Chapter – 4

RESULTS AND DISCUSSIONS

4. Results and Discussions

The fabric electrostatic discharge properties are judged and optimized by testing the following properties:

- Surface resistivity
- Field strength
- Air permeability
- Fabric particle density transfer rate

Results are categorised according to pure metal wire incorporated conductive fabrics, metal blended yarn incorporated conductive fabrics, metal plated yarn incorporated conductive fabrics, metal jari & carbon jari incorporated conductive fabrics, carbon yarn incorporated conductive fabrics etc.

Effect of material, fineness, EPI/PPI, weft space, water repellent treatment, conductive pattern etc. are discussed here in relation to different properties of fabrics. Although numbers of factors affect fabric properties, factors with prominent effects are highlighted here for more clarification.

4.1 Surface resistivity

4.1.1 Effect of material

❖ **Effect of conductive material**

Table 4.1 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-01	Ag	835	6	8.12
2	S-02	Cu-C	675	6	12.55
3	S-04	Al	580	6	20.35
4	S-05	S.S.	730	6	42.56

Effect of material (Table 4.1) is studied for surface resistivity of pure metal wire incorporated conductive fabric samples. Conductive fabrics made with silver, aluminium, copper and staineless steel wires are studied with common weft space-6. Surface resistivity analysis indicates that resistivity values are in range of 8.12 to 42.56. Resistivity value 8.12 of S-01 is lowest while value 42.56 of S-05 is highest in conductive fabrics. Value 20.35 of S-04 is found lower than 42.56 of S-05 but higher than value 12.55 of S-02. Silver wire fabric gives lowest resistivity value and stainless steel wire fabric gives highest resistivity value. Copper wire fabric has resistivity value higher than silver wire fabric but lower than aluminium and stainless steel wire fabrics. Low resistivity value of conductive fabric is due to high conductivity level of the wire to discharge the static electricity. As conductive nature of wire in fabric increases, resistivity decreases which directly increase electrostatic discharge capacity of fabric. Fabrics with material having high conductivity accumulate and dissipate the charge at comparatively higher rate than fabrics with material having low conductivity.

❖ **Effect of non-conductive material**

Table 4.2 – Metal blended yarn incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-06 (C)	S.S./P	170	1	92.19
2	S-10 (P)	S.S./P	170	1	95.22

* (C) – Cotton & (P) – Polyester

Effect of material (Table 4.2) is studied for surface resistivity of stainless steel/polyester blended yarn incorporated cotton conductive fabric sample S-06 & polyester conductive fabric sample S-10. With common conductive material & with common weft space-1, effect of cotton and polyester yarns on surface resistivity is studied. Surface resistivity analysis of conductive fabric samples indicates that surface resistivity values are in range of 92.19 to 95.22. Resistivity value 92.19 of S-06 is lower than value 95.22 of S-10.

Polyester conductive fabrics have high resistivity values due to their insulative nature (more prone to generate triboelectric charge but less prone to transfer charge within material) while cotton conductive fabrics have lower resistivity values due to their neutral nature (less prone to generate triboelectric charge) towards conductivity. High resistivity value is due to low conductivity level of polyester to discharge the static electricity. As insulative nature of material increases, resistivity increases which directly decrease electrostatic discharge capacity of fabric.

Table 4.3 – Metal jari incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-16 (C)	CuJ	135	1	52.09
2	S-22 (P)	CuJ	135	1	55.34

* (C) – Cotton & (P) – Polyester

Effect of material (Table 4.3) is studied for surface resistivity of metal jari incorporated cotton conductive fabric sample S-16 & polyester conductive fabric sample S-22. With common conductive material & with common weft space-1, effect of cotton and polyester yarns on surface resistivity is studied. Surface resistivity analysis of conductive fabric samples indicates that surface resistivity values are in range of 52.09 to 55.34. Resistivity value 52.09 of S-16 is lower than 55.34 of S-22.

Polyester conductive fabrics have high resistivity values due to their insulative nature (more prone to generate triboelectric charge but less prone to transfer charge within material) while cotton conductive fabrics have lower resistivity values due to their neutral nature (less prone to generate triboelectric charge) towards conductivity. High resistivity value is due to low conductivity level of polyester to discharge the static electricity. As insulative nature of material increases, resistivity increases which directly decrease electrostatic discharge capacity of fabric.

4.1.2 Effect of fineness

Table 4.4 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-02	Cu-C	675	6	12.55
2	S-03	Cu-F	315	6	17.60

Effect of fineness (Table 4.4) is studied for surface resistivity of pure metal (copper) wire incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common conductive material and with common weft space-6. Surface resistivity analysis of copper wire incorporated cotton conductive fabric samples indicates that surface resistivity values are in range of 12.55 to 17.60. Resistivity value 12.55 of S-02 is lower compared to 17.60 of S-03. Fabric with coarse conductive wire gives lowest resistivity value.

Low resistivity value of conductive fabric is due to high conductivity level of coarse wire to discharge the static electricity. As denier of conductive wire increases, diameter of conductive wire increases which directly increase electrostatic discharge capacity of fabric. Conductive fabrics with coarse wire accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with fine wire.

Table 4.5 –Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-20	CJ-T	790	6	44.12
2	S-21	CJ-R	435	6	53.43

Effect of fineness (Table 4.5) is studied for surface resistivity of carbon jari incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common weft space-6. Surface resistivity analysis of carbon jari incorporated cotton conductive fabric samples indicates that surface resistivity values are in range of 44.12 to 53.43. Resistivity value 44.12 of S-20 is lower compared to 53.43 of S-21. Fabric with coarse jari gives lowest resistivity value.

Low resistivity value of conductive fabric is due to high conductivity level of coarse jari to discharge the static electricity. As denier of conductive jari increases, diameter of conductive jari increases which directly increase electrostatic discharge capacity of fabric. Conductive fabrics with coarse jari accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with fine jari.

Table 4.6 – Metal plated yarn incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-12	AgN	175	6	46.11
2	S-13	CuN	75	6	63.05

Effect of fineness (Table 4.6) is studied for surface resistivity of metal plated yarn incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common weft space-6. Surface resistivity analysis of metal plated yarn incorporated cotton conductive fabric samples indicates that surface resistivity values are in range of 46.11 to 63.05. Resistivity value 46.11 of S-12 is lower than 63.05 of S-13 in metal plated conductive fabrics. Fabric containing coarse metal plated yarns gives lowest resistivity value.

Low resistivity value of conductive fabric is due to coarse conductive yarns as well as high conductivity level of silver to discharge the static electricity. As denier of conductive yarn increases, diameter increases which directly increase electrostatic discharge capacity of fabric. Conductive fabrics with coarse conductive yarns accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with fine conductive yarns.

❖ Correlation and regression analysis

Table 4.7 – Denier & surface resistivity

No.	Fabric sample code	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-01	835	6	8.12
2	S-02	675	6	12.55
3	S-03	315	6	17.60
4	S-04	580	6	20.35
5	S-05	730	6	42.56
6	S-07	170	6	94.27
7	S-12	175	6	46.11
8	S-13	75	6	63.05
9	S-20	790	6	44.12
10	S-21	435	6	53.43

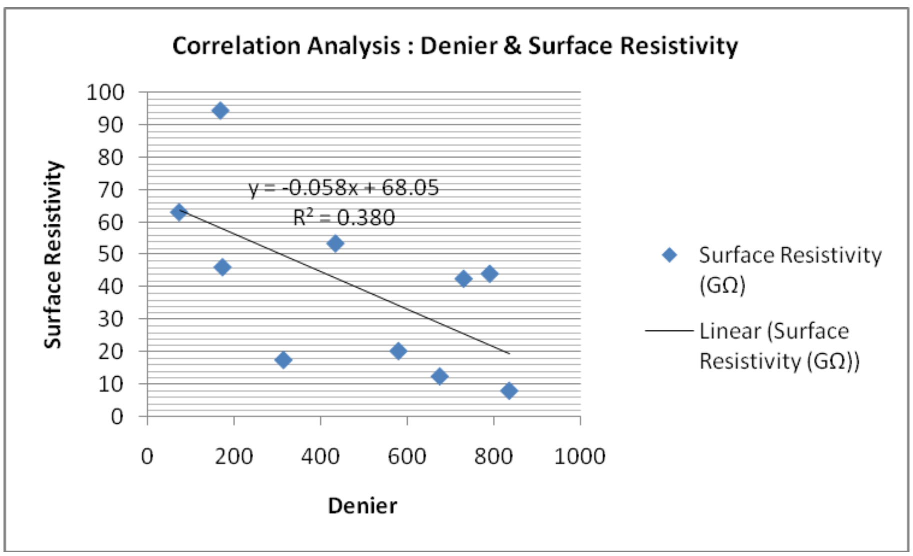

Fig. 4.1 – Correlation analysis: Denier & surface resistivity

Negative correlation with R = -0.6168

The regression line is: y = Surface resistivity = 68.0562-0.05824 X Denier

The **coefficient of determination**, R^2, is 38.04%. This means that close to 38% of the variation in the dependent variable (Surface resistivity) is explained by the independent variables (Denier).

