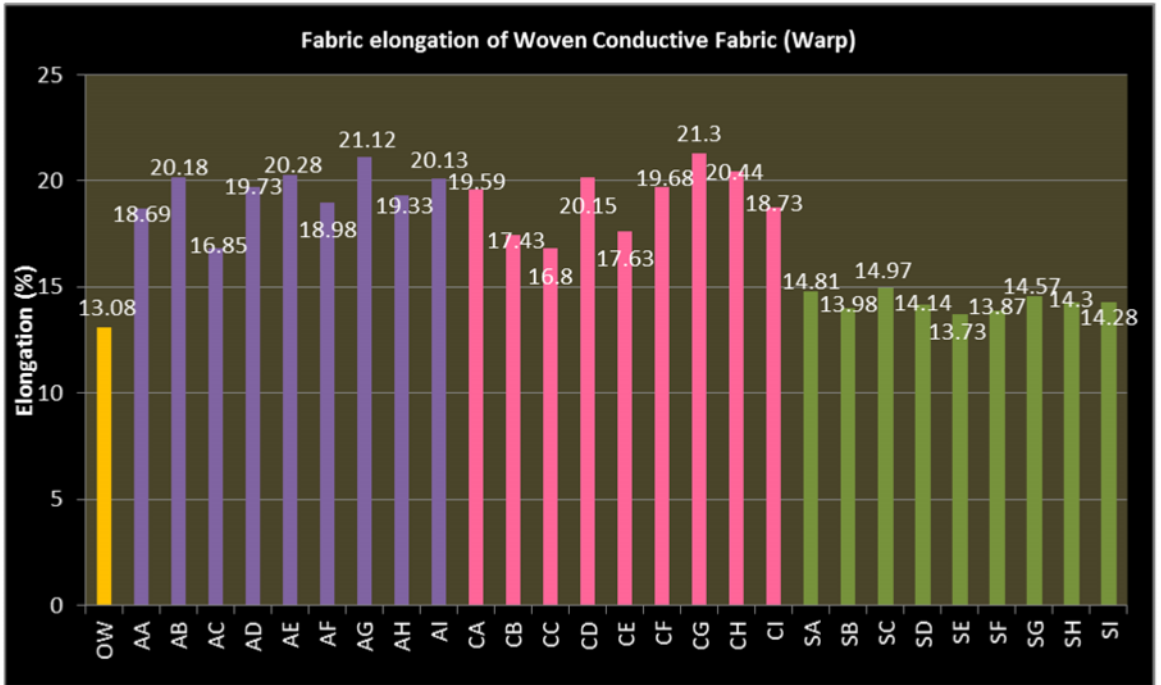


Figure- 14
Fabric elongation of Woven Conductive Fabric (Warp)

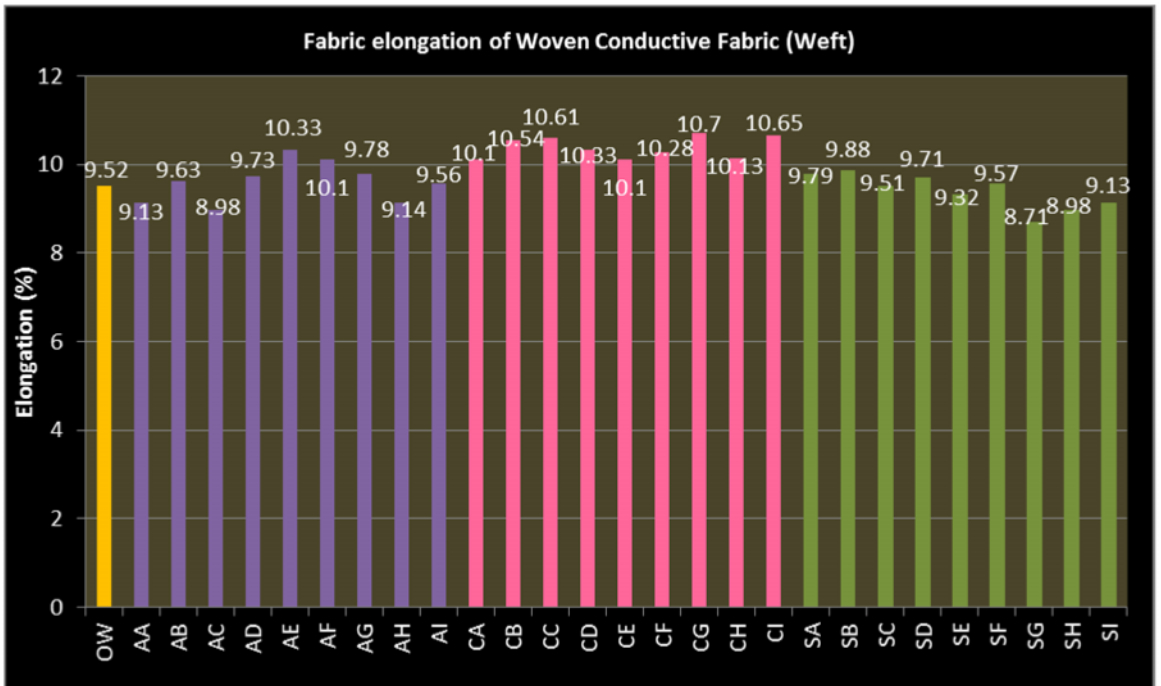


Figure- 15
Fabric elongation of Woven Conductive Fabric (Weft)

4.4.3 Fabric Abrasion resistance

4.4.3.1 Fabric Abrasion resistance (Warp)

Fabric abrasion resistance in warp direction for the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are summarized in Table XIV and represented in the Figure-16.

From the Table XIV and Figure-16, it was evident that all the samples of the aluminium conductive fabric showed increased abrasion strength in warp direction except the sample AE when compared with plain cotton fabric (OW). The sample AI took maximum number of cycles to abrade the surface as 73. Also it is noted that the samples AC, AF, AI with 1cm conductive yarn which took maximum number of cycles for abrasion revealing good strength in warp direction when compared in groups as AA, AB, AC (with 15cm cotton width yarns), AD, AE, AF (with 10cm cotton width yarns) and AG, AH, AI (with 5cm cotton width yarns). Thus it clear that the difference in width of conductive yarn influence the abrasion of the fabric in warp direction.

With regard to copper conductive fabrics, all the samples showed high abrasion strength in warp direction when compared with plain cotton fabric (OW) and the maximum number of cycles to abrade was recorded in the sample CG as 119. Also when compared in groups as CA, CB, CC (with 15cm cotton width yarns), CD, CE, CF (with 10cm cotton width yarns) and CG, CH, CI (with 5cm cotton width yarns), the samples CA, CD, CG with 5cm conductive yarns showed highest number of cycles amongst the groups. Therefore, it is clear that the difference in width of copper conductive yarn influence the abrasion in warp direction.

Considering the silver conductive woven fabrics, it is clear that the sample SA amongst the group SA, SB, SC (with 15cm cotton width yarns) showed the highest in abrasion strength as it recorded high number of cycles to abrade as 77. Similarly amongst the groups SD, SE, SF (with 10 cm cotton width yarns) and SG, SH, SI (with 5 cm cotton width yarns), the samples SD and SG recorded highest number of cycles to abrade the surface as 75 and 72 respectively. When compared with plain cotton fabric, all the samples high abrasion strength except the sample SI.

Table-XIV
Abrasion resistance of Woven Conductive Fabric (warp)

S.No	Samples	No of cycles	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	54	-	-	-	-	-
2.	AA	64	0.10	10	1.39	17.87**	1.09 ^{NS}
3.	AB	61	0.13	13	1.41	12.12**	1.06 ^{NS}
4.	AC	67	0.24	24	1.15	25.17**	1.61 ^{NS}
5.	AD	59	0.09	9	0.82	11.18**	2.50 ^{NS}
6.	AE	46	0.15	15	1.15	15.49**	.75 ^{NS}
7.	AF	67	0.24	24	1.55	4.28**	.84 ^{NS}
8.	AG	60	0.11	11	1.15	11.62**	4.75**
9.	AH	64	0.19	19	1.15	19.87**	.18 ^{NS}
10.	AI	73	0.35	35	1.15	36.79**	.33 ^{NS}
11.	CA	110	1.04	104	1.41	97.00**	.12 ^{NS}
12.	CB	79	0.46	46	1.25	46.51**	.21 ^{NS}
13.	CC	100	0.85	85	0.94	97.58**	1.83 ^{NS}
14.	CD	118	1.19	119	1.25	119.07**	1.09 ^{NS}
15.	CE	85	0.57	57	0.82	69.32**	1.25 ^{NS}
16.	CF	95	0.76	76	0.94	86.97**	1.83 ^{NS}
17.	CG	119	1.20	120	0.82	14.34**	1.75 ^{NS}
18.	CH	82	0.52	52	0.82	62.61**	.75 ^{NS}
19.	CI	99	0.83	83	0.82	98.42**	1.41 ^{NS}
20.	SA	77	0.43	43	0.82	51.43**	.75 ^{NS}
21.	SB	70	0.30	30	0.94	33.94**	.24 ^{NS}
22.	SC	57	0.06	6	0.82	6.78**	.18 ^{NS}
23.	SD	75	0.39	39	0.82	46.96**	.75 ^{NS}
24.	SE	74	0.37	37	1.15	38.73**	.52 ^{NS}
25.	SF	54	0	0	1.15	0.00 ^{NS}	10.75**
26.	SG	72	0.33	33	1.15	34.86**	.15 ^{NS}
27.	SH	69	0.28	28	1.15	29.05**	.42 ^{NS}
28.	SI	51	0.06	6	0.82	6.71**	.00 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

Thus it is proven that the samples SA, SD, SG with 5cm of conductive yarn showed good abrasion resistance in warp direction. Comparable results were reported by Thomas (2015) that uniform tightly woven conductive yarns into uniform flat fabrics are most resistant to abrasion as they allow the user to wear a evenly distributed fabric.

Hence it could be concluded that the integration of conductive yarns into the fabric influence the abrasion resistance in warp direction. This may be 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.

4.4.3.2 Fabric Abrasion resistance (weft)

Fabric abrasion resistance in weft direction for the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are tabulated in Table XV and illustrated in the Figure-17.

Table XV and Figure-17 describes the sample AB to have highest number of cycles to abrade the surface amongst the group of aluminium fabric samples AA, AB, AC (with 15cm of cotton yarns) as 785. Similarly amongst the groups AD, AE, AF (with 10cm cotton width yarns) and AG, AH, AI (with 5cm cotton width yarns), the sample AE and AH showed the highest weight loss in abrasion in weft direction. Thus it proves that the samples AB, AE and AH with 2cm conductive yarns showed the maximum weight loss in abrasion resistance.

Considering the copper conductive fabric, the sample CB showed the highest abrasion resistance amongst the group CA, CB, CC (with 15cm of cotton width yarns) as it scored 249 numbers of cycles to abrade. Similarly amongst the groups of 10cm of cotton yarns and 5cm of cotton yarns, the samples CE and CG showed highest abrasion resistance in weft direction. It is clear that the integration of conductive yarns affects the abrasion resistance of the fabric.

