# DEVELOPMENT OF PERSONAL PROTECTIVE WEAR FOR FIREWORK EMPLOYEES

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**Abstract -** The fireworks industry is well known for being a hazardous industry, from the initial manufacturing phase to the transportation and storage of fireworks. The industry is situated in Sivakasi, Tamilnadu where more than 800000 people are employed. Most of the accidents occur in the filling of chemicals and storage of raw materials due to improper handling, lack of awareness on safety measures and not using any protective clothing (wear). Hence an attempt is made in this research to develop a protective wear from PVC coated Cotton fabric. In the initial phase, cotton yarn is selected based on commercial availability. The yarn properties such as yarn count, lea strength, single yarn strength, elongation and TPI were evaluated as per standards. It is observed from the results that the cotton yarn has lea strength of 75.39 lbf, single yarn strength of 0.26kg/f and Rate of elongation is observed as 18.8 mm. In the second phase the yarn samples are coated with PVC and fabric samples are developed. The fabric samples are tested for flammability, LOI, abrasion resistance, air permeability and comfort properties.

***Key Words***: protective wear, cotton, pvc, flame retardant, comfort.

## 1.INTRODUCTION

Protective clothing (wear) is any clothing that is specifically designed, treated, or manufactured to protect personnel from hazards caused by extreme environmental conditions or a hazardous work environment. Personal protective equipment (PPE) is clothing worn to reduce exposure to hazards that cause serious workplace injuries and illnesses. Protective clothing (wear) is worn in nearly every workplace, from commercial kitchens to construction sites. It shields the wearer from injury caused by blunt impacts, electrical hazards, heat, chemicals, and other factors. Depending on the hazards present and the body part or function at risk, different types of PPE are used. Protective clothing (wear) is one type of PPE. It is intended to isolate the entire body or different body parts from one or more hazards to which one may be exposed. Protective clothing (wear) is classified according to the part of the body it protects. Bunker suits, lab coats, coveralls, gowns, lifejackets, bulletproof vests, safety harnesses, and aprons, for example, fall into the first category because they cover the entire body or the torso. Pants, chaps, gaiters, booties, and boots can provide protection for the legs and feet. Arm and hand protection can be provided by gloves and arm guards, while the head can be protected by hoods and balaclavas. Aside from protective clothing, other types of PPE include respirators, goggles, face shields, helmets, and earmuffs. Clothing worn to protect workers from fire is known colloquially as "FRC," which stands for Flame Resistant Clothing. Materials with excellent flame resistance, such as Nomex, Kevlar, and Modacrylic, are commonly used to make elements of FR garments. Other fabrics, such as cotton, are naturally flame resistant and can be treated with specialist chemicals to improve their heat resistance and protective qualities. Wool, modacrylic, 100 percent polyester, and flame-retardant treated fabrics with a tight weave are all good options. Flame retardants are classified according to whether they contain bromine, chlorine, phosphorus, nitrogen, metals, or boron. Chlorinated flame retardants — These are the most commonly used flame retardants and contain chlorine. PVC contains high chlorine content, which acts as a fire retardant, preventing flames from spreading. Furthermore, when the source of the flame is removed, PVC self-extinguishes. In this research natural cotton yarn is taken for the study. And the flammability of the yarn after coating with Polyvinyl chloride (PVC) is analysed and the results were discussed.

## 2. LITERATURE REVIEW

Protective textiles are garments and other fabric-related items worn for their protection performance or functional characteristics rather than their aesthetic or decorative value. Personal protective equipment clothing is now an important application for textiles and is classified as technical or industrial textiles. Thermal protection, cold protection, flame protection, and chemical protection are some of the end-use functions of personal protective textiles. Mechanical protection, radiation protection, biological protection, electrical protection, and wearer visibility are all important considerations.[1] The protective clothing should offer adequate protection while also being comfortable to wear. Appropriate material selection, clothing design, and result evaluation all play important roles in predicting clothing performance and comfort. Personal protective equipment

