



Conference Article

Development of a Multi-Use Personal Protective Isolation Suit Suitable for Repeated Washing - Drying Process

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Abstract

Personal protective equipment (PPE) corresponds to any device, tool or material designed to be worn, placed or carried by person for protection against one or more health and safety hazards [1].

Nowadays, when personal protective insulation coveralls are considered, they are widely used in medicine, painting, maintenance, food processing, agriculture, chemistry, mechanical works, automotive, mining, woodworking and insulation works; which are among the sectors and areas where protective overalls are the most used. Researchers continue to work on raw materials, chemicals and fabric, taking the needs and demands into account in these areas. Moreover, the ability of the produced textile material to perform several functions simultaneously instead of a single function is also among the studies that have been carried out. In addition, the ability of the



textile material produced to fulfill a single function instead of a single function is also among the studies carried out. [2] [3].

Within the scope of this study, three-layer laminated fabrics will be produced in order to develop personal protective coveralls. While producing layered structures with the hot-melt lamination production method, breathability as well as high waterproofness is provided. Thanks to the special membrane used in layered structure production, it is aimed to develop a reusable insulation coverall that has higher performance and comfort compared to its disposable insulation coverall counterparts, has less environmental effect, and is more breathable and suitable for reusing.

Keywords: lamination, membrane, washable insulation coverall, sustainability, functional textiles

1. Introduction

Protective textile materials are defined as clothing used primarily for their protective performance or functional properties rather than for aesthetic or decorative purposes. [4].

According to the U.S. Occupational Safety and Health Administration (OSHA), Personal Protective Equipment (PPE) is "equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses."

Hazards take different forms in each working environment; workers may encounter sharp edges, falling objects, flying sparks, chemicals, noise and countless other potentially hazardous situations.

In situations that engineering, work practices and administrative controls are not feasible or do not provide adequate protection, employers should provide their employees with personal protective equipment and ensure its use. Examples of personal protective equipment include items such as gloves, foot and eye protection, protective hearing aids (earplugs, muffs), hard hats, respirators, as well as full body suits and body suits. The main purpose of personal protective textiles is to provide a safe and comfortable microclimate environment around the skin while protecting the human body against external hazards such as chemical, thermal, mechanical, biological and radiation [5].

Isolation suits are preferred as protective clothing, and as they are disposable, they cause a significant environmental problem in terms of carbon footprint and sustainability. The majority of these products made of plastics have a rapidly increasing use today for various reasons (epidemics, infectious diseases, etc.). Therefore, it causes additional waste generation, a major threat to the environment along with other wastes [6] [7]. The use of disposable PPE is not environmentally sustainable [8]. Coveralls suitable for repeated use offer a more sustainable alternative with their resistance to multiple uses.



These garments are designed to be subject to appropriate cleaning and disinfection with each use. Coveralls suitable for repeated washing help minimize resource consumption and waste generation by reducing the need for constant replacement. This means less waste, lower energy consumption, reduced greenhouse gas emissions and less water use throughout their lifecycle.

In this project, reusable, multi-layered, breathable, chemical-resistant fabric to produce insulation coveralls have been developed using lamination technology. Compared to disposable isolation coveralls, long-lasting, washable textile structures suitable for repeated use have been developed.

2. Materials and Methods

In this study, a layered fabric structure in the form of "fabric-membrane-fabric" was obtained by laminating the fabric structure used in the production of washable insulation coveralls. The fabric quality was subjected to tests and analyzes to improve the production and finishing processes and optimum values were tried to be obtained.

2.1 Materials and Production

In the hot-melt lamination process; the adhesive melts under the influence of heat, is transferred to a textile surface with the help of dot-shaped gravure cylinders. With this method, different layers are brought together and combined. In this way, more breathable fabrics are produced. The viscosity and temperature of the adhesive are important and effective parameters. Hot-melt lamination technique was used for the production of breathable insulation coveralls. After the lamination process, the multilayer textile material was allowed to cure in a fixed position at 20°C for 4 days to complete the lamination adhesion.