Table-XV
Abrasion resistance of Woven Conductive Fabric (weft)

S.No	Samples	No of cycles	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	55	-	-	-	-	-
2.	AA	208	2.76	276	3.28	105.23**	.97 ^{NS}
3.	AB	785	13.22	1322	9.02	204.18**	.28 ^{NS}
4.	AC	180	2.27	227	2.60	95.48**	.83 ^{NS}
5.	AD	352	5.40	540	2.72	222.60**	.63 ^{NS}
6.	AE	1606	28.20	2820	4.48	888.27**	.62 ^{NS}
7.	AF	169	2.07	207	3.41	76.83**	4.50 ^{NS}
8.	AG	549	8.98	898	3.00	354.85**	6.86**
9.	AH	562	9.22	922	3.00	364.18**	.88 ^{NS}
10.	AI	196	2.56	256	2.88	103.12**	.33 ^{NS}
11.	CA	209	2.80	280	2.20	125.05**	.57 ^{NS}
12.	CB	249	3.53	353	2.84	143.29**	.85 ^{NS}
13.	CC	136	1.47	147	3.68	52.26**	2.99 ^{NS}
14.	CD	215	2.91	291	3.65	103.96**	.53 ^{NS}
15.	CE	245	3.45	345	3.54	125.63**	.97 ^{NS}
16.	CF	129	1.35	135	3.63	48.22**	1.09 ^{NS}
17.	CG	259	3.71	371	2.83	150.71**	.835 ^{NS}
18.	CH	235	3.27	327	3.48	120.20**	3.54 ^{NS}
19.	CI	145	1.64	164	3.50	59.97**	.78 ^{NS}
20.	SA	93	0.69	69	3.94	23.71**	1.08 ^{NS}
21.	SB	117	1.13	113	4.16	37.52**	2.97 ^{NS}
22.	SC	63	0.15	15	3.07	5.89**	.94 ^{NS}
23.	SD	97	0.76	76	2.86	31.11**	3.83 ^{NS}
24.	SE	122	1.22	122	3.50	44.68**	1.20 ^{NS}
25.	SF	59	0.07	7	1.84	3.92**	7.10**
26.	SG	91	0.65	65	3.79	23.50**	3.97 ^{NS}
27.	SH	128	1.33	133	3.09	52.02**	.46 ^{NS}
28.	SI	60	0.09	9	2.31	4.70**	.24 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

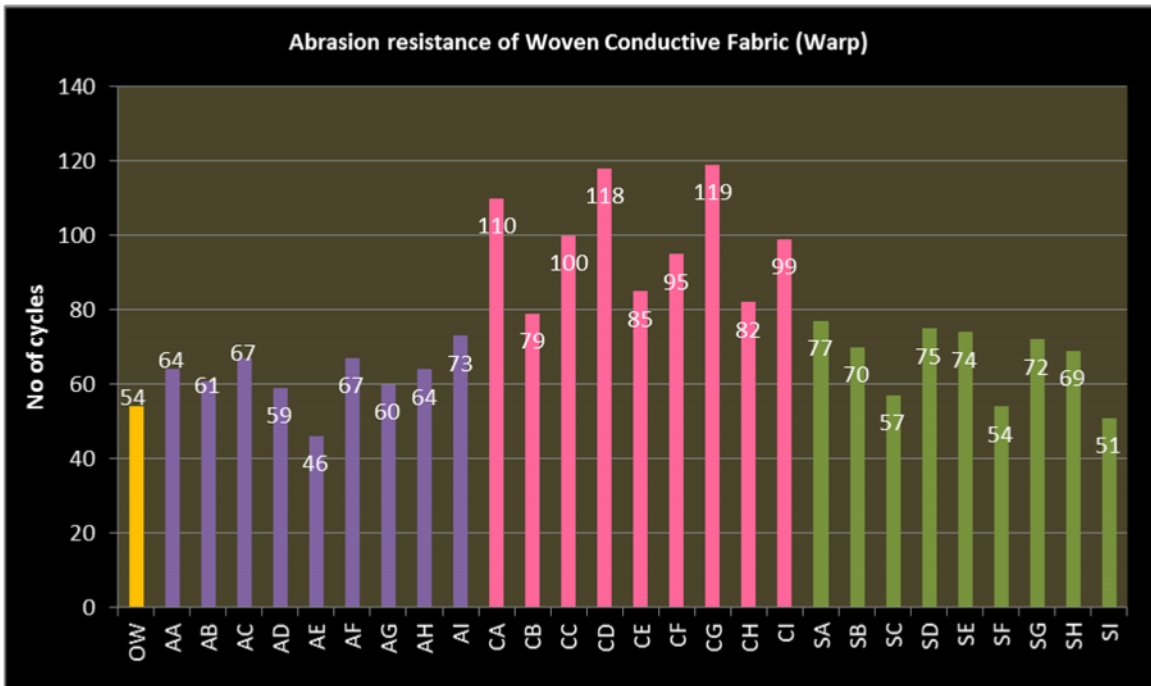


Figure.16
Abrasion resistance of Woven Conductive Fabric (Warp)

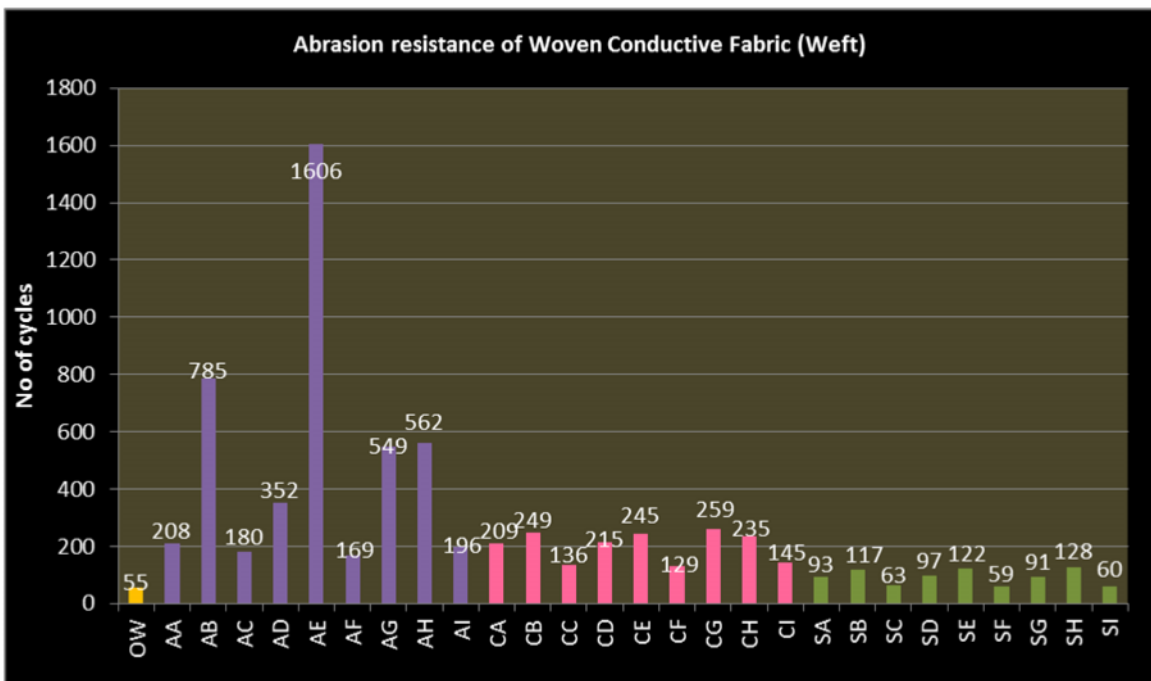


Figure.17
Abrasion resistance of Woven Conductive Fabric (Weft)

With regard to silver conductive woven fabric, the samples SB amongst the group SA, SB, SC (with 15cm of cotton width yarns), SE amongst the group SD, SE, SF (with 10cm of cotton width yarns) and SH amongst the group SG, SH, SI (with 5cm of cotton width yarns) showed highest abrasion resistance in weft direction. Thus it is clear that the samples SB, SE and SH with 2cm of conductive yarn recorded the maximum number of cycles to abrade and it is proven that the samples SC, SF and SI with 1 cm conductive yarns which scored minimum number of cycles to abrade are weak in abrasion resistance. When comparing the samples of three conductive fabrics with plain cotton fabric, all the samples showed good abrasion resistance in weft direction.

Hence it could be concluded that the integration of conductive yarn influence the abrasion resistance and also the difference in width of conductive yarns affects the abrasion resistance of the fabrics. On statistical analysis, all the samples showed 1% level significance. The F values of samples AG and SF are significant at 1% level.

4.4.4 Fabric Bursting Strength

Fabric Bursting Strength of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples are summarized in Table-XVI and represented in the Figure-18.

It is noticeable from the Table XVI and Figure.18 that the sample AA showed the highest mean bursting strength amongst the group AA, AB, AC with 15cm cotton width yarn as 6 kgs/sq.cm. Also amongst the group AD, AE, AF with 10cm cotton width yarn and AG, AH, AI with 5 cm cotton width yarn, the samples AD and AG showed the highest mean bursting strength as 8.5 kgs/sq.cm and 10 kgs/sq.cm respectively. Thus it is clearly shows that the samples AA, AD, AG with 5cm of conductive yarn of aluminium conductive woven fabric observed the highest bursting strength and also showed increase in strength when compared with plain cotton fabric.

Table-XVI
Fabric Bursting Strength of Woven Conductive Fabric

S.No	Samples	Mean (kgs/sq.cm)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OW	5.7	-	-	-	-	-
2.	AA	6	-0.05	-5	0.13	3.14**	1.10 ^{NS}
3.	AB	5.15	0.10	10	0.26	4.60**	0.41 ^{NS}
4.	AC	5.4	0.05	5	0.19	2.85**	1.50 ^{NS}
5.	AD	8.5	-0.49	-49	0.33	20.87**	0.80 ^{NS}
6.	AE	5.5	0.04	4	0.18	1.94 ^{NS}	0.86 ^{NS}
7.	AF	5.3	0.07	7	0.30	3.14**	1.32 ^{NS}
8.	AG	10	-0.75	-75	0.23	38.21**	0.68 ^{NS}
9.	AH	5.2	0.09	9	0.32	3.80**	1.11 ^{NS}
10.	AI	5.5	0.04	4	0.18	1.94 ^{NS}	2.83 ^{NS}
11.	CA	5	0.12	12	0.20	6.58**	0.56 ^{NS}
12.	CB	4.7	0.18	18	0.23	8.89**	3.18 ^{NS}
13.	CC	5.9	-0.04	-4	0.24	1.73 ^{NS}	0.29 ^{NS}
14.	CD	5.3	0.07	7	0.30	3.14**	9.50**
15.	CE	4.7	0.18	18	0.23	8.89**	2.93 ^{NS}
16.	CF	5.8	-0.02	-2	0.31	0.77 ^{NS}	2.11 ^{NS}
17.	CG	5.2	0.09	9	0.32	3.80**	3.10 ^{NS}
18.	CH	4.8	0.16	16	0.33	6.71**	0.90 ^{NS}
19.	CI	5.9	-0.04	-4	0.24	1.73 ^{NS}	2.20 ^{NS}
20.	SA	4.8	0.16	16	0.33	6.71**	0.52 ^{NS}
21.	SB	5.7	0	0	0.27	0.00 ^{NS}	1.44 ^{NS}
22.	SC	5.7	0	0	0.27	0.00 ^{NS}	0.10 ^{NS}
23.	SD	5.1	0.11	11	0.31	4.62**	0.36 ^{NS}
24.	SE	5.8	-0.02	-2	0.31	0.77 ^{NS}	13.84**
25.	SF	5.6	0.02	2	0.20	0.97 ^{NS}	0.36 ^{NS}
26.	SG	5.3	0.07	7	0.32	3.04**	0.83 ^{NS}
27.	SH	5.8	-0.02	-2	0.27	0.82 ^{NS}	2.22 ^{NS}
28.	SI	5.7	0	0	0.27	0.00 ^{NS}	0.82 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

With regard to copper conductive woven fabrics when comparing the samples as groups CA, CB, CC (with 15cm of cotton yarns in between the conductive yarn) CD, CE, CF (with 10cm of cotton yarns in between the conductive yarn) and CG, CH, CI (with 5cm of cotton yarns in between the conductive yarn) it was shown that the samples with 1cm conductive yarns in each group namely CC, CF and CI scored the highest mean bursting strength of 5.9 kgs/sq.cm, 5.8 kgs/sq.cm and 5.9 kgs/sq.cm respectively. The study done by Perumalraj and Dasaradhan (2009) reported that with the increase in diameter of conductive yarn, the bending of copper yarn or other conductive yarns become more difficult resulting in openness in the fabric structure, thereby providing less shielding effectiveness in physical properties as compared to other samples.

Thus it shows less integration of copper conductive yarns gives more bursting strength to the fabric whereas increased width of conductive yarns resulting in openness of the fabric structure.

Considering the silver conductive woven fabrics, it is evident that all the samples recorded similar values without much variation when compared in groups and also showed values related to plain cotton fabric. The result of the bursting strength is statistically proven and all the samples showed significant difference at 1% level except AE, AI, CC, CF, CI, SB, SC, SE, SF, SH and SI. The F value of the samples CD and SE showed 1% level significance.

4.5 Evaluation of the Absorbency Properties of the Woven Conductive Fabric

The water absorbance property of the original woven, aluminium conductive woven, copper conductive woven and silver conductive woven samples were evaluated by conducting wicking test, sinking test and drop test. The results of water absorbency are tabulated below in Table- XVII and Figure-19.

