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# Surface Modification of Synthetic Fabric by Polyurethane Coating to Reduce Harmful Formaldehyde Content and Produce Water Repellent Fabric

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**ABSTRACT**
Synthetic fabrics such as 100 percent polyester and viscose are inherently durable press because these are treated with chemicals i.e. formaldehyde during manufacturing. Formaldehyde, a carcinogen, is a substance capable of causing cancer in living tissue. This paper aims to describe how to reduce the formaldehyde content from polyester and viscose fabric and develop sustainable water repellent properties in synthetic fabrics. In this study, the formaldehyde has been reduced by applying Polyurethane (PU) coating on the fabric surface. After applying coating, formaldehyde content in the fabric, water repellency and wash fastness have been evaluated. The result shows that the water repellent property of the fabric has been improved after coating. The different layer of coatings such as single layer and the double layer has been applied on the fabric surface and a comparison has been made between the improved properties of the fabric. It has been found that the polyurethane coatings have good water repellent property and used for reducing the formaldehyde in the fabric. The result shows that the number of increasing layer of PU coating on fabric surface has inverse relation to the amount of formaldehyde content of fabric and direct relation to the water repellent property of the same fabric. As a consequence of increasing layer of coating, the amount of formaldehyde reduce in the both type of fabric composition. But the water repellent property increases with the increasing number of PU coating in the fabric surface. Moreover, wash fastness of the coating on the polyester fabric surface is excellent but the coating on the viscose fabric has poor wash fastness. The paper has provided a better solution to develop water repellent property in the fabric and to reduce the carcinogenic formaldehyde that could be implemented in sustainable water repellent applications.

Keywords: Formaldehyde, Carcinogen, Water-Repellency, Synthetic Fabric, Polyurethane

## 1. Introduction

Polyester and viscose, synthetic fabrics, which are permanently durable press, do not need further treatment because during manufacturing they are treated with chemicals containing formaldehyde. Formaldehyde is a carcinogenic substance that is responsible for causing cancer in living tissue. Urea-formaldehyde resins are applied to fabric to impart the simple care properties such as permanent/ durable press, anti-cling, anti-static, anti-wrinkle, anti-shrink (especially shrink proof wool), waterproofing, perspiration proof, moth proof and so on. These resins usually emit significant amount of formaldehyde. The release of formaldehyde from coated textiles increase with both the increase of temperature (hot days, ironing coated textiles) and humidity [1]. Formaldehyde is also known as methanol that is a colorless and flammable gas having a pungent smell and is soluble in water. Its chemical formula can be written as HCHO or CH2O, and its chemical structure is shown in Fig.1 [2].

Polyester is very durable, hence it is resistant to most chemicals, stretching, shrinking, mildew and abrasion. Polyester could be easily washed and dried because of its hydrophobic nature. Woven or knitted fabric made of polyester thread or yarn is used widely in apparels, bed sheets, blankets, upholstered furniture and computer mouse mats. Polyester fibers, yarns and ropes are also used in car tire reinforcements, fabrics for conveyor and safety belts, coated fabrics and plastic reinforcements with high-energy absorption [3]. During synthesis of polyester, methanol is the byproduct of the esterification reaction [4].

Viscose Rayon is a fiber produced from recycled wood pulp or bamboo cellulose and it is processed by a combination of many chemicals. Carbon disulphide is one of those chemicals which can cause nausea, headache, vomiting, chest and muscle pain, and insomnia. Viscose rayon, a soft fiber, is commonly used in dresses, linings, shirts, shorts, coats, jackets, and other outerwear. It is also used in industrial yarns (tyre cord), upholstery, carpets, and in the casting of cellophane [5]. During drying and curing, cross-linking takes place with the hydroxyl groups of cellulose and HCHO is released by thermal or hydrolytic cleavage. While some free formaldehyde is eliminated with the exhaust gas during drying and curing, some of them react with the hydroxyl groups of cellulose and the rest contains on the fabric [6].