(PPE) and personal protective clothing (PPC) are materials that form a protective barrier between the hazardous environment and the human. The performance level of PPC is the most important factor in determining the clothing's ability to save lives or prevent injuries. The level of performance is determined by the nature of the fire, the type, design, and unique features of the PPC.[2]
PPC must safeguard industrial workers against a variety of hazards, including sun damage, abrasion, chemical spills, and electrical burns; competing demands invariably compromise thermal performance. Fiber type, textile material construction and treatment, as well as garment fit and construction, must all be considered when designing functional PPC that provides adequate protection and comfort to wearers.[3]
Personal protective clothing is designed to shield the wearer from various hazards (mechanical, biological, chemical, thermal, radiological, and so on) as well as hostile environmental conditions that can cause harm or even death. Personal protective clothing comes in a variety of styles and materials, depending on the hazards and end user requirements. High weight, bulky nature, lack of mobility, heat stress, low heat dissipation, high physical stress, deteriorating dexterity, deteriorating scope of vision, lack of breathability, and reduced pathogen protection and hazards are all disadvantages of traditional protective clothing.[4]
Personal protective textiles are difficult to classify because no single classification can clearly summarize all types of protection. Overlap of definitions is common because there are so many occupations and applications that even the same class of protective clothing often has different requirements in technique and protection. Personal protective textiles are classified into industrial protective textiles, civilian protective textiles, medical protective textiles, sports protective textiles, and space protective textiles based on their end use.[5]
Highly extensible elastomeric fibres, cellulose-based fibres, commodity synthetic fibres, high strength inorganic materials, and high-performance polymer fibres are the six categories of fibres. Polyester-based elastic fibres and shape memory polyurethane are two new developments in highly extensible elastomeric fibres. In the case of cellulose-based fibres, environmentally friendly processes and nanotechnology-enabling treatments for natural fibres are being developed, with the goal of transferring interesting properties of the feedstock to regenerated cellulose fibres. Polyolefins, polyester, and polyamide are examples of commodity synthetic fibres that have recently seen advances in surface functionalization and the formation of nanoscale structures. Basalt fibres and carbonaceous materials have seen increased use in PPE as high strength inorganic materials. Boron is also a popular material for fibres and coatings. High-performance polymer fibre research includes enhancing their short- and long-term performance, moving to the nanoscale for new functionalities, and investigating their recyclability. A separate section covers a wide range of special textile structures relevant to PPE, such as 3D textile structures, auxetic textile structures, shear thickening fabrics, nano porous structures, and phase change materials, and some specially designed textile-based composite structures for improved mechanical protection.[6]
Stab resistance vests are another type of personal protective equipment that protects against stabs and impacts from sharp and pointed objects. Stab resistant vests, like bullet-resistant materials, are made of high-performance fibres such as p-aramid, ultra-high molecular weight polyethylene (UHMWPE), and others. Because of its inherent cut resistance, UHMWPE fibre is found to be the most suitable. It is important to remember that a highly efficient, flexible bullet-resistant vest made of high-performance fibres may not be a good stab-resistant vest. A bullet resistant material armour can be easily penetrated by sharp objects because the fabric used to make it is not tightly woven, whereas a stab resistant vest made of high-performance fibres is woven very tightly, acting as a barrier against stabs. The type of protection in stab resistant vests, like bullet resistant jackets, is determined by the impact energy, toughness, and other factors.[7]
Medical textiles are used in the production of personal protective clothing for healthcare or medical applications, specifically to reduce the risks associated with exposure to hazardous substances such as body fluids and to reduce the risk of cross-infections. Coveralls, footwear covers, full body suits, gloves, independent sleeves, scrubs, surgical gowns, surgical masks, and scrub hats are all examples of medical clothing products. Medical protective clothing, which is typically made of synthetic fibres due to their superior liquid barrier properties, can be made using nonwoven, weaving, or knitting technologies. Nonwoven fabrics are the most popular for such clothing because they allow for relatively quick and inexpensive manufacturing, high levels of sterility, and infection control. As a result, they are frequently used in the production of disposable medical textiles such as surgical caps, surgical gowns, and surgical masks.[8]
Personal protective clothing (PPC)'s level of protection severely impedes heat exchange via sweat evaporation. As a result, work associated with wearing PPC, particularly in hot environments, entails significant physiological strain and may exhaust workers in a short period of time. Recent advancements in algorithms for describing heat transfer that account for pumping and wind effects include improved prediction of thermal stress. The available measures of thermal insulation and evaporative resistance of a given clothing ensemble can then be realistically corrected... The advancement of advanced thermal manikins and measurement procedures should result in more accurate measurements for predictive models. The results, like all methods and

models, require validation in realistic wear trials to demonstrate their relevance and accuracy.[9]