Table-XVII
Water absorbency Test (Woven)

S.No	Samples	Water absorbency Mean values		
		Wicking test (s)	Sinking test (s)	Drop test (s)
1	OW	14100	284	238
2	AA	8100	243	196
3	AB	7800	221	193
4	AC	7740	254	191
5	AD	8160	254	189
6	AE	7860	254	200
7	AF	7680	251	192
8	AG	8040	252	190
9	AH	7800	252	196
10	AI	7740	253	197
11	CA	18000	261	280
12	CB	17820	261	286
13	CC	17400	272	279
14	CD	18180	261	291
15	CE	17880	269	288
16	CF	17460	274	293
17	CG	18060	276	290
18	CH	17820	275	289
19	CI	17520	271	286
20	SA	21900	354	230
21	SB	21720	354	231
22	SC	21600	331	236
23	SD	22200	334	228
24	SE	22080	334	229
25	SF	22260	331	234
26	SG	21840	333	233
27	SH	21600	334	236
28	SI	21780	332	232

Wicking Test

Table XVII and Figure.19 furnished that all the aluminium conductive woven fabric samples took less time to wick 5cm length when compared with plain cotton fabric. On comparing as groups, the sample AC showed minimum time to wick 5cm length amongst the group AA, AB, AC with 15cm cotton width yarn. Also the samples AF and AI recorded minimum time to wick 5cm length amongst the groups AD, AE, AF with 10cm cotton width yarn and AG, AH, AI with 5 cm cotton width yarn. This indicates that the samples AC, AF and AI with 1cm width of conductive yarn took less time in wicking providing better wicking.

Similarly for copper conductive woven fabric, the samples CC, CF and CI amongst the groups CA, CB, CC (with 15cm cotton width yarn), CD, CE, CF (with 10 cm cotton width yarn) and CG, CH, CI (with 5cm cotton width yarn) took minimum time to wick 5cm length of fabric. All the copper conductive fabrics samples took more time to wick 5cm length of fabric when compared with plain cotton fabric. Therefore it is clearly noted that the samples CC, CF, CI with width of 1cm conductive yarn had good wicking.

With regard to silver conductive fabric, all the samples showed increase in time to wick 5cm length of fabric when compared to plain cotton fabric and it is clearly seen that all samples showed similar values without much variation.

Sinking test

Table XVII and Figure.19 depicts that all the samples of aluminium conductive woven fabric and copper conductive woven fabric showed similar time to sink and it reveals that the difference in width of conductive yarns and in width of cotton yarn did not affect absorbency capacity of the conductive fabric. Also when compared with plain cotton woven fabric (OW), all the aluminium conductive and copper conductive fabric samples showed minimum time to sink and this may be due to the weight of conductive yarn.

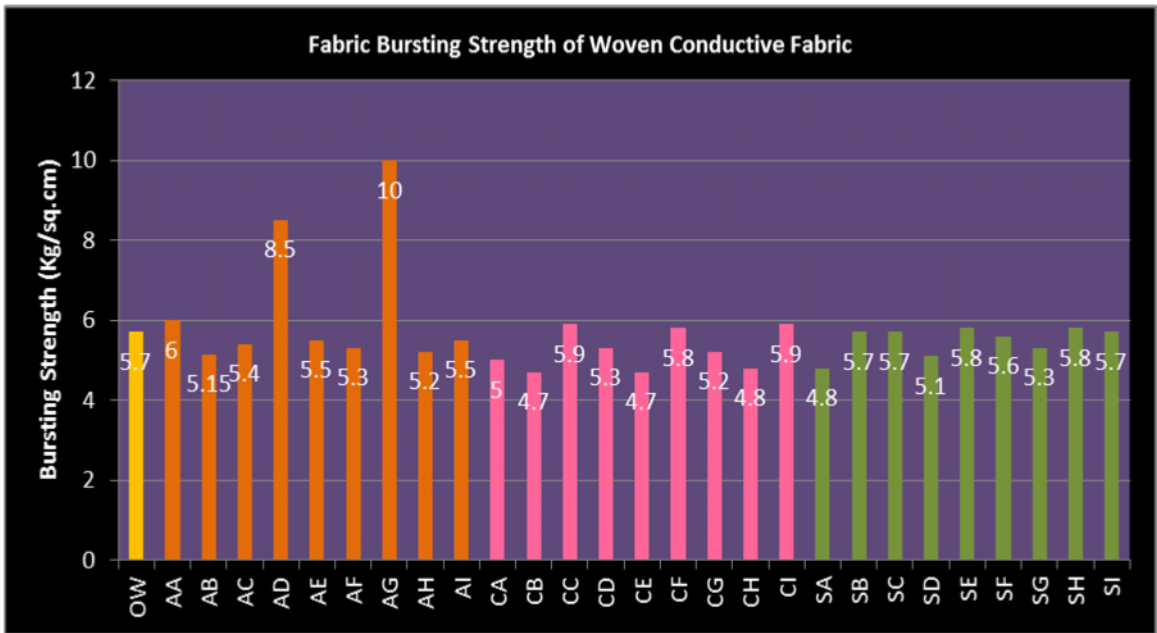


Figure.18

Fabric Bursting Strength of Woven Conductive Fabric

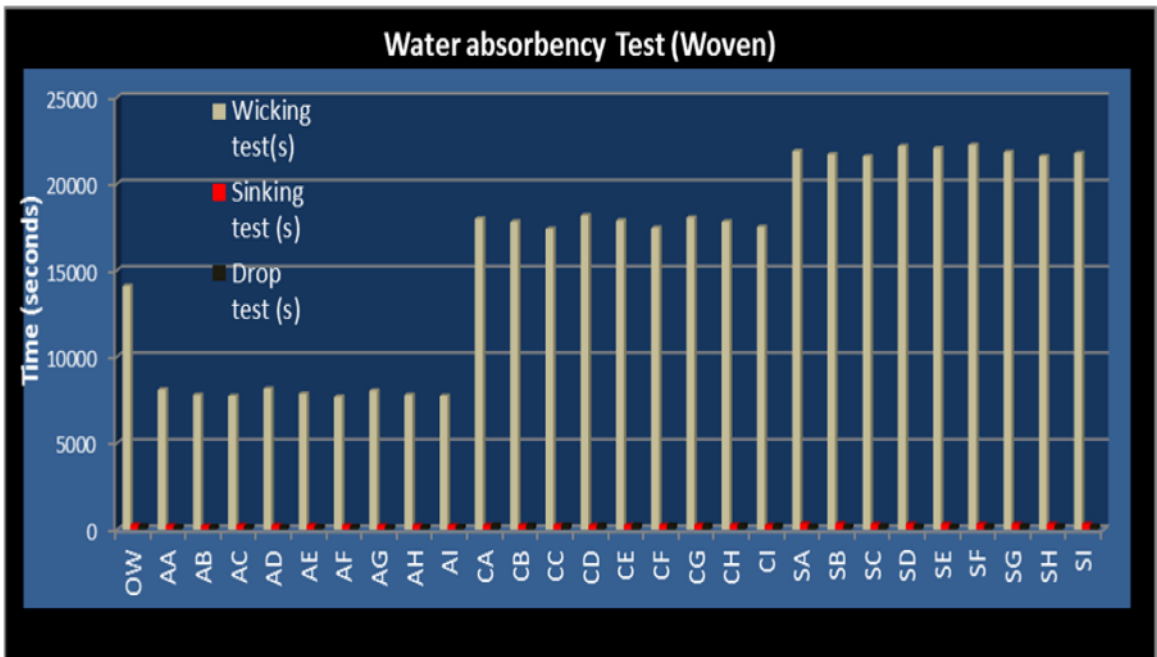


Figure.19

Water absorbency Test (Woven)

With regard to the silver conductive woven fabrics, all the samples showed increase in time to sink when compared with plain cotton fabric and also the time taken by all the samples are similar. Also when comparing all the three conductive fabrics, the aluminium conductive samples showed minimum time to sink. Hence it could be concluded that the weight of conductive fabric is directly proportional to the sinking capacity of the fabric. This result is in par with the studies reported by Xu et al(2017), the use of metal wires as conductive yarns increased the weight of the fabric thereby forcing it to sink soon.

Drop test

From the Table XVII and Figure.19 it is proven that all the samples of aluminium conductive woven fabrics recorded similar and minimum time to absorb a drop of water completely when compared with plain cotton woven fabric. This may be due to the thickness of aluminium conductive yarn.

With regard to copper conductive woven fabrics, all the samples took maximum time to absorb a drop of water completely when compared with plain cotton woven fabric. Also when comparing the silver conductive woven fabrics samples with plain cotton fabric, all the samples recorded similar and minimum time to absorb a drop of water completely. This result is also reported by the researches of Ghosh et al (2017) where the compactness in structure of the fabric is determined by the thickness of yarn thereby influence the absorption property of the fabric.

Hence it could be concluded that the thickness of conductive yarn is directly proportional to the absorbency capacity of the fabric.

4.6. Evaluation of the Physical Properties of the Knitted Conductive Fabric

4.6.1. Fabric Weight

Fabric weight of the original knitted, aluminium conductive knitted, copper conductive knitted and silver conductive knitted samples are disclosed in Table-XVIII and represented in the Figure- 20.

Table-XVIII**Fabric Weight of Knitted Conductive Fabric**

S.No	Samples	Mean (g)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OK	91.3	-	-	-	-	
2.	AK	293.9	0.69	69	2.60	187.07**	4.49**
3.	CK	239.2	0.62	62	3.43	111.78**	1.22 ^{NS}
4.	SK	94.9	0.04	4	2.77	3.03**	.49 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

Table XVIII and Figure- 20 illustrates an increase of weight in all the three types of conductive knitted fabrics when compared with the plain cotton knitted fabric. The highest mean weight is seen in aluminium conductive fabric (AK) as 293.9g. The minimum weight gain was seen in silver conductive fabric (SK) as 94.9gm. Hence it was conducted that the weight of conductive yarn has increased the weight of the fabric. The increase in weight of the conductive fabric in comparison with plain cotton fabric is significant at 1% level. The F value of AK is also significant at 1% level.

4.6.2. Fabric Thickness

Fabric thickness of the original knitted, aluminium conductive knitted, copper conductive knitted and silver conductive knitted samples are summarized in Table- XIX and represented in the Figure- 21.

Table-XIX**Fabric Thickness of Knitted Conductive Fabric**

S.No	Samples	Mean (mm)	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OK	1.38	-	-	-	-	
2.	AK	1.71	0.24	24	0.18	6.46**	2.14 ^{NS}
3.	CK	0.89	-0.36	-36	0.03	34.30**	.15 ^{NS}
4.	SK	1.19	-0.14	-14	0.03	11.05**	24.32**

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

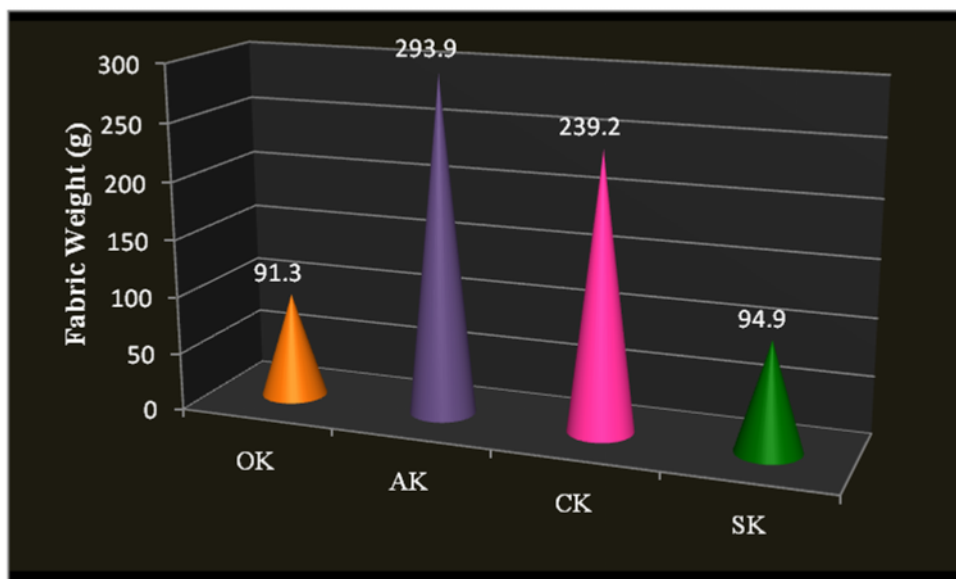


Figure.20

Fabric Weight of Knitted Conductive Fabric

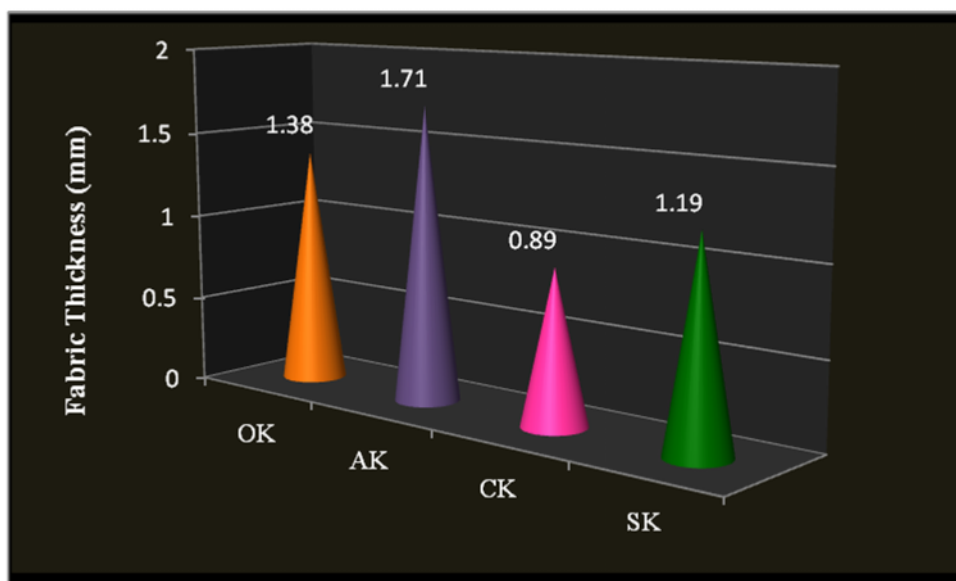


Figure.21

Fabric Thickness of Knitted Conductive Fabric

From the Table XIX and Figure- 21, it is clear that the aluminium conductive knitted fabric (AK) samples ranks high in fabric thickness followed by silver conductive knitted fabric (SK) and copper conductive knitted fabric (CK) respectively. When comparing all the three conductive fabrics with plain knitted fabric, AK showed high in thickness as 1.71mm and the fabric samples CK and SK showed thickness 0.89mm and 1.19mm respectively. Reports by Bonner et al., (2017) in his study states that the thickness of the stainless steel processed yarn or other conductive yarn and the gauge of the knitting machine decides the thickness of the knitted fabrics. These results are similar to the results obtained by the investigator.