The Environmental Protection Agency has categorized formaldehyde as a "probable human carcinogen". Based on data from studies in people and from lab research, National Cancer Institute researchers found that exposure to formaldehyde might cause leukemia, particularly myeloid leukemia, in humans. Animal studies have found

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that inhalation of formaldehyde can cause irritation and damage to the nose and throat lining. High concentrations can also affect the lung. According to the ATSDR, formaldehyde acts as a respiratory irritant and causes chest pain, shortness of breath, coughing, and nose and throat irritation. It is also liable for cancer, and has been linked to an increased risk of asthma and allergies in kids [7].

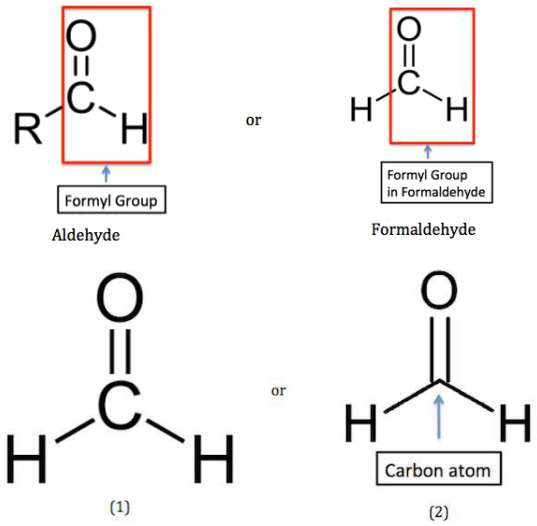



**Fig.1** Chemical Structure of Formaldehyde

Modifying a material surface by imparting different physical, chemical or biological properties from the original one is known as surface modification. The modification can be done by different methods in order to change characteristics of its surface, such as roughness, surface energy, surface charge, biocompatibility, hydrophilicity, reactivity and so on [8].

The objective of this study is to find out the adverse effect of polyester and viscose fabric and the harmful chemicals contained into those fabrics. To identify the way of reducing the activity of this chemical by fabric surface modification is the main focus of the study. Besides, investigating whether this surface modification could enhance other properties is another outcome of this research. Many materials and methods can be used for surface modification but in this research Polyurethane is used for surface modification.

One of the most important types of amino plastic resins is Urea-formaldehyde (UF) resin which is based on the manifold reaction of urea and formaldehyde monomers. Polyurethane Elastomers (PUs) are widely used in many fields due to their unique property. It can combine high damping together with high strength, and high toughness. Thermodynamically incompatible hard and soft segments constitute PU in which the soft-segments mainly control the toughness and low-temperature properties of PUs. In contrast the hard-segments particularly provide high modulus, hardness, and tear of the elastomer. Though polyurethane is flexible but it is chemically and mechanically durable and resilient. These properties are very desirable for a polymer for medical uses such as catheters, vascular grafts, surgical drapes, ligament and tendon prostheses. UF is generally prepared based on the reaction of formaldehyde with the active hydrogen atom in primary amine of urea. The plenty of secondary amines present on the chains of PU accelerate the addition and condensation reactions between formaldehyde and PU. Hence good toughening effect would be achieved by chemically introducing the soft segments onto UF molecular chains. [9][13][14][15].

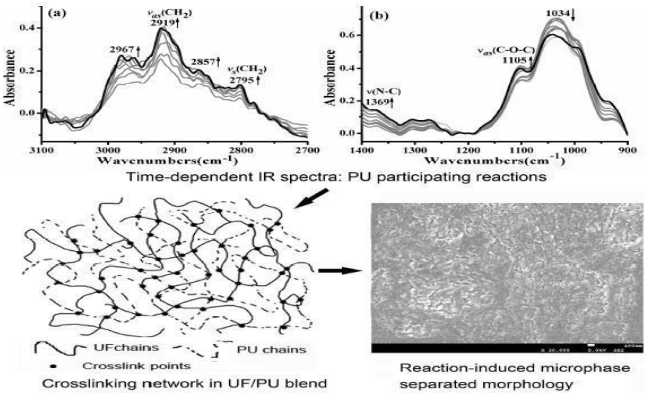



**Fig.2** Reaction between Urea Formaldehyde and Polyurethane

## 2. Materials and methods

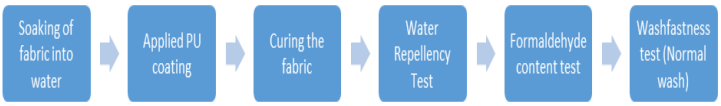



**Fig.3** Flow chart of total working process

2.1 Coating method

Materials

Polyester and viscose fabric, Polyurethane solution, and Distill water.