Even at moderate exposure temperatures, protective clothing limits body heat dissipation and may cause thermal stress and discomfort. PCMs can be used to reduce thermal stress and improve thermal comfort in people who wear protective clothing. PCM are distinguished by their ability to absorb energy when they transition from a solid to a liquid state and to release heat when they return to the solid phase.. PCM used in clothing undergoes phase change at temperatures close to the skin's thermally neutral temperature, 28-32 °c. Because the temperature does not change during the phase change, PCM can stabilise body temperature. The cooling effect of PCM is determined by its ability to absorb heat when the external heat load or body heat production exceeds the heat loss. The net effect of PCM in practical use is reduced by the fact that PCM in clothing adds to the wearer's total weight and thus increases metabolic heat production. PCM also acts as an additional barrier to evaporative heat loss and moisture transport through clothing layers. As a result, the potential cooling contribution provided by PCM, as well as the body's ability to maintain thermal neutrality and comfort, should be identified and evaluated as part of the total heat exchange mechanism via the clothing system.[10]

The phase change properties of heat-preserving materials (HPMs) distinguish them. Heat is used to induce a phase change, which is often associated with the melting of the primary constituent substance. When the temperature effect on the main active HPM is reversed, the substance solidifies again. The specific energy of these HPMs is relatively high. HPMs of various types are widely used, including phase change materials (PCMs) in dispersion embedded in polymer matrix, as well as organic gels and hydrogels.[11]

In an automobile encapsulating plant, the level of comfort of personal protective equipment (PPE) was investigated. Up to 96.2% of employees used one or more types of PPE. Only 8% of the workers thought their respirators were comfortable, 30% tolerated them, and 62% found them uncomfortable. Employees rated their PPE (other than a respirator) as comfortable in a range of 32 to 52%. Coveralls/aprons received a 52% comfort rating, safety glasses received a 51% rating, rubber gloves received a 42% rating, and hearing protectors received a 36% rating. For about 30% of the employees, PPE was tolerable (just acceptable). To improve the effectiveness and safety of PPE, human-factor aspects of PPE design should be prioritised, and quality improvement should include PPE wearability.[12]

Production injury occurs in fire work industry when on wooden trays, chemicals such as fuels, oxidizers, igniters, sand, and special effect chemicals are manually mixed. The main causes of accidents in this case are impact, friction, static electricity charges, and human error. Products are dried on specially prepared platforms where dust accumulation and overheating can lead to accidents. Products are manufactured and stored locally, where push carts and trucks are used for transportation. Careless handling, impact loading, overloading, and dragging of materials may cause accidents during this phase.[13]

Because all chemicals are flammable in nature, any source of ignition will result in unfavourable incidents. Electricity is not permitted inside the working shed to avoid a source of ignition. Furthermore, some of the measures include using fewer chemicals, avoiding chemical friction, proper housekeeping, frisking, adhering to proper handling procedures, having experienced supervision, and so on. According to reports, the majority of accidents in the fireworks industry occurred in the filling and fancy sections. Only in these two sections do workers handle chemicals in powder form. During the chemical filling process, airborne dusts accumulated in the room, resulting in a dust explosion. Mishandling of chemicals, worker carelessness, and overfilling of chemicals in a single stroke may also be factors in fatal accidents. Mishandling causes intense friction, resulting in massive heat generation and, eventually, explosion. In the production of fancy fireworks, the chemicals are prepared into a slurry and formed into ball-shaped chemicals to perform the aerial display. As a result, the chemicals are mixed with an appropriate amount of water, resulting in decomposition. To avoid heat accumulation, proper drying time and ventilation must be maintained. Even minor ignorance can result in a fire.[14]

The goal of fire protective clothing is to keep the wearer safe from heat hazards such as flames, hot combustion gases, steam, hot objects, or any combination of these conditions. It must meet several criteria, including flame resistance (FR), thermal insulation, and good mechanical properties. The purpose of fire-resistant clothing is to slow the rate at which human skin heats up, giving the wearer enough time to react and escape. To make flame retardant clothing and textiles, inherently flame-retardant materials such as Kevlar and Nomex, a flame-retardant finish, or a combination of these methods are commonly used.[15]

The most important fabric properties to address in flame, radiant heat, and hot surface contact exposures are thickness and thermal resistance. Exposure to steam and hot water (splash and immersion with compression) allows mass transfer through fabrics. Fabric thickness, air or water vapour permeability, and evaporative resistance are important properties to consider when protecting the human body from steam jet pressure or water.[16]