Significance F = 0.05749

P Value = 0.05749 < 0.10

Model: Statistically marginally significant

4.1.3 Effect of weft space

❖ **Cotton conductive fabrics**

Table 4.8 – Metal blended yarn incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-06	S.S./P	170	1	92.19
2	S-07	S.S./P	170	6	94.27
3	S-08	S.S./P	170	10	97.08
4	S-09	S.S./P	170	14	98.27

Effect of weft space (Table 4.8) is studied for surface resistivity of metal (stainless steel/polyester) blended yarn incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for weft space variations of 1, 6, 10 and 14. Surface resistivity analysis of stainless steel/polyester blended yarn incorporated cotton conductive fabric samples indicates that surface resistivity values are in range of 92.19 to 98.27. Resistivity value 92.19 of S-06 (weft space-1) is lower than 98.27 of S-09 (weft space-14) in stainless steel/polyester conductive fabrics. It is observed that resistivity values gradually increase with respect to increase in weft space from 1 to 14. For the fabric with weft space-14, resistivity value is highest among other fabrics. High resistivity values of conductive fabrics with weft space-14 represent low conductivity level of the fabrics to discharge the static electricity. As weft space of conductive yarns in fabric increases, ratio of conductive to non conductive material decreases which directly reduce electrostatic discharge capacity of fabric. Conductive fabrics with low weft space accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with high weft space.

Table 4.9 – Metal jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-16	CuJ	135	1	52.09
2	S-17	CuJ	135	6	55.25
3	S-18	CuJ	135	10	58.33
4	S-19	CuJ	135	14	59.02

Effect of weft space (Table 4.9) is studied for surface resistivity of metal (copper) jari incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for weft space variations of 1, 6, 10 and 14. Surface resistivity analysis of copper jari incorporated cotton conductive fabric samples indicates that surface resistivity values are in range of 52.09 to 59.02. Resistivity value 52.09 of S-16 (weft space-1) is lower than 59.02 of S-19 (weft space-14) in copper jari conductive fabrics. It is observed that resistivity values gradually increase with respect to increase in weft space from 1 to 14.

For the fabric with weft space-14, resistivity value is highest among other fabrics. High resistivity values of conductive fabrics with weft space-14 represent low conductivity level of the fabrics to discharge the static electricity. As the weft space of conductive yarns in fabric increases, ratio of conductive to non conductive material decreases which directly reduce electrostatic discharge capacity of fabric. Conductive fabrics with low weft space accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with high weft space.

❖ **Polyester conductive fabrics**

Table 4.10 – Metal blended yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-10	S.S./P	170	1	95.22
2	S-11	S.S./P	170	3	96.37

Effect of weft space (Table 4.10) is studied for surface resistivity of metal (stainless steel/polyester) blended yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations 1 and 3. Surface resistivity analysis of stainless steel/polyester blended yarn incorporated polyester conductive fabric samples indicates that surface resistivity values are in range of 95.22 to 96.37. Due to insulative nature of polyester, overall resistivity values are somewhat on higher level. Resistivity value 95.22 of S-10 (weft space-1) is lower than value 96.37 of S-11 (weft space-3). It is observed that resistivity values gradually increase with respect to increase in weft space from 1 to 3. Fabric with weft space-3 gives highest resistivity value.

High resistivity values of conductive fabrics with weft space-3 represent low conductivity level of the fabrics to discharge the static electricity. As the weft space of conductive yarns in fabric increases, ratio of conductive to non conductive material decreases which directly reduce electrostatic discharge capacity of fabric. Conductive fabrics with low weft space accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with high weft space.

Table 4.11 – Metal plated yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-14	CuN	75	1	59.05
2	S-15	CuN	75	3	62.12

Effect of weft space (Table 4.11) is studied for surface resistivity of metal (copper) plated yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations 1 and 3. Surface resistivity analysis of conductive fabric samples indicates that surface resistivity values are in range of 59.05 to 62.12. Due to insulative nature of polyester, overall resistivity values are somewhat on higher level. Resistivity value 59.05 of S-14 (weft space-1) is lower than value 62.12 of S-15 (weft space-3). It is observed that resistivity values gradually increase with respect to increase in weft space from 1 to 3. Fabric with weft space-3 gives highest resistivity value.

High resistivity values of conductive fabrics with weft space-3 represent low conductivity level of the fabrics to discharge the static electricity. As the weft space of conductive yarns in fabric increases, ratio of conductive to non conductive material decreases which directly reduce electrostatic discharge capacity of fabric. Conductive fabrics with low weft space accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with high weft space.

❖ Correlation & regression analysis

Table 4.12 – Weft space & surface resistivity

No.	Fabric sample code	Conductive wire/yarn detail	Weft space (mm)	Surface resistivity (GΩ)
1	S-16	CuJ	1	52.09
2	S-17	CuJ	6	55.25
3	S-18	CuJ	10	58.33
4	S-19	CuJ	14	59.02

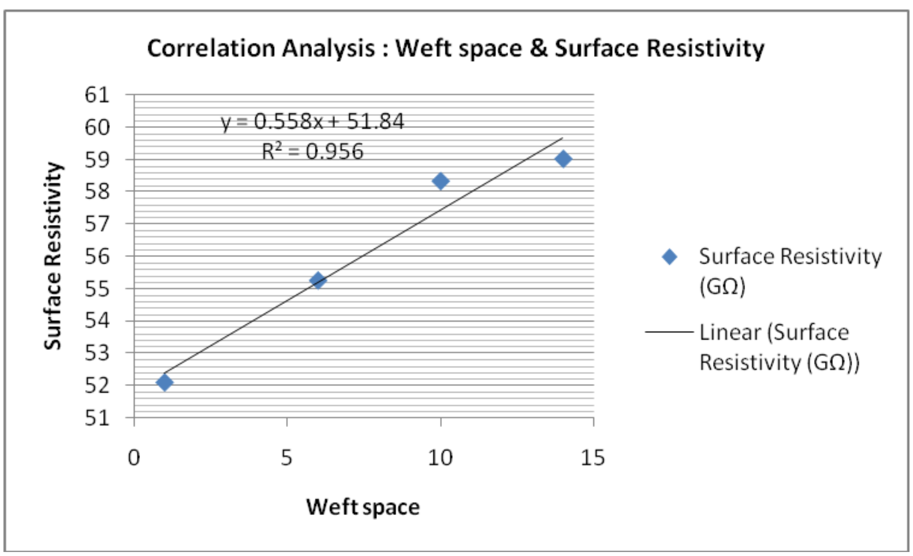

Fig. 4.2 – Correlation analysis: Weft space & surface resistivity

Positive correlation with R = 0.9778

The regression line is: y = Surface resistivity = 51.8423 + 0.55873 X Weft space

The **coefficient of determination**, R^2, is 95.62%. This means that close to 96% of the variation in the dependent variable (Surface resistivity) is explained by the independent variables (Weft space).