Therefore, it was clear that the integration of conductive yarn increases the thickness of the fabric. The increase in thickness of the conductive fabric in comparison with plain cotton fabric is significant at 1% level.

4.7. Evaluation of the Mechanical Properties of the Knitted Conductive Fabric

4.7.1. Fabric Abrasion Resistance

Fabric abrasion resistance of the original knitted, aluminium conductive knitted, copper conductive knitted and silver conductive knitted samples are summarized in Table-XX and represented in the Figure-22.

Table-XX

Fabric Abrasion Resistance of Knitted Conductive Fabric

S.No	Samples	No of cycles	Loss or Gain	Loss or Gain Percentage (%)	SD	T	F
1.	OK	98	-	-	-	-	-
2.	AK	294	-2	-200	6.65	144.76 ^{**}	5.40 ^{**}
3.	CK	239	-1.44	-144	3.07	50.21 ^{**}	3.73 ^{NS}
4.	SK	95	0.03	3	1.50	12.63 ^{**}	.24 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

From the Table XX and Figure- 22, it was evident that the aluminium conductive knitted fabric (AK) samples showed the highest abrasion resistance when comparing all three knitted fabrics followed by copper conductive knitted fabric (CK) and silver

conductive knitted fabric (SK) respectively. When compared with plain cotton fabric (OK), the maximum abrasion is seen in the silver conductive knitted fabric. Also it is noted that the aluminium conductive knitted fabric showed minimum loss of weight during abrasion.

Thus it clearly shows that the thickness of conductive yarn influence the abrasion of the fabric. The result of the abrasion resistance is statistically proven and all the samples showed 1% level significance. The F value of sample AK is significant at 1% level.

4.7.2. Fabric Bursting Strength

Fabric Bursting Strength of the original knitted, aluminium conductive knitted, copper conductive knitted and silver conductive knitted samples are summarized in Table- XXI and represented in the Figure-23 .

Table- XXI

Fabric Bursting Strength of Knitted Conductive Fabric

S.No	Samples	Mean (Kgs/sq.cm)	Loss or Gain	Loss or Gain Percentage(%)	SD	T	F
1.	OK	10.04	-	-	-	-	-
2.	AK	6.83	0.32	32	0.18	6.46 ^{**}	4.49 ^{**}
3.	CK	9.91	0.01	1.3	0.03	34.30 ^{**}	1.22 ^{NS}
4.	SK	11.81	-0.18	-18	0.03	11.05 ^{**}	.49 ^{NS}

Note : ** - Significant at 1% level; * - Significant at 5% level; NS – Not Significant

Table XXI and Figure- 23 proves that the silver conductive knitted samples showed maximum breaking load for bursting strength when compared with plain cotton knitted fabric (OK). Also when comparing all three knitted fabrics, the highest bursting strength is seen in silver conductive fabric (SK) as 11.81 Kgs/sq.cm. The minimum bursting strength is seen in aluminium conductive fabric (AK) as 6.83 Kgs/sq.cm. Dasaradhan and Perumalraj, (2009) reported that the shielding effectiveness of bursting appears to be highly influenced by knitted fabric structure and the metal wire diameter as compared to tightness factor and thickness of developed conductive knitted fabric. This fact explains the results of the bursting strength of the knitted conductive fabric.

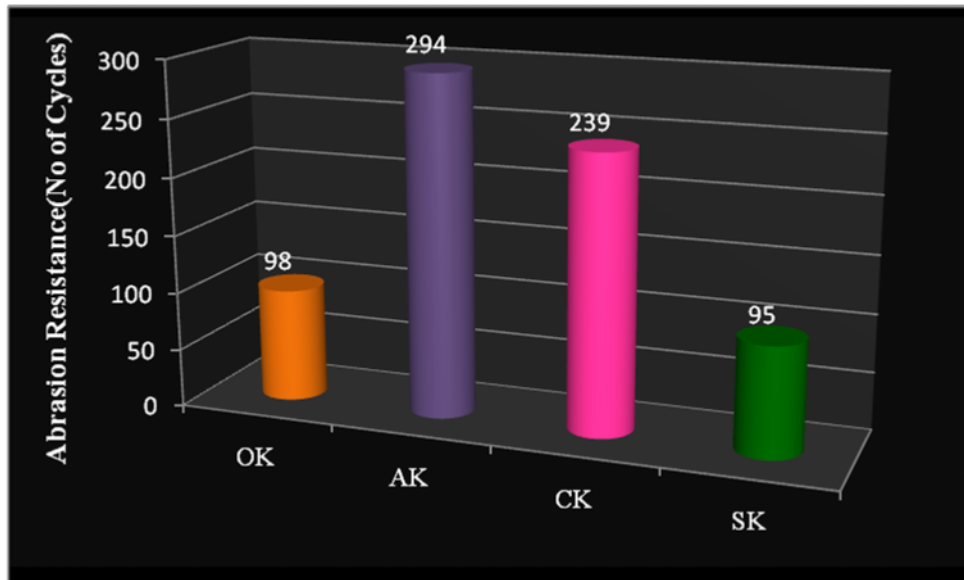


Figure.22

Fabric Abrasion Resistance of Knitted Conductive Fabric

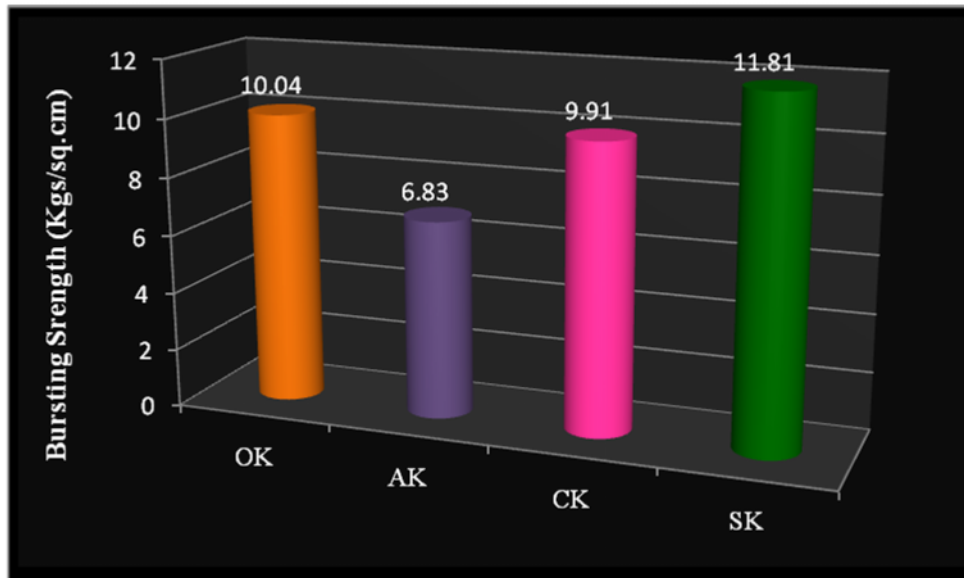


Figure.23

Fabric Bursting Strength of Knitted Conductive Fabric

Hence it was conducted that the thickness of conductive yarn has influenced the bursting strength of the fabric. The result of the bursting strength is statistically proven and all the samples showed 1% level significance.

4.8. Evaluation of the Absorbency Properties of the Knitted Conductive Fabric

Table –XXII and Figure-24 shows the water absorbance property of the original knitted, aluminium conductive knitted, copper conductive knitted and silver conductive knitted samples which were evaluated by conducting wicking test, sinking test and drop test.

Table- XXII
Water Absorbency Test (Knitted)

S.No	Samples	Water absorbency Mean values(s)		
		Wicking test (s)	Sinking test (s)	Drop test (s)
1.	OK	2700	455	450
2.	AK	7200	5	2
3.	CK	7500	262	198
4.	SK	3000	429	161

Wicking test

From the Table-XXII and Figure-24, it was evident that the silver conductive knitted fabric (SK) samples had taken the minimum time to wick 5cm length of fabric as 3000 seconds. Also the copper conductive knitted fabrics (CK) took more time to wick 5cm length of fabric when compared with plain cotton fabric. When comparing all three knitted fabrics, the silver conductive knitted fabric showed good absorbency capacity. Hence it could be concluded that the thickness of conductive yarn influence the absorbency of the fabric.

Sinking test

Table XXII and Figure-24 describes that aluminium conductive knitted fabric (AK) showed to have taken the minimum time to sink as 5 seconds and the maximum

time to sink is recorded in silver conductive knitted fabric (SK) as 429 seconds. Hence it could be concluded that the weight of conductive fabric is directly proportional to the sinking capacity of the fabric.

Drop test

From the Table XXII and Figure-24 it is proven that the aluminium conductive knitted fabrics (AK) recorded minimum time to absorb a drop of water completely as 2 seconds when compared with all the three conductive knitted fabrics. This may be due to the thickness of aluminium conductive yarn that decides the knit structure compatibility.

When compared with plain cotton knitted fabric (OK), all the three conductive knitted fabrics took minimum time to absorb a drop of water completely. Hence it could be concluded that the thickness of conductive yarn is directly proportional to the absorbency capacity of the fabric.

As reported by Barhenpurkar et al, (2015) the coating in the metal filament yarns and metal wires blocks the passage of water into it and influence the absorbency capacity of conductive fabric. This is similarly to this research results. Hence it could be concluded that the presence of metallic yarns reduces the absorbency property of the fabric.

4.9. Electrical Analysis of Conductive Yarns

Electrical resistance is the property of the material by which it opposes the flow of current through it. Electrical resistance of conductive yarns was found and shown in Table-XXIII.

Table – XXIII
Electrical Analysis of Conductive Yarns

S.No	Electrical Resistance	Mean in mΩ/Mtr
1	Copper yarn	1719.2
2	Aluminium yarn	376.4
3	Silver yarn	negligible

It is noticeable from the above Table XXIII that the electrical resistance of silver is negligible so that the electrical conductivity is high when compared with copper and aluminium with the resistance of 376.4 mΩ/Mtr and 1719.2 mΩ/Mtr accordingly.

Neelakandan and Madhusoothanan (2010) reported that woven conductive fabrics that are woven possess better electrical performance and in addition increase in electrical resistance resulting in improved electrical conductivity. Therefore, the three conductive yarns were ranked in order for electrical resistance as silver, aluminium, copper respectively and are suitable for wearable electronics as transmission lines.

4.10. Electro-mechanical Analysis of Conductive Textile Fabric

A dependence of width-related surface resistance of all conductive fabrics are measured and shown in Table-XXIV and Figure-25.

