Chapter – 5

CONCLUSIONS

5. Conclusions

5.1 Introduction

In this research work, high functional conductive woven fabrics are developed with incorporation of conductive yarns in warp and weft. Conductive yarns included use of pure metal wires (silver, copper, aluminium, stainless steel etc.), copper and carbon jari, silver and copper plated nylon yarns, stainless steel/polyester blended yarns etc. Carbon jari is specially developed from trilobal and ring type carbon yarns.

Woven fabrics are developed with different variations like type of material (different conductive and non conductive materials), type of weave (plain & twill), type of conductive pattern (stripe & grid), warp & weft space (1, 3, 5, 6, 10, 14 mm) on water jet and rapier looms. Water repellent fabrics are also developed as a special case for cleanroom applications.

Electrostatic discharge properties of fabrics are judged and optimized by testing the following properties:

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

For field strength tests and fabric particle density transfer rate tests, following set ups were developed:

➢ Development of special, low cost field (signal) strength measurement test set up for textile conductive fabrics with elimination of network analyzer/vector network analyzer. This field strength test set up has output of ultra high frequency range 2.4 – 2.8GHz (radio waves).

➢ Development of unique fabric particle density transfer rate (F-PDTR) tester for textile materials with minimum particle detection capacity of 0.8 microns. Cleanroom contamination requirements with class 1-4 of BS 5295 cleanroom standards of >=10 µm can be justified with use of this particle density transfer rate tester. Variable fan speed range from 0 to 1800 rpm is unique feature to measure particle density transfer rate of fabric in density and voltage results.

Testing 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.

Different parameters like effect of material, effect of EPI/PPI, effect of fineness, effect of weft space, effect of water repellent treatment and effect of pattern are discussed in relation to surface resistivity, field strength, air permeability and fabric particle density transfer rate. Major findings of work are as under:

5.2 Major findings of present work

Surface resistivity

- ❖ Surface resistivity of conductive fabrics shows almost “static dissipative to antistatic” nature of fabrics. Normal conductive fabrics tend to behave like “static dissipative” in nature while water repellent fabrics tend to behave like “antistatic” in nature.
- ❖ Silver wire conductive fabrics have lowest resistivity among other metal wire fabrics. Copper wire fabric has resistivity lower than aluminium and stainless steel wire fabrics. Polyester conductive fabrics give higher resistivity than cotton conductive fabrics.
- ❖ As denier of conductive yarn increases in fabric, resistivity level decreases. For the same kind of metal wire, coarse wire fabrics give lower resistivity values than fine wire fabrics.
- ❖ As weft space of conductive material increases in fabric, resistivity level increases respectively.
- ❖ Water repellent conductive fabrics give high resistivity compared to normal conductive fabrics.
- ❖ Grid pattern conductive fabrics give low resistivity compared to stripe pattern fabrics. As quantity of conductive material increases in fabric, resistivity values decreases respectively.

Field strength

- The field strength of conductive textile fabrics is dominantly influenced by source frequency and distance between sample & transmitting antenna. It is concluded that highly close mesh structure of metal base fabrics give satisfactory results for EMF protection when nearby human presence from source is necessity of working environment.
- Among metal wires, 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. Wires with higher EMF absorption & reflection nature restrict EMF transmission at comparatively higher rate than wires with lower EMF absorption & reflection nature.
- Non-conductive materials have almost no effect on field strength protection level.
- Metal wires have very good reflection and absorption properties but due to their rigidity to bend, openness give lower protection % but medium coarse conductive wire with soft nature give higher protection %. Here, wire spacing also plays the role.
- Coarse conductive yarn fabrics give higher protection %.
- As weft space of conductive material decreases in fabric, protection % increases respectively.
- Normal and water repellent conductive fabrics give almost same field strength protection %.
- Grid pattern conductive fabrics give better protection % compared to stripe pattern fabrics. As quantity of conductive material increases in fabric, field strength protection % increases respectively.