Apparatus

Scissors, Pipette, Beaker, Manual paddler, Glass rod, Electric balance, Oven, Stirrer with heat

Procedure

Coating is a process in which a polymeric layer is applied directly to one or both surfaces of the fabric. The polymer coating should make crosslink to the textile and a aperture similar to blade curbs the thickness of the viscous compound. The coated fabric sample is heated and the polymer is then cured. Depending upon the end-use requirements, successive coating layers, layer on layer could be applied on the fabric surface to get thick coating.

Heavy-duty technical textile coatings may be applied at high weight, whereas high-technology apparel requires terribly low coating weight. Direct coated products are manufactured by coating a liquid PU solution directly onto the polyester and viscose base cloth. Then paddling is done to uniform the coating by hand paddler [10][16].

Soaking of fabric

Preparation for PU coating (direct coating)

After single layer coating

Curing of the fabric in oven

**Fig.4** Coating process

2.2 Water repellency test

Water repellency is represented by the non-spreading of water globules on a textile material. Unlike water-repellent finish, water proof finish which is normally impervious to air, is done by treating the fabric with fat, wax, rubber etc in form of physical film or coating.

Standard: AATCC 22, Brand name: GESTER

Apparatus: Water repellency tester, Distill Water, Polyester and Viscose fabric Sample

Atmosphere: Temperature 25$^{o}$C and relative humidity 67%

**Fig.5** Spray rating test

Working Procedure

At first an embroidery hoop is taken to mount the sample and then it is stucked on the instrument at 45$^{o}$. After that the beaker is filled with 250 cc water that is poured on the funnel and showered through the spray nozzle on the fabric. The sample holder is detached after finishing the spray and then by tapping the frame 6 times against a solid object, with the face of the sample facing the solid object, surplus water is eliminated. Finally, the water repellency is then evaluated by standard spray ratings.

**Table 1** AATCC spray rating standard [11]

| | Rating | Description |
|---|---|---|
| 1 | 100 | No sticking or wetting of the upper surface |
| 2 | 90 | Slight random sticking or wetting of the upper |
| 3 | 80 | Wetting of upper surface at spray points. |
| 4 | 70 | Partial wetting of whole of upper surface. |
| 5 | 60 | Whole upper surface wets completely. |
| 6 | 50 | Whole upper and lower surfaces wets completely. |

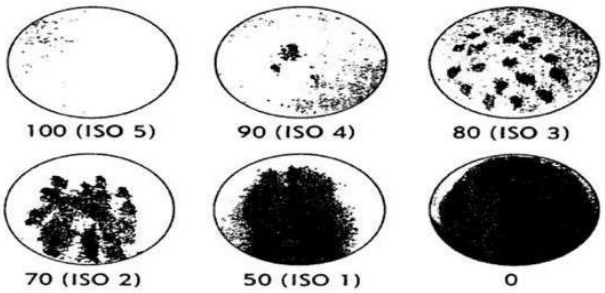



**Fig.6** Standard Spray test ratings

2.3 Formaldehyde Test

In this test, Sealed Jar Method is used that allows accelerated storage conditions and an analytical means to determine the amount of formaldehyde released. An incubator, water bath, and sealed jar have been used. [12]

Materials

Ammonium acetate, Acetyl- Acetone, Acetic acid, and Distilled water

Standard: AATCC 112, Brand name: GESTER

Reagent

For analysis reagent is prepared by dissolving 15 g ammonium acetate, 0.3 ml acetic acid and 0.2 ml acetyl acetone in 100 ml of water.