There may be differences in the modes of thermal energy transfer from fire hazards to firefighters based on thermal exposure. As a result, each type of thermal exposure and its associated mode of thermal energy must be scientifically understood. One potential strategy for preventing burn injury is to modify protective equipment, or turnout gear.[17] A system reflecting the need for surgical intervention replaced the traditional classification of burns as first, second, third, or fourth degree. Burn depth is currently classified as superficial, superficial partial-thickness, deep partial-thickness, and full-thickness. The term fourth degree burns is still used to describe the most severe burns, which extend beyond the skin into the subcutaneous soft tissue and can involve underlying vessels, nerves, muscle, bone, and/or joints.[18]

Chloro fibre is primarily made from chloride. Polyvinyl Chloride, or PVC, is a major fibre in this family. Vinyl chloride suspension polymerization is used to create PVC fibre. This fibre is non-flammable, and it does not burn, emit flames, or emit molten incandescent drops, which could spread fire to other combustible materials. PVC fiber's chemical structure consists of polymeric repeat units (-CHCL, -CCL2), which creates a high degree of chain order and thermal resistance. The fire-retardant property of PVC fibre can be improved by incorporating flame-retardant materials as additives or finishing agents into the fiber's structure.[19]

Flame retardant chemicals are used to inhibit or suppress the combustion process in fabrics. These fire retardants obstruct combustion at various stages, including heating, decomposition, ignition, and flame spread. A textile fabric, like any other matter, experiences a temperature rise when exposed to a heat source. When the temperature of the fire source is high enough and the net rate of heat transfer to the fabric is high enough, pyrolytic decomposition of the fibre substrate occurs. This decomposition produces combustible gases, non-combustible gases, and carbonaceous char as by-products. The mixture catches fire, resulting in a flame.[20]

To make the PVC resin, the polyvinyl chloride powder plasticizer was combined with diisononyl phthalate (DINP) and the oxidation stabiliser 2,6-di-tert-butyl-4-methyl-phenol (BHT). The viscosity of the polyvinyl chloride resin was controlled using decalin (PVC resin). To make the various viscosity PVC resins, PVC powder, DINP, and BHT were stirred for 2 hours with an agitator at 25 C and 300 rpm. To control the viscosity of the PVC resin, various decalin contents such as 10 phr, 8 phr, 5 phr, 2 phr, and 0 phr were added after the stirring process was completed.[21]

Assessing the fire hazard is thus a difficult task that can only be accomplished if sources of danger to life and potential injury are identified at each stage of the burning process. In contact fires, the degree of burn injury is said to be determined by heat transfer to the skin. Human tissue (skin) is extremely temperature sensitive. Total heat energy of 0.64 cal/cm2 (26.8 kJ/m2) causes pain, while 1.2 cal/cm2 (50.2KJ/m2) causes second-degree bums on exposed tissues. At 45°C, the skin feels painful, and at 72°C, the skin is completely burned. The purpose of protective clothing is thus to slow the rate of heating-up of human skin in order to give the wearer enough time to react, escape, and avoid or minimise burns.[22]

PVC is easier to flame retard than many other thermoplastics because it has a higher initial LOI. The benefit is enhanced because the chlorine in PVC interacts synergistically with many flame retardants. Among the benefits of using PVC in applications requiring fire resistance are its relatively high chlorine content (56.8%) and compatibility with a wide range of FR additives. Some FR additives, when combined with chlorine, produce free-radical scavengers that act as flame poisons. In a fire, some SS additives cause PVC to degrade into more aliphatic and less aromatic products.[23]

The atmosphere contains approximately 21% oxygen. The rest (nitrogen, CO2, water, and so on) are incompatible with combustion. Experiment has shown that increasing the oxygen-to-nitrogen ratio causes some materials that are self-extinguishing in air to burn. Materials that burn easily in air, on the other hand, self-extinguish in nitrogen-rich atmospheres. This results in a useful and general test for determining flammability. The limiting oxygen index (LOI) test attempts to determine the minimum oxygen content atmosphere in which a material will burn. In general, materials with a LOI greater than 25 are self-extinguishing in air. Those with the lowest LOI values burn the fastest. Very few materials, in fact, refuse to burn in atmospheres containing close to 100% oxygen.[24]