Air permeability

- Stainless steel wire fabric gives highest permeability. Silver wire fabric has permeability lower than stainless steel wire but higher than copper and aluminium wire fabrics.
- Conductive fabrics of high EPI and PPI with plain or possibly twill structure (having Lower float lengths) give low air permeability values.
- Coarse wires due to its resistance to bend in a fabric give more open structure than fine wires. For the same kind of metal wire, coarse wire fabrics give high air permeability values than fine wire fabrics.

- As weft space of conductive material increases in fabric, air permeability increases or decreases. It depends upon involvement of fine or coarse yarns.
- Water repellent conductive fabrics give very low air permeability compared to normal conductive fabrics.
- Grid pattern conductive fabrics give moderately high air permeability compared to stripe pattern fabrics. It also depends upon involvement of fine or coarse yarns.

Fabric particle density transfer rate (F-PDTR)

- From 0 to 400 rpm fan speed, all of the conductive fabric samples have no response in transfer rate. From 400-800 rpm, most of the cotton conductive fabric samples show their response with significant sharp increment in transfer rate. From 800-1600 rpm, response of cotton fabric samples is in increasing mode but less compared to initial sharp raise that of 400-800 rpm. Most of the polyester conductive fabric samples (with high EPI & PPI) show their response from 800-1200 rpm with significant sharp increment in transfer rate. From 1200-1600 rpm, response of polyester fabric samples is in increasing mode but less compared to initial sharp raise that of 800-1200 rpm.
- 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.
- Conductive fabrics of high EPI and PPI with plain or possibly twill structure (having lower float lengths) give low transfer rate.
- Coarse wires due to its resistance to bend in a fabric give more open structure than fine wires. For the same kind of metal wire, coarse wire fabrics give high transfer rate than fine wire fabrics.
- As weft space of conductive material increases in fabric, air permeability increases or decreases. It depends upon involvement of fine or coarse yarns.
- Water repellent conductive fabrics give very low transfer rate compared to normal conductive fabrics.
- Grid pattern conductive fabrics give moderately high transfer rate compared to stripe pattern fabrics. It also depends upon involvement of fine or coarse yarns.

Type & nature of conductive and non-conductive material, material fineness, weft space, EPI/PPI, conductive pattern, water repellent treatment etc. have significant influence on properties of conductive fabrics.

Recommended solutions for cleanroom*:

- ❖ ISO 3 & ISO 4: Fabric sample made with metal wires or carbon yarns and polyester fully drawn yarns of same deniers woven in plain weave having high EPI & PPI with 1-4 warp space and 1-4 weft space (grid pattern) can be the solution for ESD protection in cleanroom environment.

- ❖ ISO 3 & ISO 4: Fabric sample made with carbon yarns, metal (plated or blended) yarns or fine to medium coarse flexible metal wires and polyester fully drawn yarns of same deniers woven in plain weave having high EPI & PPI with 0 warp space and 0 weft space can be the solution for EMF protection in cleanroom environment.

*However with consideration of static charge, EMF source, distance, time, level & type of protection etc., final optimised condition can be successfully set through high functional conductive fabrics to achieve desired level of protection in clean room environment.

5.3 Future scope of work

1. The possible extension would be the inclusion of high scale sensor in the cleanroom fabric particle density transfer rate tester which would further improve the accuracy at micro level up to 0.1 μm. High capacity fans, sample distance variability options, state of art sample mounting without any air leakage etc. are also added options to work out for efficiency improvement of tester.
2. Improvement in field strength measurement test set up as per textile demand with miniature size.
3. Development of test set up to measure surface resistivity of textile materials at different voltage range.
4. Development of charge decay time measurement set up for textile materials.
5. Design and development of pilot weaving machine to handle metal wires and other conductive yarns for producing the conductive fabrics.
6. Design and development of modelling and optimizing techniques for producing high functional conductive materials.

7. Effective use of inherently (or intrinsically) electrically conductive polymers & nano materials-finishes for high functional applications.
8. Reduction of thickness and stiffness of conductive textile materials with use of nano materials.
9. Development of various conductive jari materials for cleanroom applications.
10. Assess performance of fabrics at actual cleanroom workplace.