Material;

Reactive Polyurethane adhesive was used in the production of the PES + Membrane + PES three-layer structure.

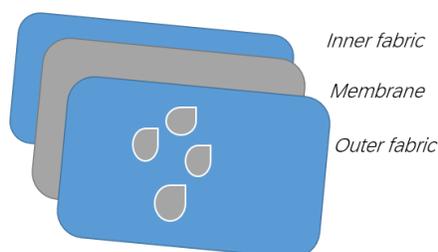


Figure 1: Three layered textile structure



2.2. Isolation Coverall Requirements

Tests and analyzes that will determine the comfort and performance properties of multi-layered textile structure is listed in Table 1 below. Clothing comfort parameters, physical and mechanical properties of the fabric and protection tests have been determined as insulation overall requirements.

Table 1. Tests and methods

<u>Test Name</u>	<u>Method</u>
Determination of mass per unit length and mass per unit area	TS 251:1991
Thickness	ASTM D1777-96:2019
Determination of resistance to water penetration – hydrostatic pressure test	ISO 811:2018
Determination of resistance to surface wetting (spray test)	TS EN ISO 4920:2013
Pneumatic method for determination of bursting strength and bursting distension	ISO 13938-2:2019
Determination of maximum force and elongation at maximum force using the strip method	ISO 13934-1:2013
Nonwovens - Test methods - Part 4: Determination of tear resistance by the trapezoid procedure	EN ISO 9073-4:2021
Determination of the abrasion resistance of fabrics by the Martindale method - Part 2: Determination of specimen breakdown	ISO 12947-2:2016
Seam tensile properties of fabrics and made-up textile articles Part 2: Determination of maximum force to seam rupture using the grab method	ISO 13935-2:2014
Domestic washing and drying procedures for textile testing	TS EN ISO 6330:2022
Protective clothing – Protection against chemicals – Determination of resistance of protective clothing materials to permeation by liquids and gases	BS EN 14325:2018 ISO 6529:2013 - Method A



Protective clothing - Protection against liquid chemicals - Test method for resistance of materials to penetration by liquids	BS EN 14325:2018 EN ISO 6530:2005
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Comfort and performance tests, listed in Table 1, were applied to the insulation overalls fabric quality before and after the washing process, which will determine its protective properties. Washing and drying processes were carried out for 50 cycles and it was proven by comparing with the test results that the protective performance of the overalls fabric maintained up to 50 washings.

Washing and drying processes were carried out in accordance with the process requirements of the "ISO 6330 - Home washing and drying processes for textile experiments" standard. The drying process was completed in a drum dryer by washing in the "4G - 40 °C delicate" program, which is one of the washing programs specified in the standard. Washed with "Type III- 100% Polyester" ballast fabric and reference detergent 1 without optical brightener with a washing capacity of 2 kg. Drying processes were carried out with a drum dryer. After 50 cycles of washing with these parameters, all tests applied to the initial state of the fabric were repeated and the data obtained was compared.

3. Results

The results of the tests and analyzes applied to the multilayered textile material before washing and after 50 washings are shown in Table 2. After the 50 cycle washing processes, no appearance change was observed on the surface of the fabrics depending on the lamination adhesion properties.