Significance F = 0.02213

P Value = 0.02213 < 0.05

Model: Statistically significant

4.1.4 Effect of water repellent treatment

Table 4.13 – Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-20	CJ-T	790	6	44.12
2	S-20W	CJ-T	790	6	124.48
3	S-21	CJ-R	435	6	53.43
4	S-21W	CJ-R	435	6	194.71

Effect of water repellent treatment (Table 4.13) is studied for surface resistivity of two types of carbon jari incorporated cotton conductive woven fabric samples. Cotton conductive fabrics are studied for normal conductive fabrics and water repellent conductive fabrics. Surface resistivity analysis of carbon jari (trilobal) conductive fabric samples with common weft space-6 indicates that 124.48 for S-20W is higher compared to 44.12 for S-20. Same effect is observed in case of fabrics made with carbon jari (ring) as value 194.71 of S-21W is higher compared to 53.43 of S-21.

Low resistivity values of normal conductive fabrics represent high conductivity level of the fabrics to discharge the static electricity. Water repellent layer acts as a barrier between conductive yarns and static electricity (to discharge it from the surface of the fabric). Normal conductive fabrics accumulate and dissipate the charge at comparatively higher rate than conductive fabrics with water repellent treatment.

4.1.5 Effect of conductive pattern

Table 4.14 – Carbon yarn incorporated polyester conductive fabric samples (stripe & grid)

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Surface resistivity (GΩ)
1	S-24	C	80	5	65.38
2	S-25	C	80	6 (Warp space-5)	59.21

Effect of conductive pattern (Table 4.14) is studied for surface resistivity of carbon yarn incorporated polyester conductive woven fabric samples. Polyester conductive fabrics are studied for stripe pattern and grid pattern. Surface resistivity analysis of carbon conductive fabrics indicates that values are in range of 59.21 to 65.38. Value 59.21 of S-25 is lower compared to value 65.38 of S-24.

Low resistivity value of grid pattern is due to high conductivity level of the fabric to discharge the static electricity. Grid pattern can attract and transfer more number of electrons from the surface of the fabric (forms better electrical conducting net). As a result, grid pattern accumulate and dissipate the charge at comparatively higher rate than stripe pattern.

4.2 Field strength

4.2.1 Effect of material

❖ **Effect of conductive material**

Table 4.15 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-01	Ag	835	6	25
2	S-02	Cu-C	675	6	23
3	S-04	Al	580	6	19
4	S-05	S.S.	730	6	18

Effect of material (Table 4.15) is studied for field strength of pure metal wire incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different conductive wire materials with common weft space-6. Field strength analysis of pure metal wire incorporated cotton conductive fabric samples indicates that field strength protection % are in range of 18% to 25%. 18% protection of S-05 is lowest while 25% of S-01 is highest in conductive fabrics. 19% of S-04 is found higher than 18% of S-05 but lower than 23% of S-02. Silver wire fabric gives highest protection %. Copper wire fabric has protection % lower than silver wire fabric but higher than aluminium and stainless steel wire fabrics. High protection % of conductive fabrics is due to high shielding level of the wire to absorb and reflect the field. As EMF absorption and reflection level of wire in fabric increases, transmission level decreases which directly increase field strength protection % of fabric. Fabrics with wires having high EMF absorption & reflection nature restrict EMF transmission at comparatively higher rate than fabrics with wires having low EMF absorption & reflection nature.

❖ **Effect of non-conductive material**

Table 4.16 – Metal blended yarn incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-06 (C)	S.S./P	170	1	32
2	S-10 (P)	S.S./P	170	1	32

* (C) – Cotton & (P) – Polyester

Effect of material (Table 4.16) is studied for field strength of metal (stainless steel/polyester) blended yarn incorporated cotton conductive fabric sample & polyester conductive fabric sample. With common conductive material & with common weft space-1, effect of cotton and polyester yarns on field strength is studied. Field strength analysis of conductive fabric samples indicates that both the fabric samples have same field strength protection 32%. It is observed that polyester and cotton conductive fabrics have almost same field strength protection %. Same protection % of polyester and cotton conductive material is due to their low level of EMF absorption and reflection properties. Polyester and cotton materials have almost nil effect on field strength protection level compared to conductive materials.

Table 4.17 – Metal jari incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-16 (C)	CuJ	135	1	35
2	S-22 (P)	CuJ	135	1	35

* (C) – Cotton & (P) – Polyester

Effect of material (Table 4.17) is studied for field strength of metal jari (copper) incorporated cotton conductive fabric sample & polyester conductive fabric sample. With common conductive material & with common weft space-1, effect of cotton and polyester yarns on field strength is studied. Field strength analysis of conductive fabric samples indicates that both the fabric samples have same field strength protection 35%. It is observed that polyester and cotton conductive fabrics have same field strength protection %. Same protection % of polyester and cotton conductive material is due to their low level of EMF absorption and reflection properties. Polyester and cotton materials have almost nil effect on field strength protection level compared to conductive materials.

4.2.2 Effect of fineness

Table 4.18 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-02	Cu-C	675	6	23
2	S-03	Cu-F	315	6	21

Effect of fineness (Table 4.18) is studied for field strength of pure metal (copper) wire incorporated cotton conductive fabric samples. With common conductive material and with common weft space-6, copper conductive fabrics are studied with different wire fineness. Field strength analysis of fabric samples indicates that field strength values are in range of 21% to 23%. Protection 23% of S-02 is higher than 21% of S-03 in copper conductive fabrics. Coarse conductive wire fabric gives higher protection %.

Metal wires due to their rigidity to bend, openness can give lower protection % but when weft space is on higher side coarse wire fabrics with good reflection and absorption properties give higher protection % compared to fine wire fabrics. Otherwise, when weft space is on lower side, fine wire serves the purpose with higher protection %.

Table 4.19 – Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-20	CJ-T	790	6	20
2	S-21	CJ-R	435	6	17

Effect of fineness (Table 4.19) is studied for field strength of carbon jari incorporated cotton conductive fabric samples. With common type of conductive material and with common weft space-6, cotton conductive fabrics are studied with different wire fineness. Field strength analysis of fabric samples indicates that field strength values are in range of 17% to 20%. Protection 17% of S-21 is lower than 20% of S-20 in carbon jari conductive fabrics. Fabric with coarse carbon jari gives higher protection %. Coarse jari due to its higher diameter absorb and reflect higher EMF and give higher protection % while fine jari due to its lower diameter absorb and reflect lower EMF and give lower protection % in fabric.

Table 4.20 – Metal plated yarn incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-12	AgN	175	6	14
2	S-13	CuN	75	6	8

Effect of fineness (Table 4.20) is studied for field strength of metal plated yarn incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common type of conductive material and with common weft space. Field strength analysis of metal plated yarn incorporated cotton conductive fabric samples indicates that field strength values are in range of 8% to 14%. Protection 8% of S-13 is lower than 14% of S-12 in conductive fabrics.

Fabric with coarse conductive yarns gives highest protection %. Parallel to the effect of conductive material like silver, coarse conductive yarns due to its higher diameter absorb and reflect higher EMF and give higher protection % while fine conductive yarns due to its lower diameter absorb and reflect lower EMF and give lower protection % in fabric.