The viscosity of the PVC resin was measured using a viscosmeter and a rheometer. The tensile, peel, and tear properties of the PVC coated fabric were investigated in relation to the viscosity of the PVC resin and the weaving structure of the base substrate. SEM and X-ray computed tomography (CT) analysis of the base substrate structure were used to examine the morphologies of the PVC coated fabrics. SEM and X-ray computed tomography (CT) analysis were used to examine the morphologies of the PVC coated fabrics.[25]

Coating with PVC/PU mixture: In the set of experiments, PVC was mixed with PU to investigate the benefits of PU's excellent adhesiveness as well as the possibility of improving porosity. In preliminary tests, different combinations of PVC and PU were used to optimise the composition. It was discovered that for equivalent add-ons, a 60:40 PVC/PU coat combination produces excellent WVP and WPR results. As a result, it was decided that 60:40 mixtures would be used in the study.[26]

A uniaxial tensile test was used to investigate the mechanical properties of a polyvinyl chloride (PVC)-coated woven fabric at high temperatures and after exposure to high temperatures. The temperature range for the test is 20o C to 170o C. The maximum stress at 170o C is reduced to 57% 59% of that at 20o C, according to the high-temperature test. The prestressing after high-temperature exposure test results show that the combined effect of high temperature and constant external force

increased stiffness while decreasing impact toughness. By comparing tensile results and analysing polymer physics, it was concluded that micro-level changes are reflected in macro-level mechanical property changes.[27]
The eco-effectiveness of PVC plastisol was compared to two commercially accepted coating agents, polyacrylate (PAA) and polyurethane (PUR), both in dispersed form in water. PVC plastisol was discovered to be the most environmentally friendly coating agent, followed by polyacrylate and polyurethane resin dispersions in water. PVC plastisol with non-toxic plasticizer and less than 5 ppm free vinyl chloride monomer was determined to be an eco-efficient material that, when managed responsibly from cradle to grave, provides long-term benefits to society.[28]
PVC-coated polyester fabrics are the most commonly used material in structural fabric construction. These fabrics are popular primarily because of their low cost, high strength, durability, resistance to wear and tear, toughness, variety of colours, and soft texture. They are frequently used for large-area surfaces, membrane-cable structures, and pneumatic structures. The goal of the research was to improve the thermal insulation properties and reduce the density of PVC-coated fabric made from PVC green plastisol incorporated by aerogel to form a novel PVC/aerogel composite on technical woven fabrics made of polyester fibres.[29]
Padding, also known as the pad-dry-cure method, is a textile finishing technique that can be used to add a variety of coatings, but it usually refers to a fibre coating for the use of micro or nanomaterials or chemical compositions. The fabric or yarn is immersed in the coating solution, and the excess is squeezed out in the rollers, determining the pick-up percentage. The fabric is then dried and cured.[30]

## 3. OBJECTIVE

- To design and develop low-cost personal protective wear for firework employees.
- To study/analyze the properties of polyvinyl chloride and to coat on yarn/fabric.
- To analyze the properties of PVC coated fabric for comfort properties, fire, chemical and electrical resistance.

## 4. MATERIALS

### 4.1 Cotton yarn

Cotton yarn is a diverse material. It is made up of a large number of individual cotton fibres that are twisted together. The higher the count of yarn in the cotton count (indirect yarn numbering) system, the finer the yarn. 100% cotton yarn with 40s count is used for this study.

### 4.2 Polyvinyl Chloride powder (PVC)

Polyvinyl chloride (PVC) is the key component which is used for this study. Where PVC is naturally flame retardant. It has a high ignition temperature and cannot be burned, and it has good thermal stability and can withstand a wide range of temperatures.

### 4.3 Di-Isononyl Phthalate (DINP)

DINP is a phthalate plasticizer that is commonly used to increase the flexibility and durability of various polymers, particularly PVC. It improves the flexibility, elongation, and softness of PVC and other polymers when added. It lowers the glass transition temperature, which makes the material more malleable.

## 5. METHODLOGY

### 5.1 flow chart

Yarn and Chemical sourcing
↓
Preparation of PVC resin
↓
Coating of PVC resin on yarns
↓
Testing of coated yarns
↓
Weaving
↓
Testing of woven fabric

### 5.1.1 Preparation of PVC resin

**Table 1**

| Time | 2 mins | 4 mins | 6 mins |
|---|---|---|---|
| Temperature | $200^0C$ | $250^0C$ | $300^0C$ |
| viscocity | 4 phr | 6 phr | 8 phr |

Table 1 shows the different time, temperature, and viscosity to optimize the procedure with time difference of 2, 4, 6 mins, temperature difference of $200^0C$, $250^0C$, $300^0C$ and viscosity difference of 4 phr, 6 phr and 8 phr.