Sample preparation

Initially the textile samples are cut into 3X3 mm pieces by using scissors. Then for analysis 5g sample is placed together with exactly 100 ml water in a 200 ml Erlenmeyer flask with ground glass stoppers. After that it is heated for 1 hour at 40$^{o}$C in a water bath and shook occasionally. Then it is allowed to cool to 20-25$^{o}$C and solid particles are filtered off with a folded filter.

Analysis

50ml of the extraction solution is mixed with 40 ml reagent in a 100 ml Erlenmeyer flask. Then the flask is closed off and heated for 10 minutes at 60$^{0}$C in a water bath. It is then made up to the mark with water for analysis after allowing it to cool to 20-25$^{0}$C. Finally it is mixed and measured at 405nm against water.

Preparation for formaldehyde Test (Stirring of coated fabric)

Insert tube of sample for formaldehyde test

**Fig.7** Formaldehyde Release (AATCC Test Procedure 112) Test

2.4 Wash fastness test

Materials

Detergent 1g/l, M: L =1:20

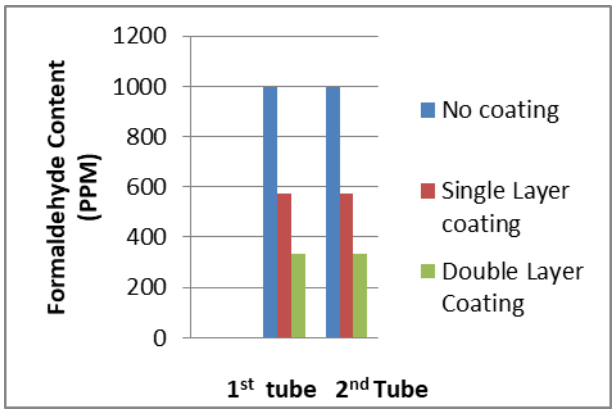
Standard: CO1 test method

Procedure

Fabric is taken into pot with detergent and run 10 min at 40$^{0}$c. Then wash the fabric with cold water and make comparison between before wash and after wash fabric.

**3. Results and Discussions**

Formaldehyde and water repellency tests were mainly performed for this project work. The numerical values of formaldehyde content and water repellency in percentage for different layer of PU coating are shown below graphically for polyester and viscose fabric respectively.

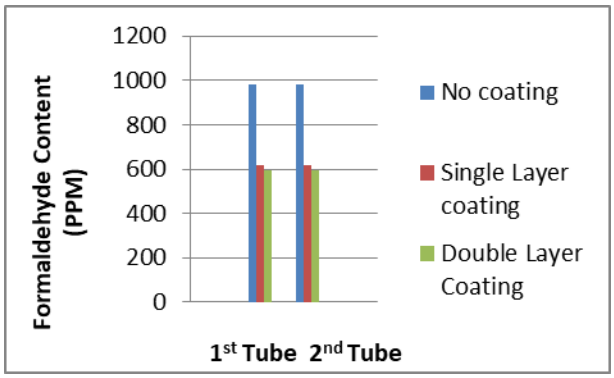



**For Polyester Fabric**

**Fig.8** Impact of PU coating on formaldehyde content of polyester fabric

Fig.8 illustrates that formaldehyde content is reduced with increase of coating layer on polyester fabric. Several chemical reactions take place between the secondary amines present in PU and

HCHO present in polyester fabric. Consequently, formaldehyde is released from the fabric during drying and curing. Hence, for no coating, the formaldehyde content is the highest amount; for increasing coating layer, formaldehyde content is reduced sequentially




**For Viscose Fabric**

**Fig.9** Impact of PU coating on formaldehyde content of Viscose fabric

Fig.9 depicts that on viscose fabric formaldehyde content is also reduced with increasing coating layer. During drying and curing, cross-linking takes place with the hydroxyl groups of cellulose and HCHO is released by thermal or hydrolytic cleavage. While some free formaldehyde is eliminated with the exhaust gas during drying and curing, some of them react with the hydroxyl groups of cellulose in viscose and the rest contains on the fabric. Therefore, for no coating, the formaldehyde content is the highest amount, but for increasing coating layer, formaldehyde content reduce subsequently.