❖ Correlation and regression analysis

Table 4.21 – Denier & field strength

No.	Fabric sample code	Denier	Weft space (mm)	Field strength protection (%)
1	S-01	835	6	25
2	S-02	675	6	23
3	S-03	315	6	21
4	S-04	580	6	19
5	S-05	730	6	18
6	S-07	170	6	11
7	S-12	175	6	14
8	S-13	75	6	8
9	S-20	790	6	20
10	S-21	435	6	17

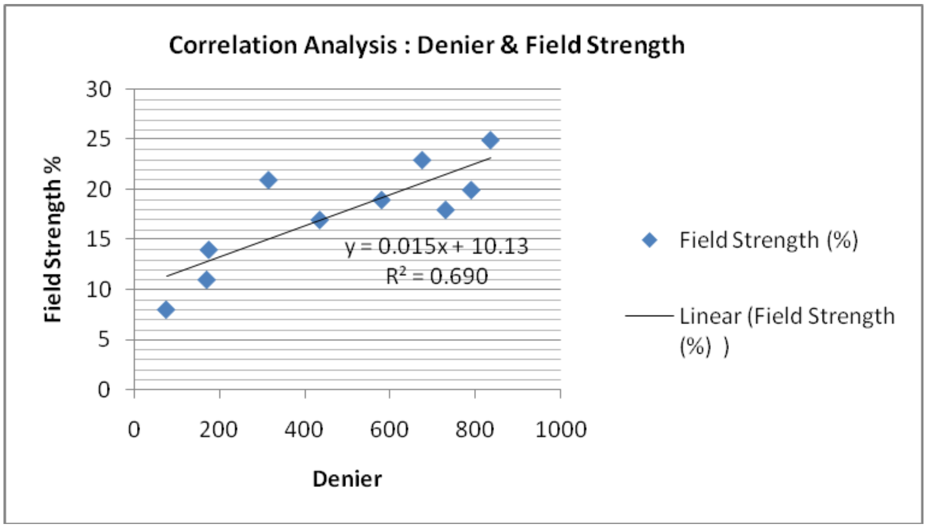

Fig. 4.3 – Correlation analysis: Denier & field strength

Positive correlation with R = 0.8308

The regression line is: y = Field strength = 10.1379 + 0.01561 X Denier

The **coefficient of determination**, R^2, is 69.03%. This means that close to 69% of the variation in the dependent variable (Field strength) is explained by the independent variables (Denier).

Significance F = 0.002902

P Value = 0.002902 < 0.01

Model : **Statistically highly significant**

4.2.3 Effect of weft space

❖ **Cotton conductive fabrics**

Table 4.22 – Metal blended yarn incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-06	S.S./P	170	1	32
2	S-07	S.S./P	170	6	11
3	S-08	S.S./P	170	10	7
4	S-09	S.S./P	170	14	5

Effect of weft space (Table 4.22) is studied for field strength of metal (stainless steel/polyester) blended yarn incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for weft space variations of 1, 6, 10 and 14. Field strength analysis of cotton conductive fabric samples indicates that field strength is in range of 5% to 32%. Protection 32% of S-06 (weft space-1) is higher than 5% of S-09 (weft space-14) in fabrics. It is observed that protection % gradually decrease with respect to increase in weft space from 1 to 14. For the fabric with weft space-1, protection % is highest among other fabrics. High protection % of conductive fabrics with weft space-1 is due to high ratio of conductive material to non conductive material in fabric while low protection % of conductive fabrics with weft space-14 is due to low ratio of conductive material to non conductive material in fabric. High quantity of conductive material with low weft space can absorb and reflect high EMF than low quantity of conductive material with high weft space.

Table 4.23 – Metal jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-16	CuJ	135	1	35
2	S-17	CuJ	135	6	15
3	S-18	CuJ	135	10	10
4	S-19	CuJ	135	14	8

Effect of weft space (Table 4.23) is studied for field strength of metal jari incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for weft space variations of 1, 6, 10 and 14. Field strength analysis of cotton conductive fabric samples indicates that field strength % are in range of 8% to 35%. Protection 35% of S-16 (weft space-1) is higher than 8% of S-19 (weft space-14) in fabrics. It is observed that protection % gradually decrease with respect to increase in weft space from 1 to 14. For the fabric with weft space-1, protection % is highest among other fabrics. High protection % of conductive fabrics with weft space-1 is due to high ratio of conductive material to non conductive material in fabric while low protection % of conductive fabrics with weft space-14 is due to low ratio of conductive material to non conductive material in fabric. High quantity of conductive material with low weft space can absorb and reflect high EMF than lower quantity of conductive material with high weft space.

❖ **Polyester conductive fabrics**

Table 4.24 – Metal blended yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-10	S.S./P	170	1	32
2	S-11	S.S./P	170	3	23

Effect of weft space (Table 4.24) is studied for field strength of metal (stainless steel/polyester) blended yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations of 1 and 3. Field strength analysis of polyester conductive fabric samples indicates that field strength % are in range of 23% to 32%. Protection 32% of S-10 (weft space-1) is higher than 23% of S-11 (weft space-3). It is observed that protection % decrease with increase of weft space. For the fabric with weft space-1, protection % is highest among fabrics. High protection % of conductive fabrics with weft space-1 is due to high ratio of conductive material to non conductive material in fabric while low protection % of conductive fabrics with weft space-3 is due to low ratio of conductive material to non conductive material in fabric. High quantity of conductive material with low weft space can absorb and reflect high EMF than lower quantity of conductive material with high weft space.

Table 4.25 – Metal plated yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-14	CuN	75	1	30
2	S-15	CuN	75	3	21

Effect of weft space (Table 4.25) is studied for field strength of metal plated yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations of 1 and 3. Field strength analysis of polyester conductive fabric samples indicates that field strength is in range of 21% to 30%. Protection 30% of S-14 (weft space-1) is higher than 21% of S-15 (weft space-3). It is observed that protection % decrease with increase of weft space. For the fabric with weft space-1, protection % is highest among fabrics.

High protection % of conductive fabrics with weft space-1 is due to high ratio of conductive material to non conductive material in fabric while low protection % of conductive fabrics with weft space-3 is due to low ratio of conductive material to non conductive material in fabric. High quantity of conductive material with low weft space can absorb and reflect high EMF than lower quantity of conductive material with high weft space.

❖ **Correlation & regression analysis**

Table 4.26 – Weft space & field strength

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-16	CuJ	135	1	35
2	S-17	CuJ	135	6	15
3	S-18	CuJ	135	10	10
4	S-19	CuJ	135	14	8

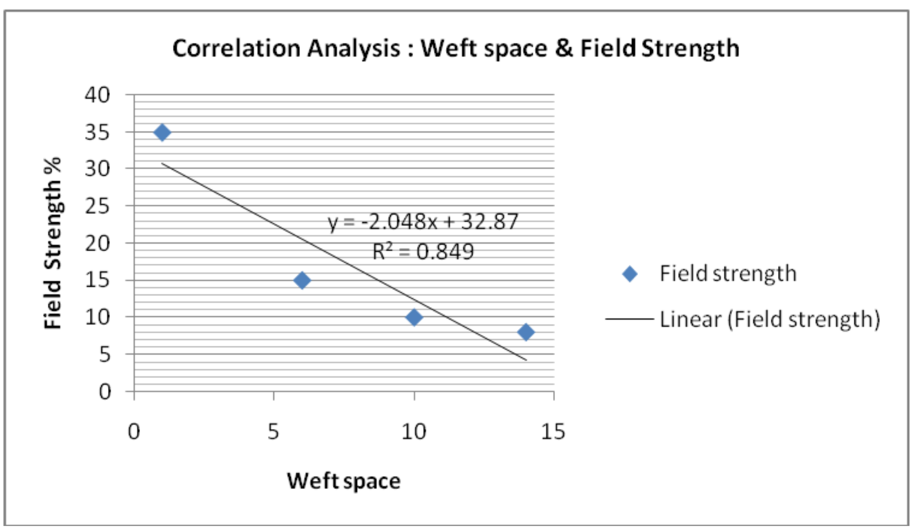

Fig. 4.4 – Correlation analysis: Weft space & field strength

Negative correlation with R = -0.92185

The regression line is: y = Field strength = 32.8760 -2.0485 X Weft space

The **coefficient of determination**, R^2, is 84.98%. This means that close to 85% of the variation in the dependent variable (Field strength) is explained by the independent variables (Weft space).