Box Behnken Experimental Design is used for optimization which is given in table 2.

**Table 2:** Optimization Process

### 5.1.2 Coating of PVC resin

The machine used for this study is SS600 single yarn sizing machine, where resin preparation and coating of yarn is done. The sample in cone form is kept in the creel of the machine. The yarn is taken from the cone, it is passed through thread guides and finally it is passed in between the immersing roller of the coating chamber. From the coating chamber the yarn goes to a drying chamber and finally it is wound on a final package cheese. The speed of the machine is 300 RPM. The process conditions of coating are maintained as given in table 2.

| S.NO | TEMPERATURE (C) | TIME (mins) | VISCOCITY (phr) |
|---|---|---|---|
| 1 | 250 | 2 | 8 |
| 2 | 250 | 4 | 6 |
| 3 | 200 | 4 | 8 |
| 4 | 300 | 6 | 6 |
| 5 | 300 | 4 | 8 |
| 6 | 200 | 4 | 4 |
| 7 | 200 | 6 | 6 |
| 8 | 250 | 6 | 4 |
| 9 | 250 | 6 | 8 |
| 10 | 200 | 2 | 6 |
| 11 | 250 | 2 | 4 |
| 12 | 300 | 4 | 4 |
| 13 | 300 | 2 | 6 |

### 5.1.3 Fabric Preparation

A plain weave fabric is developed using a sample loom. The fabric specifications are given in table 3.

**Table 3:** Fabric Parameters

| S.NO | PARAMETERS | READINGS |
|---|---|---|
| 1 | Warp count (EPI) | 82 |
| 2 | Weft count (PPI) | 52 |
| 3 | Fabric GSM | 116.24 |
| 4 | Thickness | 0.25 mm |
| 4 | Cover Factor | 22.35 |
| 5 | Tensile Strength | Warp - 450.58 kg/sq.cm<br>Weft - 195.77 kg/sq.cm |
| 6 | Elongation | Warp - 12.67 %<br>Weft – 18.57 % |

## 6.TESTING

### 6.1 Cotton Yarn

### 6.1.1 Single Yarn Strength

A Uni Stretch tester with ASTM D2256 Standard is used in this study to analyze the yarn strength of 100% cotton yarn with count of 40s.

### 6.1.2 Lea strength

To test a Lea Skein strength, a Uni Stretch tester with ASTM D1578 is used to analyze the strength of Lea in 100% cotton yarn.

### 6.1.3 Twist Per Inch (TPI)

The term TPI (twists per inch or turns per inch) is used in the textile industry. It calculates the number of twists in an inch of yarn to determine how many twists a yarn has. The amount of twist also influences the yarn's stretchiness, strength, halo, and a variety of other properties. To test twist per inch an ELE tester is used in this study.

### 6.2 Cotton Fabric

### 6.2.1 Air permeability

To test air permeability, an air tronic tester with model number 3240A and ASTM D737 is used. A volumetric counter with a minimum hourly capacity of 50 litres and a maximum hourly capacity of 5800 litres is present. Different testing areas are available which is of 2, 5, 10, 20 $cm^2$. Cotton fabric is tested using a test area of 10 $cm^2$ with a pressure drop of 100 Pa and a measuring volume of 10 litres per minute, and readings were recorded.

### 6.2.2 Flame Retardant Test

The limiting oxygen index values were used to determine the flame-retardant test. According to ASTM D-6413-08, the test is performed on one control sample and two treated samples. The vertical flame test is performed with a vertical flammability model VC-2 instrument and fabric strips (fabric size - 13cm height and 6cm width). The limiting oxygen index (LOI) is the minimum oxygen concentration that will allow a polymer to burn, expressed as a percentage. The percentage of oxygen in air is approximately 20.9%; if a material's LOI is less than this, it will easily burn in air. While grouping materials, the value of oxygen, 20.9%, can be considered as a threshold value. The LOI is determined by passing a mixture of oxygen and nitrogen over a burning specimen and gradually decreasing the oxygen level until a critical level is reached.