Table – XXIV Electro-mechanical Analysis

S.No	Surface Resistance	Copper yarn	Aluminium yarn	Silver yarn
1	Weaving width: 1.2 cm	34.3 K Ω	47 M Ω	14.5 K Ω
2	Weaving width: 2.2 cm	54.7 K Ω	495 M Ω	17 K Ω
3	Weaving width: 5.2 cm	189 K Ω	576 M Ω	17 K Ω

From the Table XXIV it is clear that the highest surface resistance of copper, aluminium and silver was noted in weaving width of 5.2 cm as 189 K Ω , 576 M Ω and 17 K Ω respectively. Sekerden (2013) reported a similar study where the surface resistivity of the fabrics changed according to the weave type and weft metal yarn type. His study also states that surface resistivity increases simultaneously with the number of warp or weft yarn insertion. Hence it could be concluded that the aluminium interlaced conductive fabric is high in surface resistance when comparing all conductive fabrics followed by copper and silver. It is also evident from the above table that the surface resistance is increasing with increased weaving width of conductive yarn in the fabric. The relation between the thermal conductivity and electrical conductivity can be explained as per Wiedemann–Franz law (Law given in Appendix XV).

By comparing the above results of the mechanical and electrical analysis of conductive yarns, it is clear from the results that copper had medium thickness, average elongation and uniform surface resistance. This indicates that the copper interlaced conductive fabric shows good result in the aspects of comfort, accuracy and safety. Adding to it, with the demand of developments in new wearable sensing systems, the copper interlaced conductive fabric is suitable for further wearable electronic design.

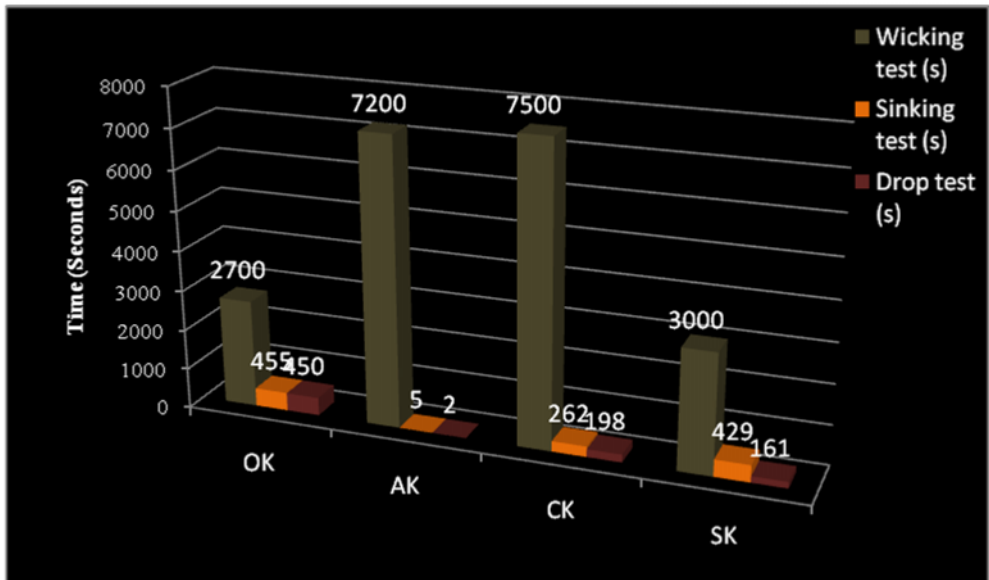


Figure-24
Water Absorbency Test (Knitted)

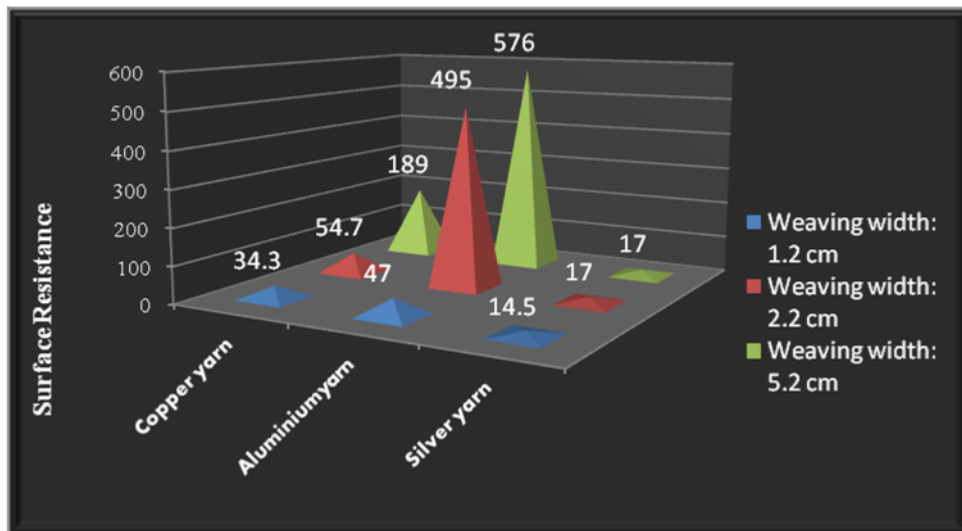


Figure.25
Electro-mechanical Analysis

4.11. Evaluation of the developed Wearable Electronic garment by animal study

Wearable electronic band using aluminium conductive fabric was constructed and wrapped around the rat to conduct the wear study for monitor its body temperature and the readings are tabulated in Table-XXV and illustrated Figure-26.

Table-XXV

Assessment of Body Temperature using Aluminium Wearable Electronic Band

S.No	Band	Mean Time (Min)	Mean Temperature (°C) at normal condition			Mean Temperature (°C) after inducing fever		
			Controlled Rats	Experimental Rats		Controlled Rats	Experimental Rats	
				Using Medical Thermometer	Wearable Electronic Band		Using Medical Thermometer	Wearable Electronic Band
1	AA	1	35.9	37.3	37.3	38	38.7	38.6
2		2	35.6	37	37.8	37.9	38.4	38.9
3		3	36.4	37.2	37.4	38.1	39.2	39.3
4		4	36.6	37	37.1	38	39.4	39.1
5		5	36.3	37.2	37.2	37.9	39.1	39.1
6		6	36	37.4	37.6	37.7	38.8	38.9
7		7	36.1	37.5	37.5	37.8	38.9	39
8		8	35.6	37	37.1	37.9	38.4	38.8
9		9	35.8	37.2	37.2	37.7	38.6	38.9
10		10	36.1	37.5	37.2	37.8	38.9	39
11		11	36	37.4	37.4	38	38.8	39
12		12	36.2	37.4	37.8	37.7	39	38.9
13		13	36.5	37.1	37	37.9	39.3	39.1
14		14	36.7	37.1	37.2	38.1	39.5	39.3
15		15	36.3	37.2	37.2	37.9	39.1	39.1
16		16	36.2	37.3	37.3	37.9	39	39.1
17		17	36.3	37.2	37.2	38.1	39.1	39.3
18		18	36.4	37.2	37	38.1	39.2	39.3
19		19	36.5	37.2	37.2	38.2	39.3	39.6

20		20	36.3	37.3	37.3	38	39.1	39.2
21	AB	1	35.9	37.3	37.5	38	38.7	39
22		2	35.6	37	37.1	37.9	38.4	38.4
23		3	36.4	37.2	37.2	38.1	39.2	39.3
24		4	36.6	37	37.1	37.9	39.4	39.1
25		5	36.3	37.2	37.2	37.9	39.1	39.1
26		6	36	37.4	37.4	37.7	38.8	38.9
27		7	36.1	37.5	37.5	37.8	38.9	39
28		8	35.6	37	37.1	38	38.4	38.5
29		9	35.8	37.2	37.2	37.7	38.6	38.7
30		10	36.1	37.5	37.5	37.8	38.9	39
31		11	36	37.4	37.4	38	38.8	39
32		12	36.2	37.6	37.5	37.7	39	38.4
33		13	36.5	37.6	37.5	37.9	39.3	39.1
34		14	36.7	37.2	37.1	38.1	39.5	39.3
35		15	36.3	37.1	37.2	37.9	39.1	39.1
36		16	36.2	37.3	37.3	37.9	39	39.1
37		17	36.3	37.3	37.5	38.1	39.1	39.3
38		18	36.4	37.5	37.5	38.1	39.2	39.3
39		19	36.5	37.1	37	38.2	39.3	39.4
40		20	36.3	37.2	37.2	38	39.1	39.2
41	AC	1	35.9	37.3	37.3	38	38.7	38.7
42		2	35.6	37	37	37.9	38.4	38.6
43		3	36.4	37.3	37.5	38.1	39.2	39.3
44		4	36.6	37	37	37.9	39.4	39.4
45		5	36.3	37.3	37.5	37.9	39.1	39.1
46		6	36	37.4	37.4	37.7	38.8	38.9
47		7	36.1	37.5	37.5	37.8	38.9	39
48		8	35.6	37.1	37.3	37.9	38.4	38.5
49		9	35.8	37.2	37.8	37.7	38.6	38.7
50		10	36.1	37.6	37.4	37.8	38.9	39

51	11	36	37.4	37.5	38	38.8	38.9
52	12	36.2	37.2	37.3	37.7	39	38.9
53	13	36.5	37.4	37.4	37.9	39.3	39.1
54	14	36.7	37.1	37.1	38.1	39.5	39.3
55	15	36.3	37.4	37.4	38	39.1	39.1
56	16	36.2	37.2	37.8	37.9	39	39.1
57	17	36.3	37.4	37.3	38.1	39.1	39.3
58	18	36.4	37.3	37.3	38.1	39.2	39.3
59	19	36.5	37.4	37.4	38.2	39.3	39.6
60	20	36.3	37.2	37.3	38	39.1	39.2

From Table XXV and Figure 26 it is clear that the normal body temperature of the controlled rats at normal conditions ranged between 35.6 to 36.7°C. Whereas the body temperature of the experimental rats ranged between 37 to 37.6°C and 37 to 37.8°C, when calculated using the common medical tool and the Aluminium wearable electronic band.

The table shows a very slight difference between the body temperature measures by common medical tool and the aluminium wearable electronic band. But on the average it is negotiable. The slight difference in body temperature in controlled and experimental rats may be due to the removal of the dorsal hair or being caged, in order to fix the Aluminium wearable electronic band to the rat.

After induction of fever, the body temperature of the control rats ranged between 37.9 to 38.2°C. In case of the experimental rats, the temperature showed range between 38.4 to 39.5 °C and 38.4 to 39.6 °C when measured using the common medical tool and as per the display in the smart phone which was noted due to the contact of rat's body with the aluminium wearable electronic band. Hence it could be concluded that the designed Aluminium wearable electronic band could be used to calculate the actual body temperature of the rats.

Wearable electronic band using copper conductive fabric was constructed and wrapped around the rat to conduct the wear study for monitor its body temperature and the readings are tabulated in Table-XXVI and illustrated Figure-27.

Table-XXVI

Assessment of Body Temperature using Copper Wearable Electronic Band

S.No	Band	Mean Time (Min)	Mean Temperature (°C) at normal condition			Mean Temperature (°C) after inducing fever		
			Controlled Rats	Experimental Rats		Controlled Rats	Experimental Rats	
				Using Medical Thermometer	Wearable Electronic Band		Using Medical Thermometer	Wearable Electronic Band
1	CA	1	36	37.4	37.4	37.7	38.8	38.9
2		2	36.1	37.5	37.5	37.8	38.9	39
3		3	35.6	37.1	37.3	37.9	38.4	38.5
4		4	35.8	37.2	37.1	37.7	38.6	38.7
5		5	36.1	37.6	37.4	37.8	38.9	39
6		6	36	37.4	37.5	38	38.8	38.9
7		7	36.2	37.2	37.3	37.7	39	38.9
8		8	36.5	37.4	37.4	37.9	39.3	39.1
9		9	36.7	37.1	37.1	38.1	39.4	39.3
10		10	36.3	37.4	37.4	37.9	39.1	39.1
11		11	36.2	37.2	37.3	37.9	39	39.1
12		12	36.3	37.4	37.3	38.1	39.1	39.3
13		13	36.4	37.3	37.3	38.1	39.2	39.3
14		14	36.5	37.4	37.4	38.2	39.3	39.5
15		15	36.3	37.2	37.3	38	39.1	39.2
16		16	35.9	37.3	37.3	38	38.7	38.6
17		17	35.6	37	37.1	37.9	38.4	38.3
18		18	36.4	37.2	37.4	38.1	39.2	39.3
19		19	36.6	37	37.1	37.9	39.4	39.1
20		20	36.3	37.2	37.2	37.9	39.1	39.1
21	CB	1	36	37.4	37.4	37.7	38.8	38.9
22		2	36.1	37.5	37.5	37.8	38.9	39
23		3	35.6	37	37.1	37.9	38.4	38.3
24		4	35.8	37.2	37.2	37.7	38.6	38.9
25		5	36.1	37.5	37.2	37.8	38.9	39
26		6	36	37.4	37.4	38	38.8	39
27		7	36.2	37.5	37.8	37.7	39	38.9