Significance F = 0.07814

P Value = 0.07814 < 0.10

Model : **Statistically marginally significant**

4.2.4 Effect of water repellent treatment

Table 4.27 – Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-20	CJ-T	790	6	20
2	S-20W	CJ-T	790	6	20
3	S-21	CJ-R	435	6	17
4	S-21W	CJ-R	435	6	17

Effect of water repellent treatment (Table 4.27) is studied for field strength of two types of carbon jari incorporated cotton conductive woven fabric samples. Cotton conductive fabrics are studied for normal conductive fabrics and water repellent conductive fabrics. Field strength analysis of cotton conductive fabric samples made with carbon jari (trilobal) and with common weft space-6 indicates 20% protection for S-20 & S-20W. Cotton conductive fabric samples made with carbon jari (ring) & common weft space-6 indicates 17% protection for S-21 and S-21W.

It is observed that normal conductive fabrics and water repellent conductive fabrics have almost same field strength protection level. Water repellent layer has very low i.e. nil effect on protection %. It is due to very low thickness and non-conductive nature of water repellent layer.

4.2.5 Effect of conductive pattern

Table 4.28 – Carbon yarn incorporated polyester conductive fabric samples (stripe & grid)

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Field strength protection (%)
1	S-24	C	80	5	10
2	S-25	C	80	6 (Warp space-5)	15

Effect of conductive pattern (Table 4.28) is studied for field strength of carbon yarn incorporated polyester conductive woven fabric samples. Polyester conductive fabrics are studied for stripe pattern and grid pattern. Field strength analysis of conductive fabric samples indicates that 10% of S-24 is lower compared to 15% of S-25. Grid pattern gives highest protection % among fabrics.

It is because S-25 is made from the warp/weft interlacing of carbon yarns at right angles. Hence it forms a better electrical conducting net. It easily intercepts EMFs and destroys their tenacity, resulting in better field strength protection %. On the other hand, if the fabric has carbon yarn in only one direction (warp or weft), its field strength protection will certainly be on lower side. Same kinds of observations are obtained by Ching-Iuan Su and Jin-Tsair Chern in their research work[108].

4.3 Air permeability

4.3.1 Effect of material

Table 4.29 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-01	Ag	835	6	28.15
2	S-02	Cu-C	675	6	24.95
3	S-04	Al	580	6	22.05
4	S-05	S.S.	730	6	31.50

Effect of material (Table 4.29) is studied for air permeability of pure metal wire incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different conductive wire materials with common weft space-6. Air permeability analysis of pure metal wire incorporated cotton conductive fabric samples indicates that air permeability values are in range of 22.05 to 31.50. Air permeability value 22.05 of S-04 is lowest while 31.50 of S-05 is highest in conductive fabrics. Value 28.15 of S-01 is found higher than 24.95 of S-02 & 22.05 of S-04 but lower than 31.50 of S-05. Stainless steel wire fabric gives highest permeability. Silver wire fabric has permeability lower than stainless steel wire fabric but higher than copper and aluminium wire fabrics.

High permeability of conductive fabrics is the effect of metal hardness according to nature of material. Stainless steel wire fabric due to high metal hardness contribute higher opening in fabric and higher air permeability value while aluminium wire fabric due to low metal hardness contribute lower opening in fabric and lower air permeability value.

4.3.2 Effect of ends/inch and picks/inch (EPI and PPI)

Table 4.30 – Metal blended yarn incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	EPI/PPI	Air permeability ($cm^3/cm^2/sec$)
1	S-06 (C)	S.S./P	170	1	72/72	19.80
2	S-10 (P)	S.S./P	170	1	82/82	16.90

* (C) – Cotton & (P) – Polyester

Effect of EPI/PPI (EPI-ends/inch & PPI-picks/inch)(Table 4.30) is studied for air permeability of metal (stainless steel/polyester) blended yarn incorporated cotton conductive fabric sample & polyester conductive fabric sample. With common conductive material & with common weft space-1, effect of EPI/PPI for cotton and polyester yarns on air permeability is studied. Air permeability values are in range of 16.90 to 19.80. Air permeability analysis of conductive fabric samples indicates that value 19.80 of S-06 is higher than value 16.90 of S-10.

Polyester conductive fabrics give lowest air permeability. It is observed that polyester conductive fabrics have low air permeability values due to round, straight and cylindrical shape of filaments & close and compact arrangement of continuous filament yarns in fabrics with high EPI and PPI while cotton conductive fabrics have high air permeability values due to short staple fibre yarns in fabrics with low EPI and PPI.

Table 4.31 – Metal jari incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	EPI/PPI	Air permeability ($cm^3/cm^2/sec$)
1	S-16 (C)	CuJ	135	1	72/72	14.30
2	S-22 (P)	CuJ	135	1	82/82	13.35

* (C) – Cotton & (P) – Polyester

Effect of EPI/PPI (Table 4.31) is studied for air permeability of metal (copper) jari yarn incorporated cotton conductive fabric sample & polyester conductive fabric sample. With common conductive material & with common weft space-1, effect of EPI/PPI for cotton and polyester yarns on air permeability is studied. Air permeability values are in range of 13.35 to 14.30. Air permeability analysis of conductive fabric samples indicates that value 14.30 of S-16 is higher than value 13.35 of S-22.

Polyester conductive fabrics give lowest air permeability. It is observed that polyester conductive fabrics have low air permeability values due to round, straight and cylindrical shape of filaments & close and compact arrangement of continuous filament yarns in fabrics with high EPI and PPI while cotton conductive fabrics have high air permeability values due to short staple fibre yarns in fabrics with low EPI and PPI.

4.3.3 Effect of fineness

Table 4.32 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-02	Cu-C	675	6	24.95
2	S-03	Cu-F	315	6	21.20

Effect of fineness (Table 4.32) is studied for air permeability of pure metal (copper) wire incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common conductive material (copper) and with common weft space-6. Air permeability analysis of fabric samples indicates that values are in range of 21.20 to 24.95. Air permeability value 24.95 of S-02 is higher than 21.20 of S-03 in copper conductive fabrics. Fabric with coarse conductive wire gives high air permeability value. The reason is that the air flowing through coarse wires in fabric has less yarn surface to flow past.

Though EPI/PPI is same & cover factor is on higher side, fabric with coarse metal wires due to their rigidity to bend, openness give high air permeability. Highly coarse wires due to its resistance to bend in a fabric give open structure and high air permeability while fine wires with their flexible nature give close structure and low air permeability in fabric.

Table 4.33 – Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-20	CJ-T	790	6	24.20
2	S-21	CJ-R	435	6	21.30

Effect of fineness (Table 4.33) is studied for air permeability of carbon jari incorporated cotton conductive fabric samples. Fabrics are studied for different fineness with common type of conductive material and with common weft space-6. Air permeability analysis of fabric samples indicates that values are in range of 21.30 to 24.20. Air permeability value 24.20 of S-20 is higher than 21.30 of S-21 in carbon jari conductive fabrics. Fabric with coarse jari gives high air permeability value. The reason is that the air flowing through course jari in fabric has less yarn surface to flow past.

Though EPI/PPI is same & cover factor is on higher side, fabric with coarse jari due to their rigidity to bend, openness give high air permeability. Highly coarse jari due to its resistance to bend in a fabric give open structure and high air permeability while fine jari with their flexible nature give close structure and low air permeability in fabric.

4.3.4 Effect of weft space

- **Cotton conductive fabrics**

Table 4.34 – Metal blended yarn incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-06	S.S./P	170	1	19.80
2	S-07	S.S./P	170	6	17.00
3	S-08	S.S./P	170	10	16.45
4	S-09	S.S./P	170	14	15.55

Effect of weft space (Table 4.34) is studied for air permeability of metal (stainless steel/polyester) blended yarn incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for weft space variations of 1, 6, 10 and 14. Air permeability analysis of cotton conductive fabric samples indicates that air permeability are in range of 15.55 to 19.80. Air permeability 19.80 of S-06 (weft space-1) is highest while 15.55 of S-09 (weft space-14) is lowest in fabrics. It is observed that permeability gradually decrease with respect to increase in weft space from 1 to 14. For the fabric with weft space-1, air permeability value is highest among other fabrics. Here though EPI/PPI is same, difference in the air flow is due to the variations of the large diameter and small diameter yarns according to weft space – 1, 6, 10, 14 in heterogeneous fabrics.