## 7.RESULT AND DISCUSSION

### 7.1 Single Yarn Strength

**Table 4:** Single Yarn Strength of Cotton Sample

| S. No | Parameter | | Before Coating | After Coating |
|---|---|---|---|---|
| 1 | Single Yarn Strength | Single Peak Force (kgf) | 0.26 | 0.31 |
| | | Elongation (mm) | 18.80 | 15.17 |

Table 4 shows the result of single yarn strength for 100% cotton yarn, before coating and after coating the yarn with PVC. From the result, it is shown that the untreated Cotton yarn has an elongation with 18.80 mm and single peak force with 0.26 kg/f and treated fabric has the elongation with 15.17mm and single peak force of 0.31kgf. which concludes that yarn coated with PVC has more strength compared to untreated cotton yarn.

### 7.2 Lea Strength

**Table 5:** Lea strength of cotton sample

| S. NO | Lea strength | Before Coating | After Coating |
|---|---|---|---|
| 1 | Br. Force (lbf) | 75.39 | 78.41 |

Table 5 shows the result of lea strength, for the selected cotton yarn sample. Untreated Cotton has a lea strength with a breaking force of 75.39 lbf and treated cotton yarn has a breaking force of 78.41 lbf.

### 7.3 Twist Per Inch

**Table 6:** TPI of cotton sample

| S.NO | Before coating | After coating |
|---|---|---|
| 1. | 16 | 14 |

Table 6 shows the result for TPI of the selected sample yarn. Untreated cotton yarn has a greater number of TPI with 19, and treated Cotton yarn with 14 TPI.

### 7.4 Air Permeability

Table 7 shows the results of testing the air permeability of the fabric samples. When compared to the treated cotton fabric samples, the untreated cotton fabric has higher air permeability characteristics.

**Table 7:** Air permeability of fabric samples

| S.NO | Untreated fabric (l/min) | Treated fabric (l/min) |
|---|---|---|
| 1 | 18.6 | 13.7 |
| 2 | 18.8 | 14.3 |
| 3 | 18.2 | 13.8 |
| 4 | 17.5 | 13.5 |
| 5 | 18.3 | 13.0 |
| Average | 18.25 | 13.66 |

### 7.5 Flame retardant test

**Table 8:** Flame retardant activity of Treated and untreated samples

Tc – time of continue burning, Ts – time of slow burning, DL – damaged length

| S. No | Samples | LOI (%) | Vertical Burning test | | | Inference |
|---|---|---|---|---|---|---|
| | | | Tc (s) | Ts (s) | DL (mm) | |
| 1 | Untreated | 18.2 | 41 | 95 | 275 | Flammable |
| 2 | Treated | 35.4 | 0 | 0 | 62 | Self-extinguishing |

From the above table, it was evident that, untreated sample burnt upto 275mm, whereas the treated sample burnt up to only 62mm respectively indicating that the treated samples were stable as per the LOI classification table percentage values. LOI of untreated is 18.2% (flammable), treated sample LOI value is 35.4%.(self-extinguishing).

## 8. CONCLUSIONS

For this research, 100% Cotton yarn sample is sourced. Important yarn properties, such as yarn count, single yarn strength, elongation, lea strength and TPI were evaluated. The nominal yarn count of the yarn samples is 40 Ne, and the actual yarn count for cotton is 39.5s. Untreated cotton yarn has a lower strength of 0.26 kg/f and treated yarn has the highest strength of 0.31 kg/f.

100% cotton untreated yarn has the highest elongation of 18.80 mm and treated yarn has the lowest elongation of 15.17mm. The result of Lea strength shows that untreated Cotton yarn has a least lea strength of 75.39 lbf. And treated yarn has a highest lea strength of 78.41 lbf. 40s Count 100% Cotton yarn has TPI of 16 before coating and TPI of 14 after coating with PVC.

PVC treated cotton yarn has the good flame-retardant property which burns less than untreated fabric with

62mm and the PVC treated sample is self-extinguishable as per the LOI classification where LOI % is between 28% and 100% is considered as self-extinguishing.

Finally, it is concluded that 100% Cotton yarn of $40^S$ Ne which is treated with PVC has higher Single yarn strength, Elongation, lea strength than untreated yarn. Treated yarn has lower air permeability when compared to untreated yarn as the coating treatment blocks the pores of the fabric.

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