28		8	36.5	37.1	37	37.9	39.3	39.1
29		9	36.7	37.1	37.2	38.1	39.4	39.3
30		10	36.3	37.2	37.2	37.9	39.1	39.1
31		11	36.2	37.3	37.3	37.9	39	39.1
32		12	36.3	37.2	37.2	38.1	39.1	39.3
33		13	36.4	37.2	37	38.1	39.2	39.3
34		14	36.5	37.2	37.2	38.2	39.3	39.5
35		15	36.3	37.3	37.3	38	39.1	39.2
36		16	35.9	37.3	37.8	38	38.7	39
37		17	35.6	37	37.1	37.9	38.4	38.4
38		18	36.4	37.2	37.2	38.1	39.2	39.3
39		19	36.6	37	37.1	37.9	39.4	39.1
40		20	36.3	37.2	37.2	37.9	39.1	39.1
41	CC	1	36	37.4	37.4	37.7	38.8	38.9
42		2	36.1	37.5	37.5	37.8	38.9	39
43		3	35.6	37	37.1	37.9	38.4	38.3
44		4	35.8	37.2	37.2	37.7	38.6	38.7
45		5	36.1	37.5	37.5	37.8	38.9	39
46		6	36	37.4	37.4	38	38.8	39
47		7	36.2	37.6	37.5	37.7	39	38.9
48		8	36.5	37.6	37.5	37.9	39.3	39.1
49		9	36.7	37.2	37.1	38.1	39.4	39.3
50		10	36.3	37.1	37.2	37.9	39.1	39.1
51		11	36.2	37.3	37.3	37.9	39	39.1
52		12	36.3	37.3	37.5	38.1	39.1	39.3
53		13	36.4	37.5	37.5	38.1	39.2	39.3
54		14	36.5	37.1	37	38.2	39.3	39.5
55		15	36.3	37.2	37.2	38	39.1	39.2
56		16	35.9	37.3	37.3	38	38.7	38.7
57		17	35.6	37	37	37.9	38.4	38.3
58		18	36.4	37.3	37.5	38.1	39.2	39.3
59		19	36.6	37	37	37.9	39.4	39.4
60		20	36.3	37.3	37.5	37.9	39.1	39.1

From Table XXVI and Figure 27 it is shown that the range of normal body temperature of the control rats at normal conditions is between 35.6 to 36.7°C. When calculating the body temperature of the experimental rats using the common medical

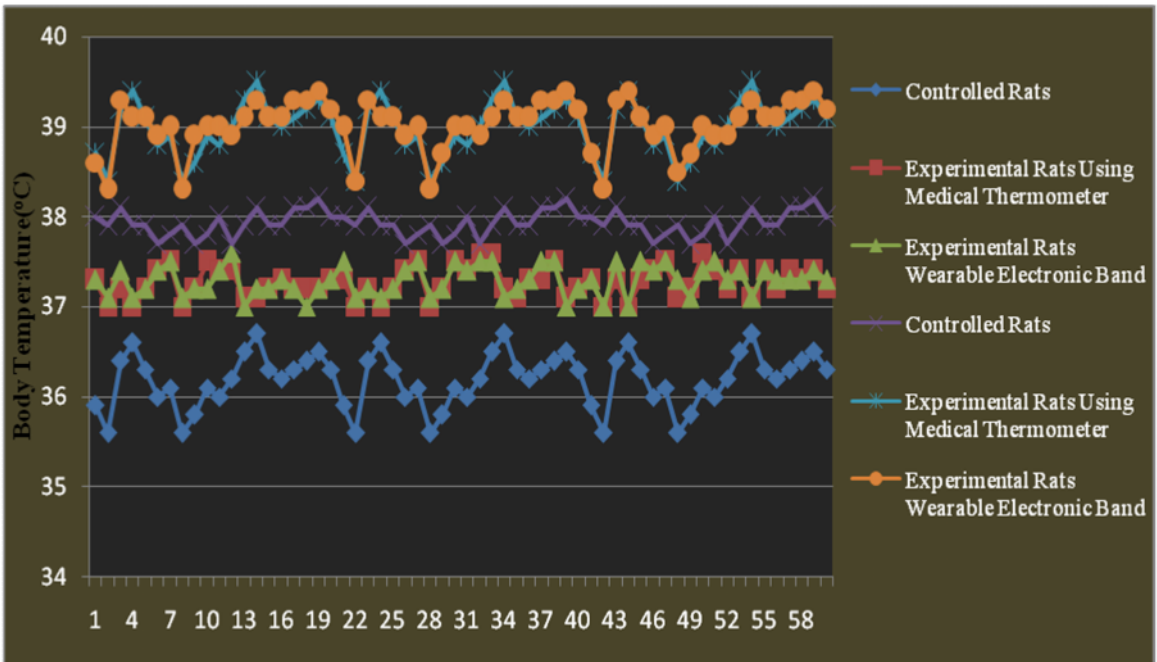


Figure.26

Assessment of Body Temperature using Aluminium Wearable Electronic Band

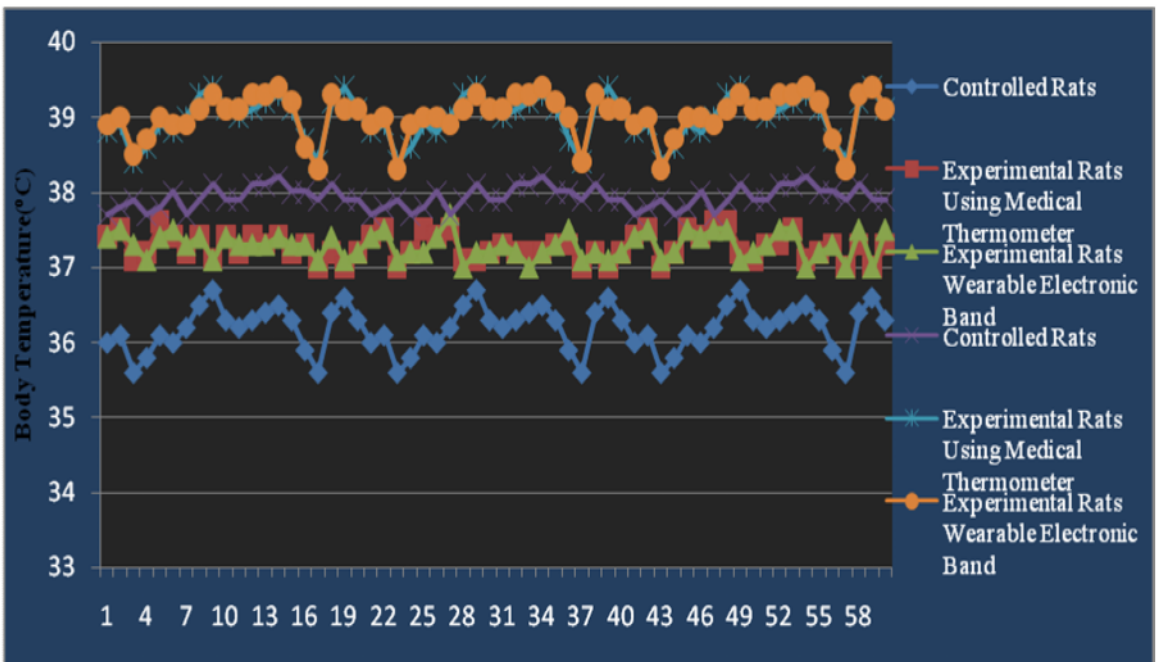


Figure.27

Assessment of Body Temperature using Copper Wearable Electronic Band

tool and the copper wearable electronic band, it is ranged between 37 to 37.6 °C and 37 to 37.8 °C .

The table shows a very slight difference between the body temperature measures by common medical tool and the copper wearable electronic band. But on the average it is negotiable. The minute difference in body temperature in controlled and experimental rats may be due to the removal of the dorsal hair or being caged, in order to fix the copper wearable electronic band to the rat.

After inducing the fever, the body temperature of the control rats ranged between 37.7 to 38.2°C. When considering the experimental rats, the body temperature is ranged between 38.4 to 39.4°C and 38.3 to 39.5 °C on measured using the common medical tool and as per the temperature display in the smart phone which was noted with the help of wrapping the copper wearable electronic band around the rats to get in touch with the body. Therefore it is concluded that the designed copper wearable electronic band could be used to calculate the actual body temperature of the rats.

Wearable electronic band using silver conductive fabric was constructed and wrapped around the rat to conduct the wear study for monitor its body temperature and the readings are tabulated in Table-XXVII and illustrated Figure-28.

Table-XXVII
Assessment of Body Temperature using Silver Wearable Electronic Band

S.No	Band	Mean Time (Min)	Mean Temperature (°C) at normal condition			Mean Temperature (°C) after inducing fever		
			Controlled Rats	Experimental Rats		Controlled Rats	Experimental Rats	
				Using Medical Thermometer	Wearable Electronic Band		Using Medical Thermometer	Wearable Electronic Band
1	SA	1	36	37.4	37.4	37.7	38.8	38.9
2		2	36.1	37.5	37.5	37.8	38.9	39
3		3	35.6	37	37.1	37.9	38.4	38.3
4		4	35.8	37.2	37.2	37.7	38.6	38.7

5		5	36.1	37.5	37.5	37.8	38.9	39
6		6	36	37.4	37.4	38	38.8	39
7		7	36.2	37.8	37.5	37.7	39	38.9
8		8	36.5	37.8	37.5	37.9	39.3	39.1
9		9	36.8	37.2	37.1	38.1	39.5	39.3
10		10	36.3	37.1	37.2	37.9	39.1	39.1
11		11	36.2	37.3	37.3	37.9	39	39.1
12		12	36.3	37.3	37.5	38.1	39.1	39.3
13		13	36.4	37.5	37.5	38.1	39.2	39.3
14		14	36.5	37.1	37	38.3	39.3	39.4
15		15	36.3	37.2	37.2	38	39.1	39.2
16		16	35.9	37.3	37.3	38	38.7	38.7
17		17	35.6	37	37	37.9	38.4	38.3
18		18	36.4	37.3	37.5	38.1	39.2	39.3
19		19	36.6	37	37	37.9	39.4	39.4
20		20	36.3	37.3	37.5	37.9	39.1	39.1
21	SB	1	36	37.4	37.4	37.7	38.8	38.9
22		2	36.1	37.5	37.5	37.8	38.9	39
23		3	35.6	37.1	37.3	37.9	38.4	38.5
24		4	35.8	37.2	37.1	37.7	38.6	38.7
25		5	36.1	37.8	37.4	37.8	38.9	39
26		6	36	37.4	37.5	38	38.8	38.9
27		7	36.2	37.2	37.3	37.7	39	38.9
28		8	36.5	37.4	37.4	37.9	39.3	39.1
29		9	36.7	37.1	37.1	38.1	39.5	39.3
30		10	36.3	37.4	37.4	37.9	39.1	39.1
31		11	36.2	37.2	37.3	37.9	39	39.1
32		12	36.3	37.4	37.3	38.1	39.1	39.3
33		13	36.4	37.3	37.3	38.1	39.2	39.3
34		14	36.5	37.4	37.4	38.3	39.3	39.5
35		15	36.3	37.2	37.3	38	39.1	39.2
36		16	35.9	37.3	37.3	38	38.7	38.6
37		17	35.6	37	37.1	37.9	38.4	38.3
38		18	36.4	37.2	37.4	38.1	39.2	39.3
39		19	36.6	37	37.1	37.9	39.4	39.1
40		20	36.3	37.2	37.2	37.9	39.1	39.1

41	SC	1	36	37.4	37.4	37.7	38.8	38.9
42		2	36.1	37.5	37.5	37.8	38.9	39
43		3	35.6	37	37.1	37.9	38.4	38.3
44		4	35.8	37.2	37.2	37.7	38.6	38.9
45		5	36.1	37.5	37.2	37.8	38.9	39
46		6	36	37.4	37.4	38	38.8	39
47		7	36.2	37.4	37.8	37.7	39	38.9
48		8	36.5	37.1	37	37.9	39.3	39.1
49		9	36.8	37.1	37.2	38.1	39.5	39.3
50		10	36.3	37.2	37.2	37.9	39.1	39.1
51		11	36.2	37.3	37.3	37.9	39	39.1
52		12	36.3	37.2	37.2	38.1	39.1	39.3
53		13	36.4	37.2	37	38.1	39.2	39.3
54		14	36.5	37.2	37.2	38.2	39.3	39.5
55		15	36.3	37.3	37.3	38	39.1	39.2
56		16	35.9	37.3	37.5	38	38.7	39
57		17	35.6	37	37.1	37.9	38.4	38.4
58		18	36.4	37.2	37.2	38.1	39.2	39.3
59		19	36.6	37	37.1	37.9	39.4	39.1
60		20	36.3	37.2	37.2	37.9	39.1	39.1

From Table XXVII and Figure 28 it is clear that the normal body temperature of the control rats at normal conditions ranged between 35.6 to 36.8°C. Whereas the body temperature of the experimental rats ranged between 37 to 37.8 °C and 37 to 37.8 °C, when calculated using the common medical tool and the silver wearable electronic band.