- **Polyester conductive fabrics**

Table 4.35 – Metal blended yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-10	S.S./P	170	1	16.90
2	S-11	S.S./P	170	3	15.85

Effect of weft space (Table 4.35) is studied for air permeability of metal (stainless steel/polyester) blended yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations of 1 and 3. Air permeability analysis of polyester conductive fabric samples indicates that air permeability are in range of 15.85 to 16.90. Air permeability 16.90 of S-10 (weft space-1) is highest while 15.85 of S-11 (weft space-3) is lowest in fabrics. It is observed that permeability decrease with increase of weft space. For the fabric with weft space-1, air permeability value is highest among other fabrics. Here though EPI/PPI is same, difference in the air flow is due to the variations of the large diameter and small diameter yarns according to weft space – 1, 3 in heterogeneous fabrics.

Table 4.36 – Metal plated yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-14	CuN	75	1	6.90
2	S-15	CuN	75	3	7.85

Effect of weft space (Table 4.36) is studied for air permeability of metal plated yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations of 1 and 3. Air permeability analysis of polyester conductive fabric samples indicates that air permeability values are in range of 6.90 to 7.85. Air permeability 6.90 of S-14 (weft space-1) is lower than 7.85 of S-15 (weft space-3) in fabrics. It is observed that permeability increase with increase of weft space. For the fabric with weft space-1, air permeability value is lowest among other fabrics. Here though EPI/PPI is same, difference in the air flow is due to the variations of the large diameter and small diameter yarns according to weft space – 1, 3 in heterogeneous fabrics.

❖ Correlation & regression analysis

Table 4.37 – Weft space & air permeability

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-06	S.S./P	170	1	19.80
2	S-07	S.S./P	170	6	17.00
3	S-08	S.S./P	170	10	16.45
4	S-09	S.S./P	170	14	15.55

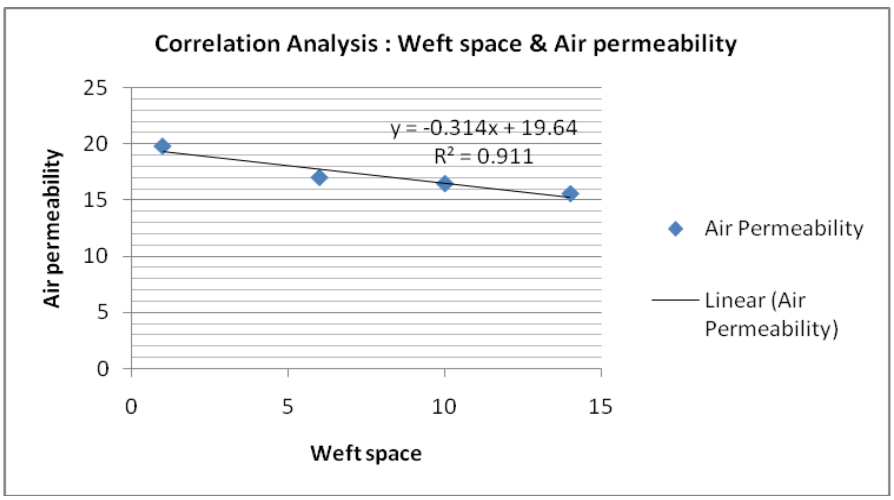

Fig. 4.5 – Correlation analysis: Weft space & air permeability

Negative correlation with R = -0.9547

The regression line is: y = Air permeability = 19.6398-0.3148 X Weft space

The **coefficient of determination**, R^2, is 91.15 %. This means that close to 91% of the variation in the dependent variable (Air permeability) is explained by the independent variables (Weft space).

Significance F = 0.045253

P Value = 0.045253 < 0.05

Model **Statistically significant**

4.3.5 Effect of water repellent treatment

Table 4.38 – Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-20	CJ-T	790	6	24.20
2	S-20W	CJ-T	790	6	4.50
3	S-21	CJ-R	435	6	21.30
4	S-21W	CJ-R	435	6	3.20

Effect of water repellent treatment (Table 4.38) is studied for air permeability of two types of carbon jari incorporated cotton conductive woven fabric samples. Cotton conductive fabrics are studied for normal conductive fabrics and water repellent conductive fabrics. Air permeability analysis of carbon jari (trilobal) conductive fabric samples made with common weft space-6 indicates that air permeability 4.50 of S-20W is very low compared to 24.20 of S-20. Same effect is observed in case of fabrics made with carbon jari (ring) as air permeability 3.20 of S-21W is lower than 21.30 of S-21.

It is observed that water repellent conductive fabrics have very low air permeability compared to normal conductive fabrics. Low air permeability of water repellent conductive fabric is due to the presence of water repellent layer on surface of fabric which acts as a barrier to pass the air from the fabric.

4.3.6 Effect of conductive pattern

Table 4.39 – Carbon yarn incorporated polyester conductive fabric samples (stripe & grid)

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Air permeability ($cm^3/cm^2/sec$)
1	S-24	C	80	5	2.85
2	S-25	C	80	6 (Warp space-5)	3.35

Effect of conductive pattern (Table 4.39) is studied for air permeability of carbon yarn incorporated polyester conductive woven fabric samples. Polyester conductive fabrics are studied for stripe pattern and grid pattern. Air permeability analysis of conductive fabric samples indicates that 2.85 of S-24 is lower compared to 3.35 of S-25.

Grid pattern fabrics give higher permeability compared to stripe pattern fabrics. High permeability is due to presence of high number of conductive yarns with grid pattern in fabric while low permeability is due to presence of low number of conductive yarns with stripe pattern in fabric. High variations of conductive and non conductive yarns increase air permeability of cotton conductive fabrics.

4.4 Fabric particle density transfer rate (F-PDTR)

Results of fabric particle density transfer rate (F-PDTR) (voltage difference) in % at variable fan speed from 0 to 1600 rpm in spot points 400, 800, 1200 & 1600 rpm are presented in the Tables. Effect of material, EPI/PPI, fineness, weft space, water repellent treatment and pattern at highest fan speed (1600 rpm) are discussed below:

4.4.1 Effect of material

Table 4.40 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-01	Ag	835	6	400	0.00
					800	25.80
					1200	27.65
					1600	28.50
2	S-02	Cu-C	675	6	400	0.00
					800	22.87
					1200	24.62
					1600	25.37
4	S-04	Al	580	6	400	0.00
					800	20.00
					1200	21.75
					1600	22.50
5	S-05	S.S.	730	6	400	0.00
					800	29.30
					1200	31.10
					1600	31.90

Response of fabric particle density transfer rate in % at variable fan speed for pure metal wire incorporated cotton conductive fabric samples (Table 4.40) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, fabric samples show their response with significant sharp increment in transfer rate. From 800-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm.

Effect of material is studied for fabric particle density transfer rate of pure metal wire incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different conductive wire materials with common weft space-6. At 1600 rpm, fabric particle density transfer rate analysis of pure metal wire incorporated cotton conductive fabric samples indicates that transfer rate 22.50% of S-04 is lowest while 31.90% of S-05 is highest in conductive fabrics. 28.50% of S-01 is found higher than 25.37% of S-02 & 22.50% of S-04 but lower than 31.90% of S-05. Stainless steel wire fabric gives highest transfer rate. Silver wire fabric has transfer rate lower than stainless steel wire fabric but higher than copper and aluminium wire fabrics. High transfer rate of conductive fabrics is the effect of metal hardness according to nature of material. Stainless steel wire fabric due to higher metal hardness contribute higher opening in fabric and higher transfer rate while aluminium wire fabric due to lower metal hardness contribute lower opening in fabric and lower transfer rate.