**Table 2** Amount of formaldehyde in treated and untreated fabric

| **Fabric Type** | **Coating Type** | **Formaldehyde PPM (1st tube)** |
|---|---|---|
| Polyester | No coating | 999 |
| Polyester | Single layer | 574 |
| Polyester | Double layer | 333 |
| Viscose | No coating | 984 |
| Viscose | Single layer | 615 |
| Viscose | Double layer | 597 |

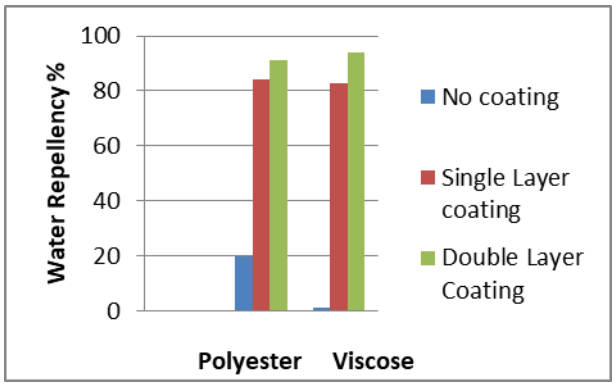
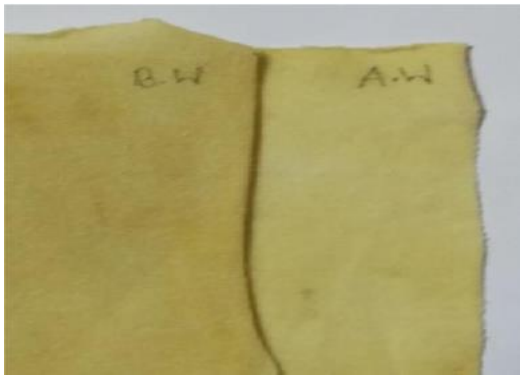



**Fig.10** Impact of PU coating on water repellency of polyester and viscose fabric

Fig.10 illustrates that water repellent property is improved with increase in coating layer on polyester and viscose fabric respectively. When Polyurethane is used in its liquid form, it can be transformed into a permanent waterproof treatment**.** Therefore, for no coating, the water repellency is the least amount, but for single layer, water repellency is more and for double layer water repellency is much more improved.

**Table 3** Water repellency% of treated and untreated fabric

| **Fabric Type** | **Water Repellency %** | **Rating (AATCC)** |
|---|---|---|
| Bleached Polyester | 20 | 0 |
| Single layer coated polyester | 84 | 80 |
| Double layer coated polyester | 91 | 90 |
| Bleached viscose | 1 | 0 |
| Single layer coated viscose | 83 | 80 |
| Double layer coated viscose | 94 | 90 |



Viscose fabric sample before wash (B.W.) & after wash (A.W.)

Polyester fabric sample before wash (B.W.) & after wash (A.W.)

**Fig.11** Wash fastness Test

Wash fastness has been seen visually after hand washing by CO1 test method. Fig.11 represents the wash fastness samples. It has been found from the visual inspection that the wash fastness of PU coated polyester fabric is excellent rather than the wash fastness of PU coated viscose fabric.

## 4. Conclusion

In this research work, attempts were made to reduce formaldehyde, the most harmful carcinogenic chemical, present in polyester and viscose fabric. Polyester and viscose fabrics were coated with polyurethane to reduce formaldehyde in fabric. This coating has also improved the water repellent property of the fabric. Samples of single layer coated, and double layer coated have been prepared and a comparison has been made of their properties that were shown graphically. The results show that with increasing coating layer of polyurethane, the reduction percentage of formaldehyde and the water repellent property were significantly increased. The wash fastness of PU coated fabric of polyester is excellent but wash fastness of PU coated fabric of viscose is poor. This project work has provided a better solution to develop water repellent property in the fabric and to reduce the carcinogenic formaldehyde that could be implemented in water repellent applications such as umbrella, over coat in cold country, outer and inner garments.

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