The table shows a very slight difference between the body temperature measures by common medical tool and the silver wearable electronic band. But on the average it is negotiable. The slight difference in body temperature in experimental rats may be due to the removal of the dorsal hair or being caged, in order to fix the silver wearable electronic band to the rat.

This action might have caused fear or anxiety in the rats, resulting in changes in body condition (temperature). Studies conducted by Spencer et al (2005) on the

“Behavioral Brain Research” have proved changes in body conditions due to anxiety and fear.

After induction of fever the body temperature of the control rats ranged between 37.7 to 38.°C. In case of the experimental rats, the temperature showed range between 38.4 to 39.5°C and 38.3 to 39.5 °C when measured using the common medical tool and as per the display in the smart phone which was noted due to the contact of rat’s body with the silver wearable electronic band. Hence it could be concluded that the designed silver wearable electronic band could be used to calculate the actual body temperature of the rats.

From the above results it is clear that the wearable electronic band is effective in monitoring the body temperature of rats irrespective of types of conductive fabrics used. When comparing the readings shown in smart phone with the reading shown in medical thermometer, the values are more or less similar. Hence it could be concluded that the wearable electronic band is good in monitoring the body temperature.

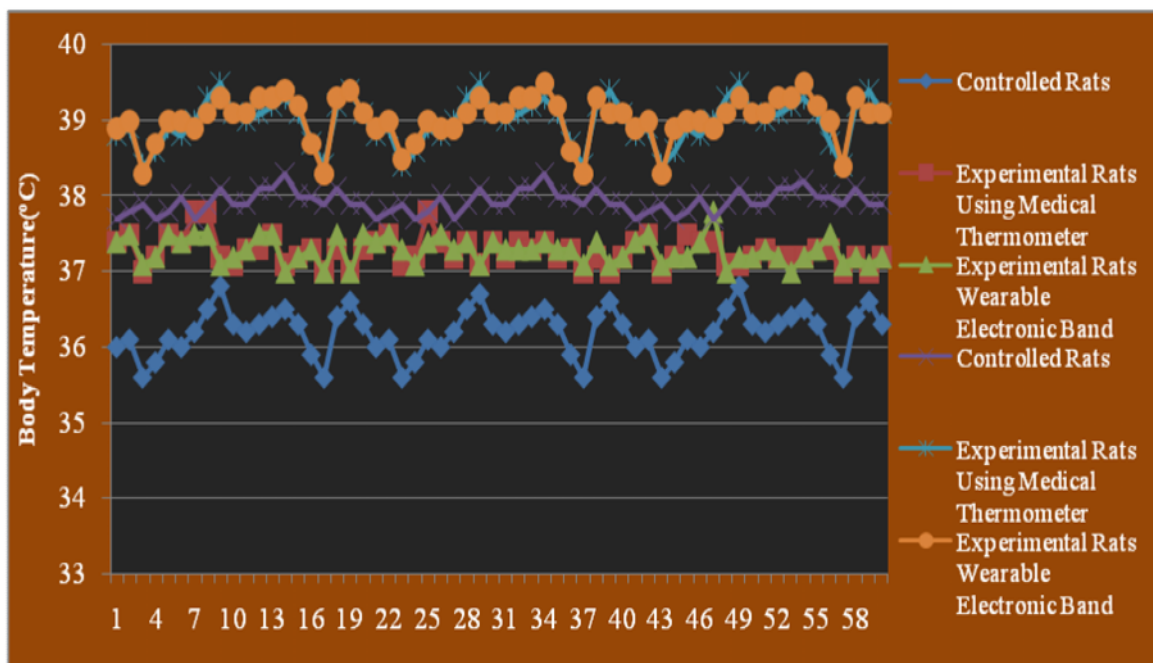


Figure.28
Assessment of Body Temperature using Silver Wearable Electronic Band

Wearable electronic band using aluminium conductive fabric was constructed and wrapped around the rat to conduct the wear study for monitor its heart rate and the readings are tabulated in Table-XXVIII and illustrated Figure-29.

Table-XXVIII
Assessment of Heart Rate using Aluminium Wearable Electronic Band

S.No	Band	Mean Time (Min)	Mean Heart Rate (bpm) at normal condition			Mean Heart Rate (bpm) after inducing fever		
			Controlled Rats	Experimental Rats		Controlled Rats	Experimental Rats	
				Using Medical Tool	Wearable Electronic Band		Using Medical tool	Wearable Electronic Band
1	AA	1	334	350	359	375	383	389
2		2	342	345	354	383	391	397
3		3	338	348	357	379	387	393
4		4	337	342	351	378	386	392
5		5	331	344	353	372	379	386
6		6	343	340	349	384	392	398
7		7	349	345	354	390	398	399
8		8	346	350	359	387	395	397
9		9	347	348	357	388	396	399
10		10	343	349	358	384	392	398
11		11	338	345	354	379	387	390
12		12	339	340	349	380	388	389
13		13	340	337	346	381	389	387
14		14	343	338	347	384	392	391
15		15	346	342	351	387	395	394
16		16	339	344	353	380	388	390
17		17	337	340	349	378	386	386
18		18	341	339	348	382	390	395
19		19	344	345	354	385	393	398
20		20	345	340	349	386	394	397
21	AB	1	334	350	360	375	383	389
22		2	342	345	354	383	391	397
23		3	338	348	357	379	387	393
24		4	337	342	351	378	386	392

25		5	331	344	353	372	380	386
26		6	343	340	349	384	392	398
27		7	349	345	354	390	398	399
28		8	346	350	359	387	395	397
29		9	347	348	357	388	396	399
30		10	343	349	358	384	392	398
31		11	338	345	354	379	387	390
32		12	339	340	349	380	388	389
33		13	340	337	346	381	389	387
34		14	343	338	347	384	392	391
35		15	346	342	351	387	395	394
36		16	339	344	353	380	388	390
37		17	337	340	349	378	386	385
38		18	341	339	348	382	390	395
39		19	344	345	354	385	393	398
40		20	345	340	349	386	394	397
41	AC	1	334	351	359	375	383	389
42		2	342	345	354	383	391	397
43		3	338	348	357	379	387	393
44		4	337	342	351	378	386	392
45		5	331	344	353	372	380	386
46		6	343	340	349	384	392	398
47		7	349	345	354	390	398	399
48		8	346	350	359	387	395	397
49		9	347	348	357	388	396	399
50		10	343	349	358	384	392	398
51		11	338	345	354	379	387	390
52		12	339	340	349	380	388	389
53		13	340	337	345	381	389	387
54		14	343	338	347	384	392	391
55		15	346	342	351	387	395	394
56		16	339	344	353	380	388	390
57		17	337	340	349	378	386	386
58		18	341	339	348	382	390	395
59		19	344	345	354	385	393	398
60		20	345	340	349	386	394	397

From Table XXVIII and Figure 29 it is clear that the normal heart rate of the controlled rats at normal conditions ranged between 331 to 349 bpm. Whereas the heart rate of the experimental rats ranged between 337 to 351 bpm and 345 to 360 bpm, when calculated using the common medical tool and the Aluminium wearable electronic band.

The table shows a very slight difference between the heart rate measures by common medical tool and the aluminium wearable electronic band. But on the average it is negotiable. The slight difference in heart rate in controlled and experimental rats may be due to the removal of the dorsal hair or being caged, in order to fix the Aluminium wearable electronic band to the rat.

After induction of fever, the heart rate of the control rats varied from 372 to 390 bpm. In case of the experimental rats, the heart rate varied from 379 to 398 bpm and 385 to 399 bpm when measured using the common medical tool and as per the display in the smart phone which was noted due to the contact of rat's body with the aluminium wearable electronic band. Hence it could be concluded that the designed Aluminium wearable electronic band could be used to calculate the actual heart rate of the rats.

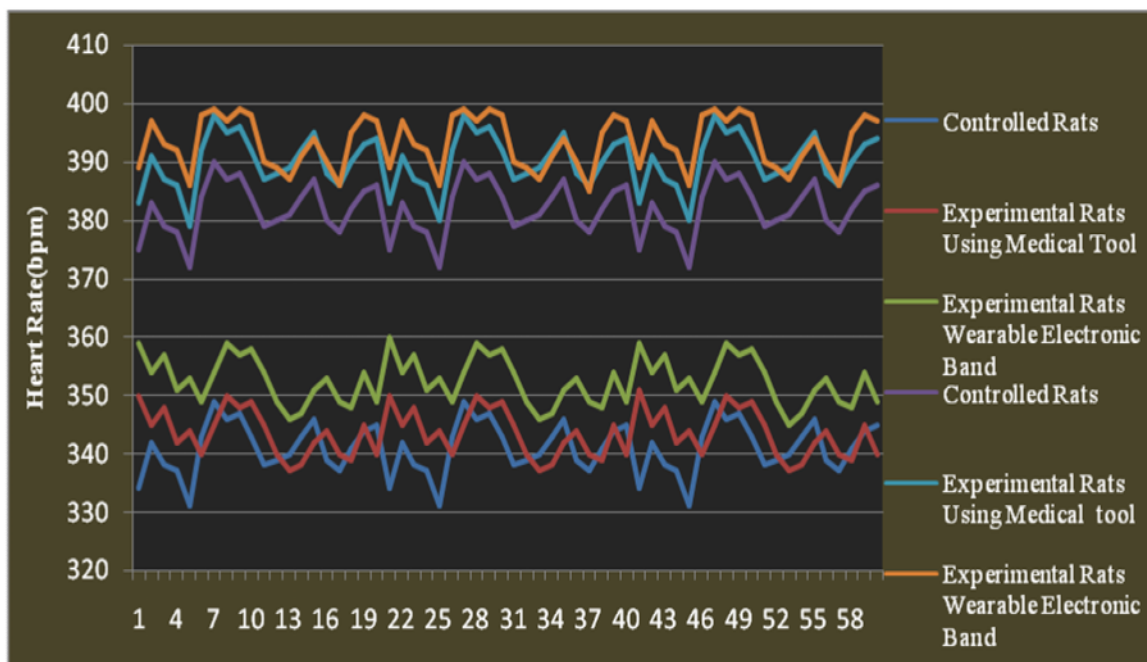


Figure.29
Assessment of Heart Rate using Aluminium Wearable Electronic Band

Wearable electronic band using copper conductive fabric was constructed and wrapped around the rat to conduct the wear study for monitor its heart rate and the readings are tabulated in Table-XXIX and illustrated Figure-30.

Table-XXIX

Assessment of Heart Rate using Copper Wearable Electronic Band

S.No	Band	Mean Time (Min)	Mean Heart Rate (bpm) at normal condition			Mean Heart Rate (bpm) after inducing fever		
			Controlled Rats	Experimental Rats		Controlled Rats	Experimental Rats	
				Using Medical Tool	Wearable Electronic Band		Using Medical tool	Wearable Electronic Band
1	CA	1	342	342	346	375	383	390
2		2	338	344	347	383	391	389
3		3	337	340	351	379	387	387
4		4	331	339	353	378	386	391
5		5	343	345	349	372	380	394
6		6	342	340	349	384	392	390
7		7	338	350	354	390	398	386
8		8	337	345	359	387	395	395
9		9	331	348	357	388	396	398
10		10	343	342	358	384	392	397
11		11	342	344	354	379	387	389
12		12	339	340	349	380	388	397
13		13	340	345	346	381	389	393
14		14	334	350	347	384	392	392
15		15	342	348	351	387	395	386
16		16	338	349	353	380	388	398
17		17	337	345	349	378	386	399
18		18	331	340	348	382	390	397

19		19	343	345	354	385	393	399
20		20	349	340	349	386	394	398
21	CB	1	346	350	359	375	383	390
22		2	347	345	354	383	391	389
23		3	343	348	357	379	387	387
24		4	338	342	351	378	386	391
25		5	339	344	353	372	380	394
26		6	340	340	349	384	392	390
27		7	343	345	354	390	398	386
28		8	346	351	359	387	395	395
29		9	339	348	357	375	396	398
30		10	337	349	358	383	392	397
31		11	341	345	354	379	387	389
32		12	344	340	349	378	388	397
33		13	345	337	346	372	389	393
34		14	334	338	347	384	392	392
35		15	342	342	351	390	395	386
36		16	338	344	353	387	388	398
37		17	334	340	349	388	386	386
38		18	342	339	348	384	390	395
39		19	338	345	354	379	393	398
40		20	337	340	349	380	394	397
41	CC	1	330	350	359	381	383	389
42		2	343	345	354	383	391	397
43		3	349	348	357	379	387	393
44		4	346	342	351	378	386	392
45		5	347	344	353	372	380	386
46		6	343	340	349	384	392	398
47		7	338	345	354	390	398	399
48		8	339	351	359	387	395	397
49		9	340	348	357	388	396	399

50	10	343	349	358	384	392	398
51	11	346	345	354	379	387	390
52	12	339	340	349	380	388	389
53	13	337	337	346	381	389	390
54	14	341	338	347	384	392	389
55	15	344	342	351	387	395	387
56	16	345	344	353	380	388	391
57	17	334	340	349	378	386	394
58	18	342	339	348	382	390	390
59	19	338	345	354	385	393	386
60	20	337	340	349	386	394	395

From Table XXIX and Figure 30 it is shown that the range of normal heart rate of the control rats at normal conditions is between 330 to 349bpm. When calculating the heart rate of the experimental rats using the common medical tool and the copper wearable electronic band, it is ranged between 337 to 351 bpm and 346 to to 359 bpm.