4.4.2 Effect of ends/inch and picks/inch (EPI and PPI)

Table 4.41 – Metal blended yarn incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space(mm)	EPI/PPI	Fan speed (rpm)	Particle density transfer rate %
1	S-06 (C)	S.S./P	170	1	72/72	400	0.00
						800	18.20
						1200	19.80
						1600	20.40
2	S-10 (P)	S.S./P	170	1	82/82	400	0.00
						800	16.60
						1200	17.00
						1600	17.50

* (C) – Cotton & (P) – Polyester

Response of fabric particle density transfer rate in % at variable fan speed for stainless steel/polyester blended yarn incorporated cotton & polyester conductive fabrics (Table 4.41) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, fabric samples show their response with significant sharp increment in particle density transfer rate. From 800-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm.

Effect of EPI/PPI (EPI-ends/inch & PPI-picks/inch) is studied for fabric particle density transfer rate of metal (stainless steel/polyester) blended yarn incorporated cotton conductive fabric sample & polyester conductive fabric sample. Effect of EPI/PPI for cotton and polyester yarns on fabric particle density transfer rate is studied with common conductive material & with common weft space-1. At 1600 rpm, fabric particle density transfer rate analysis of conductive fabric samples indicates that 20.40% of S-06 is higher than 17.50% of S-10.

It is observed that polyester conductive fabrics have lower transfer rate due to round, straight and cylindrical shape of filaments & close and compact arrangement of continuous filament yarns with high EPI/PPI in fabrics while cotton conductive fabrics have higher transfer rate due to short staple fibre yarns with low EPI/PPI in fabrics. Moreover, cotton conductive fabric itself generates particles due to presence of short staple fibres which contribute higher transfer rate.

Table 4.42 – Metal jari incorporated cotton & polyester conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	EPI/PPI	Fan speed (rpm)	Particle density transfer rate %
1	S-16 (C)	CuJ	135	1	72/72	400	0.00
						800	13.90
						1200	14.60
						1600	15.05
2	S-22 (P)	CuJ	135	1	82/82	400	0.00
						800	0.00
						1200	13.35
						1600	14.20

* (C) – Cotton & (P) – Polyester

Response of fabric particle density transfer rate in % at variable fan speed for copper jari incorporated cotton & polyester conductive fabric samples (Table 4.42) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, S-16 fabric sample shows its response with significant sharp increment in transfer rate while S-22 fabric samples have no response in transfer rate. From 800-1600 rpm, response of S-16 fabric sample is in increasing mode but less compared to initial sharp raise that of 400-800 rpm while S-22 fabric samples show their response with significant sharp increment up to 1200 rpm and then after in increasing mode but less compared to initial sharp raise that of 800-1200 rpm in transfer rate.

Effect of EPI/PPI is studied for fabric particle density transfer rate of metal (copper) jari yarn incorporated cotton conductive fabric sample & polyester conductive fabric sample. With common conductive material & with common weft space-1, effect of EPI/PPI for cotton and polyester yarns on fabric particle density transfer rate is studied. At 1600 rpm, fabric particle density transfer rate analysis of conductive fabric samples indicates that 15.05% of S-16 is higher than value 14.20% of S-22.

It is observed that polyester conductive fabrics have lower transfer rate due to round, straight and cylindrical shape of filaments & close and compact arrangement of continuous filament yarns with high EPI/PPI in fabrics while cotton conductive fabrics have higher transfer rate due to short staple fibre yarns with low EPI/PPI in fabrics. Moreover, cotton conductive fabric itself generates particles due to presence of short staple fibres which contribute higher transfer rate.

4.4.3 Effect of fineness

Table 4.43 – Pure metal wire incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-02	Cu-C	675	6	400	0.00
					800	22.87
					1200	24.62
					1600	25.37
2	S-03	Cu-F	315	6	400	0.00
					800	19.20
					1200	20.90
					1600	21.60

Response of fabric particle density transfer rate in % at variable fan speed for copper wire incorporated cotton conductive fabric samples (Table 4.43) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, fabric samples show their response with significant sharp increment in transfer rate. From 800-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm. Effect of fineness is studied for fabric particle density transfer rate of pure metal (copper) wire incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common conductive material (copper) and with common weft space-6. At 1600 rpm, fabric particle density transfer rate analysis of fabric samples indicates that transfer rate 25.37% of S-02 is higher than 21.60% of S-03 in copper conductive fabrics. Fabric with coarse conductive wire gives high transfer rate. The reason is that the air flowing through coarse wires in fabric has less yarn surface to flow past. Though EPI/PPI is same & cover factor is on higher side, fabric with coarse metal wires due to their rigidity to bend, openness give high transfer rate. Highly coarse wires due to its resistance to bend in a fabric give open structure and high transfer rate while fine wires with their flexible nature give close structure and low transfer rate in fabric.

Table 4.44 –Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space(mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-20	CJ-T	790	6	400	0.00
					800	23.05
					1200	24.10
					1600	24.85
2	S-21	CJ-R	435	6	400	0.00
					800	19.80
					1200	21.10
					1600	21.95

Response of fabric particle density transfer rate in % at variable fan speed for carbon jari incorporated cotton conductive fabric samples (Table 4.44) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, fabric samples show their response with significant sharp increment in transfer rate. From 800-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm. Effect of fineness is studied for fabric particle density transfer rate of carbon jari incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for different fineness with common type of conductive material and with common weft space. At 1600 rpm, fabric particle density transfer rate analysis of fabric samples indicates that transfer rate 24.85% of S-20 is higher than 21.95% of S-21 in carbon jari conductive fabrics. Fabric with coarse conductive jari gives high transfer rate. The reason is that the air flowing through course jari in fabric has less yarn surface to flow past. Though EPI/PPI is same & cover factor is on higher side, fabric with coarse jari due to their rigidity to bend, openness give high transfer rate. Highly coarse jari due to its resistance to bend in a fabric give open structure and high transfer rate while fine jari with their flexible nature give close structure and low transfer rate in fabric.

4.4.4 Effect of weft space

❖ **Cotton conductive fabrics**

Table 4.45 – Metal blended yarn incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-06	S.S./P	170	1	400	0.00
					800	18.20
					1200	19.80
					1600	20.40
2	S-07	S.S./P	170	6	400	0.00
					800	16.25
					1200	17.00
					1600	17.60
3	S-08	S.S./P	170	10	400	0.00
					800	15.90
					1200	16.45
					1600	17.10
4	S-09	S.S./P	170	14	400	0.00
					800	15.00
					1200	15.55
					1600	16.05

Response of fabric particle density transfer rate in % at variable fan speed for stainless steel/polyester blended yarn incorporated cotton conductive fabric samples (Table 4.45) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, fabric samples show their response with significant sharp increment in transfer rate. From 800-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm.

Effect of weft space is studied for fabric particle density transfer rate of metal (stainless steel/polyeste) blended yarn incorporated cotton conductive fabric samples. Cotton conductive fabrics are studied for weft space variations of 1, 6, 10 and 14. At 1600 rpm, fabric particle density transfer rate analysis of cotton conductive fabric samples indicates that transfer rate 20.40% of S-06 (weft space-1) is highest while 16.05% of S-09 (weft space-14) is lowest in fabrics. It is observed that transfer rate gradually decrease with respect to increase in weft space from 1 to 14. For the fabric with weft space-1, transfer rate is highest among other fabrics. Here though EPI/PPI is same, difference in the transfer rate is due to the variations of the large diameter and small diameter yarns according to weft space – 1, 6, 10, 14 in heterogeneous fabrics.

❖ **Polyester conductive fabrics**

Table 4.46 – Metal blended yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-10	S.S./P	170	1	400	0.00
					800	16.60
					1200	17.00
					1600	17.50
2	S-11	S.S./P	170	3	400	0.00
					800	15.70
					1200	16.40
					1600	16.90

Response of fabric particle density transfer rate in % at variable fan speed for stainless steel/polyester blended yarn incorporated polyester conductive fabric samples (Table 4.46) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate.

From 400-800 rpm, fabric samples show their response with significant sharp increment in rate. From 800-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm.