The table shows a very slight difference between the heart rate measures by common medical tool and the copper wearable electronic band. But on the average it is negotiable. The minute difference in heart rate in controlled and experimental rats may be due to the removal of the dorsal hair or being caged, in order to fix the copper wearable electronic band to the rat.

After inducing the fever, the heart rate of the control rats ranged between 372 to 390 bpm. When considering the experimental rats, the heart rate is ranged between 380 to 398 bpm and 386 to 399 bpm on measured using the common medical tool and as per the heart rate display in the smart phone which was noted with the help of wrapping the copper wearable electronic band around the rats to get in touch with the body. Therefore it is concluded that the designed copper wearable electronic band could be used to calculate the actual heart rate of the rats.

Wearable electronic band using silver conductive fabric was constructed and wrapped around the rat to conduct the wear study for monitor its heart rate and the readings are tabulated in Table-XXX and illustrated Figure-31.

Table-XXX

Assessment of Heart Rate using Silver Wearable Electronic Band

S.No	Band	Mean Time (Min)	Mean Heart Rate (bpm) at normal condition			Mean Heart Rate (bpm) after inducing fever		
			Controlled Rats	Experimental Rats		Controlled Rats	Experimental Rats	
				Using Medical Tool	Wearable Electronic Band		Using Medical tool	Wearable Electronic Band
1	SA	1	336	344	354	378	389	386
2		2	343	340	349	382	392	395
3		3	337	339	346	385	380	398
4		4	339	345	351	386	392	397
5		5	333	340	353	375	398	389
6		6	343	350	349	383	395	397
7		7	349	345	354	379	396	393
8		8	346	348	359	378	392	392
9		9	347	342	357	372	387	386
10		10	343	344	358	384	388	398
11		11	343	340	354	379	389	399
12		12	349	345	349	380	392	397
13		13	346	350	346	381	395	399
14		14	347	348	347	384	388	398
15		15	343	349	351	387	386	390
16		16	338	345	353	380	390	389
17		17	339	340	349	378	393	387
18		18	340	337	348	382	394	391
19		19	343	338	354	385	392	394
20		20	346	342	349	386	387	390

21	SB	1	339	350	359	375	388	386
22		2	337	345	354	383	389	395
23		3	341	348	357	379	392	398
24		4	337	342	351	378	395	386
25		5	331	344	353	372	388	395
26		6	343	340	349	384	386	398
27		7	349	345	354	390	390	397
28		8	346	350	359	387	393	389
29		9	347	348	357	388	394	397
30		10	343	349	358	384	383	393
31		11	338	345	354	379	391	392
32		12	339	340	349	380	387	386
33		13	340	337	346	381	386	398
34		14	343	338	347	384	380	391
35		15	346	342	351	387	392	394
36		16	339	344	353	380	398	390
37		17	337	340	349	378	395	385
38		18	341	339	348	382	396	395
39		19	344	345	354	385	392	398
40		20	345	340	349	386	387	397
41	SC	1	334	350	359	375	388	389
42		2	342	345	354	383	389	397
43		3	338	348	357	379	392	393
44		4	337	342	351	378	395	392
45		5	331	344	353	379	388	386
46		6	336	340	349	380	386	398
47		7	343	345	354	381	390	399
48		8	337	350	359	384	393	397
49		9	339	348	357	387	394	399
50		10	333	349	358	380	392	398
51		11	343	345	354	378	387	397

52	12	349	340	349	382	388	393
53	13	346	337	346	385	389	392
54	14	347	338	347	386	392	386
55	15	343	342	351	375	395	398
56	16	343	344	353	383	388	399
57	17	349	345	349	379	386	397
58	18	346	348	348	378	390	399
59	19	347	342	354	372	393	398
60	20	343	344	349	379	394	390

From Table XXX and Figure 31 it is clear that the normal heart rate of the control rats at normal conditions ranged between 331 to 349 bpm. Whereas the heart rate of the experimental rats ranged between 337 to 350 bpm and 346 to 359 bpm, when calculated using the common medical tool and the silver wearable electronic band.

The table shows a very slight difference between the heart rate measures by common medical tool and the silver wearable electronic band. But on the average it is negotiable. This slight increase in heart rate of the experimental rats when compared to the controlled rats at normal condition may also be due to the result of removing the rats from the group caging them separately to wrap the wearable electronic band around their bodies. This is well supported by the study “Role of interleukin_1 beta in impairment of contextual fear conditioning caused by social isolation” by Pugh et al., (1999).

After induction of fever the heart rate of the control rats ranged between 375 to 388 bpm. In case of the experimental rats, the heart rate showed range between 380 to 398 bpm and 385 to 399 bpm when measured using the common medical tool and as per the display in the smart phone which was noted due to the contact of rat’s body with the silver wearable electronic band. Hence it could be concluded that the designed silver wearable electronic band could be used to calculate the actual heart rate of the rats.

From the above results it is clear that the wearable electronic band is effective in monitoring the Heart rate of rats irrespective of types of conductive fabrics used. When comparing the readings shown in smart phone with the reading shown in medical tool,

the values are similar. Hence it could be concluded that the wearable electronic band is good in monitoring the heart rate.

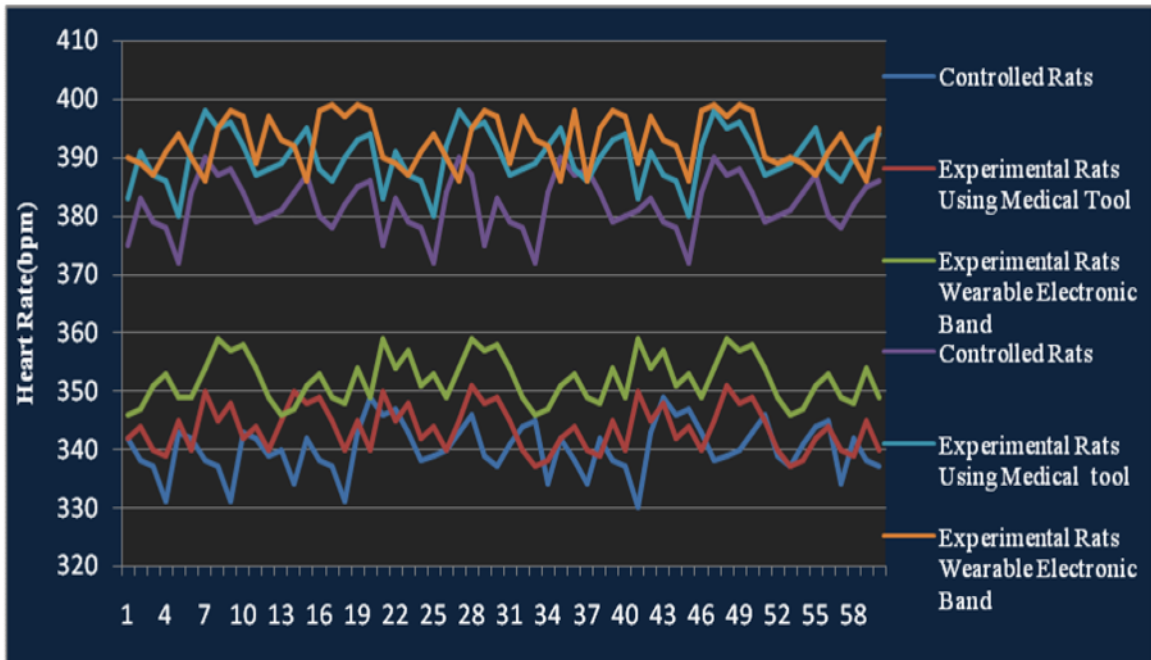


Figure.30
Assessment of Heart Rate using Copper Wearable Electronic Band

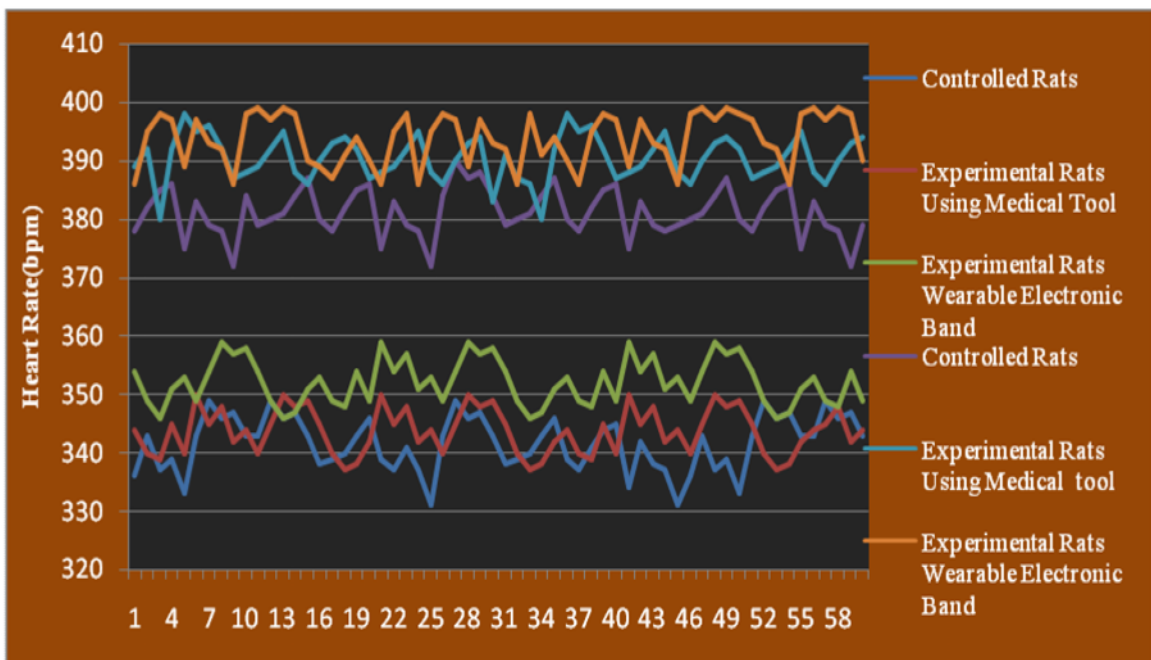


Figure.31
Assessment of Heart Rate using Silver Wearable Electronic Band

4.12. Cost analysis for developed Wearable electronic garment

The cost analysis for the research work done of developing conductive fabric for wearable electronic garment and band are tabulated in the Table-XXXI.

Table-XXXI

Cost analysis

S.No	Parameters	Quantity	Cost (Rs)
1	Aluminium Woven Conductive Fabric	1 meter	511
2	Copper Woven Conductive Fabric	1 meter	644
3	Silver Woven Conductive Fabric	1 meter	977
4	Aluminium Knitted Conductive Fabric	1/2 meter	780
5	Copper Knitted Conductive Fabric	1/2 meter	890
6	Silver Knitted Conductive Fabric	1/2 meter	1240
Wearable Electronic Garment			
7	Aluminium Conductive Fabric		128
8	Copper Conductive Fabric		161
9	Silver Conductive Fabric		245
Wearable Electronic Band			
10	Aluminium Conductive Fabric		26
11	Copper Conductive Fabric		32
12	Silver Conductive Fabric		49

From the above Table-XXXI it is clear that 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.