Effect of weft space is studied for fabric particle density transfer rate of metal (stainless steel/polyeste) blended yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations of 1 and 3. At 1600 rpm, fabric particle density transfer rate analysis of polyester conductive fabric samples indicates that transfer rate 17.50% of S-10 (weft space-1) is higher than 16.90% of S-11 (weft space-3) in fabrics. It is observed that transfer rate decrease with increase of weft space. For the fabric with weft space-1, transfer rate value is highest among fabrics. Here though EPI/PPI is same, difference in the air flow is due to the variations of the large diameter and small diameter yarns according to weft space – 1, 3 in heterogeneous fabrics.

Table 4.47 – Metal plated yarn incorporated polyester conductive fabric samples

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-14	CuN	75	1	400	0.00
					800	0.00
					1200	6.90
					1600	7.40
2	S-15	CuN	75	3	400	0.00
					800	0.00
					1200	7.85
					1600	8.35

Response of fabric particle density transfer rate in % at variable fan speed for copper plated nylon yarn incorporated polyester conductive fabric samples (Table 4.47) indicates that from 0 to 800 rpm, all of the fabric samples have no response in transfer rate. From 800-1200 rpm, fabric samples show their response with significant sharp increment in particle density transfer rate. From 1200-1600 rpm, response of fabric samples is in increasing mode but less Compared to initial sharp raise that of 800-1200 rpm.

Effect of weft space is studied for fabric particle density transfer rate of metal plated yarn incorporated polyester conductive fabric samples. Polyester conductive fabrics are studied for weft space variations of 1 and 3. At 1600 rpm, fabric particle density transfer rate analysis of polyester conductive fabric samples indicates that transfer rate 7.40% of S-14 (weft space-1) is lower than 8.35% of S-15 (weft space-3) in fabrics. It is observed that transfer rate increase with increase of weft space. For the fabric with weft space-1, transfer rate is lowest among other fabrics. Here though EPI/PPI is same, difference in the air flow is due to the variations of the large diameter and small diameter yarns according to weft space – 1, 3 in heterogeneous fabrics.

❖ Correlation & regression analysis

Table 4.48 – Weft space & fabric particle density transfer rate

No.	Fabric sample code	Conductive wire/yarn detail	Denier	Weft space (mm)	Fabric particle density transfer rate %
1	S-06	S.S./P	170	1	20.40
2	S-07	S.S./P	170	6	17.60
3	S-08	S.S./P	170	10	17.10
4	S-09	S.S./P	170	14	16.05

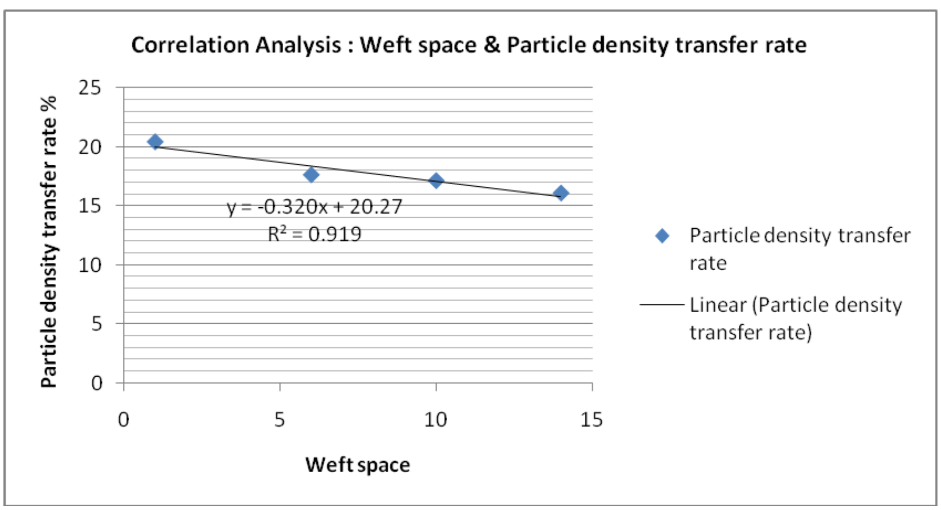

Fig. 4.6 – Correlation analysis: Weft space & fabric particle density transfer rate

Negative correlation with R = -0.9588

The regression line is: y = Transfer rate = 20.2702-0.3203 X Weft space

The **coefficient of determination**, R^2, is 91.94%. This means that close to 92% of the variation in the dependent variable (Fabric particle density transfer rate) is explained by the independent variables (Weft space).

Significance F = 0.04110

P Value = 0.04110 < 0.05

Model **Statistically significant**

4.4.5 Effect of water repellent treatment

Table 4.49 – Carbon jari incorporated cotton conductive fabric samples

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-20	CJ-T	790	6	400	0.00
					800	23.05
					1200	24.10
					1600	24.85
2	S-20W	CJ-T	790	6	400	0.00
					800	0.00
					1200	4.50
					1600	5.10
3	S-21	CJ-R	435	6	400	0.00
					800	19.80
					1200	21.10
					1600	21.95
4	S-21W	CJ-R	435	6	400	0.00
					800	0.00
					1200	3.15
					1600	3.60

Response of fabric particle density transfer rate in % at variable fan speed for carbon jari incorporated cotton conductive fabric samples (Table 4.49) indicates that from 0 to 400 rpm, all of the fabric samples have no response in transfer rate. From 400-800 rpm, normal fabric samples show their response with significant sharp increment in transfer rate while water repellent fabric samples have no response in transfer rate. From 800-1600 rpm, response of normal fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm while water repellent fabric samples show their response with significant sharp increment up to 1200 rpm and then after in increasing mode but less compared to initial sharp raise that of 800-1200 rpm in transfer rate.

Effect of water repellent treatment is studied for fabric particle density transfer rate of two types of carbon jari incorporated cotton conductive woven fabric samples. Cotton conductive fabrics are studied for normal conductive fabrics and water repellent conductive fabrics. At 1600 rpm, fabric particle density transfer rate analysis of carbon jari (trilobal) conductive fabric samples made with common weft space-6 indicates that transfer rate 5.10% of S-20W is very low compared to 24.85% of S-20. Same effect is observed in case of fabrics made with carbon jari (ring) as transfer rate 3.60% of S-21W is lower than 21.95% of S-21. It is observed water repellent conductive fabrics have very low transfer rate compared to normal conductive fabrics. Low transfer rate of water repellent conductive fabric is due to the presence of water repellent layer on surface of fabric which acts as a barrier to pass the air from the fabric.

4.4.6 Effect of conductive pattern

Table 4.50 – Carbon yarn incorporated polyester conductive fabric samples (stripe & grid)

No.	Fabric sample code	Conductive material	Denier	Weft space (mm)	Fan speed (rpm)	Particle density transfer rate %
1	S-24	C	80	5	400	0.00
					800	0.00
					1200	2.95
					1600	3.15
2	S-25	C	80	6 (Warp space-5)	400	0.00
					800	0.00
					1200	3.10
					1600	3.45

Response of fabric particle density transfer rate in % at variable fan speed for carbon yarn incorporated polyester conductive fabric samples (Table 4.50) indicates that from 0 to 800 rpm, all of the fabric samples have no response in transfer rate. From 800-1200 rpm, all of the fabric samples show their response with significant sharp increment in transfer rate. From 1200-1600 rpm, response of fabric samples is in increasing mode but less compared to initial sharp raise that of 800-1200 rpm.

Effect of conductive pattern is studied for fabric particle density transfer rate of carbon yarn incorporated polyester conductive woven fabric samples. Polyester conductive fabrics are studied for stripe pattern and grid pattern. At 1600 rpm, fabric particle density transfer rate analysis of conductive fabric samples indicates that transfer rate 3.15% of S-24 is lower compared to 3.45% of S-25.

Grid pattern fabrics give high transfer rate compared to stripe pattern fabrics. High transfer rate is due to presence of high number of conductive yarns with grid pattern in fabric while low transfer rate is due to presence of low number of conductive yarns with stripe pattern in fabric. High variations of conductive and non conductive yarns increase transfer rate of cotton conductive fabrics.