Table 2. Test results of fabrics

<i>Test Name</i>	<i>Standard</i>	<i>Before Washing</i>	<i>After 50 cycle Washing processes</i>
Mass per unit area (g/m ²)	TS 251:1991	150,0	150,0
Thickness (mm)	ASTM D1777-96:2019	0,50	0,50
Resistance to water penetration (mmH ₂ O)	ISO 811:2018	>15.000	>15.000
Water penetration (Grade)	TS EN ISO 4920:2013	ISO 5	ISO 3



Bursting strength (kPa)	ISO 13938-2:2019	650,0	642,1
Tensile strength (N)	ISO 13934-1:2013	Warp: 482,97 Weft: 310,48	Warp: 457,10 Weft: 255,57
Tear strength (N)	EN ISO 9073-4:2021	Warp: 105,96 Weft: 98,82	Warp: 84,39 Weft: 93,82
Resistance to abrasion (Cycle)	ISO 12947-2:2016	>30.000	>30.000
Seam strength (N)	ISO 13935-2:2014	Warp: 287,75 Weft: 324,69	Warp: 274,135 Weft: 246,715
Resistance to Liquid Penetration (%)	BS EN 14325:2018 EN ISO 6529:2013–Metod A	>90 Class 3	-
Resistance to Penetration of Chemicals (Min)	BS EN 14325:2018 EN ISO 6530:2005	≥480 Class 6	-

When the results of the comfort and performance tests were examined, it was seen that there was no change in the sample weight and thickness before washing and after 50 washing processes. It was determined by the high pressure water column values obtained that the membrane used in the interlayer layer of the layered sample does not allow liquid permeation. It was seen with the pressure value obtained that this feature continued unaffected by washing processes. Water repellency and whether the liquid contacted with the outer fabric surface of the sample was evaluated by visual evaluations. Within the scope of the specified water repellency test standard content, it is stated that the ISO 5 liquid does not form any wetness on the surface after the application of the image evaluation grades and is exactly the same as the dry state before the test. While the prepared insulation overall quality fabric appeared completely dry after the test before washing, it was observed that after 50 washing processes, it did not completely lose its repellency effect and droplet-shaped wetness was obtained on the surface. In terms of explosion resistance, it was observed that the explosion resistance of the sample exceeded the measurement capacity of the device and was higher than 750.00 kPa, and no explosion occurred in the samples. In the tensile strength measurements carried out with the strip method, high tensile strength values were obtained and it was observed that the washing process had a low effect on strength loss. It has been observed that the strength values of



the sample against tearing are higher compared to the trapezoidal tearing method chosen in accordance with the test methods of laminated structures, and it has been proven that the washing effect causes low losses in resistance to tearing. In the abrasion resistance tests performed on the Martindale device, no appearance changes or thread breaks were observed in the sample even after 30,000 cycles. It has been observed that the seam strength test results, which enable the control of garment ready-made processes, are very similar to the results obtained in fabric breaking and tearing tests, and that high strength values are obtained and washing causes a low level of strength loss.

Table 3. Comparison of comfort features with commercial product

	<i>Protective Isolation Coverall</i>	<i>Commercial Product Code 1</i>	<i>Commercial Product Code 2</i>
<i>Structure Features</i>	3 Layers Laminated Knitting Fabric + Membrane + Knitting Fabric	2 Layers Laminated Nonwoven + Nonwoven	2 Layers Laminated Nonwoven + Membrane
<i>Weight (g/m²)</i>	150	47	67
<i>Water Repellency (Grade)</i>	ISO 5	ISO 2	ISO 5
<i>Waterproof – Hydrostatic (mmH₂O)</i>	>10.000	200	2500
<i>Water Vapor Resistance (RET)(m²Pa/W)</i>	16,75	2,57	21,22

Comparison of the waterproof performances of the commercial product Code1 and the three-layer fabric developed within the scope of this study is given in Table 3. In this comparison, it was seen that the commercial product code1 fabric was not resistant to water and any liquid chemicals under pressure. In this comparison, Code1 fabric is unsuccessful in terms of personal protection. When the commercial product Code2 disposable product and three-layer laminated protective textile fabric are compared; the fabric developed within the scope of the study is approximately 30% better than the two-layer commercial product in terms of comfort parameters. It is possible to say this by interpreting the resistance to water vapor resistance. The 3-layer protective isolation overalls developed within the scope of the study are notable for being more breathable, more protective, and more sustainable with their suitability for reuse, and they serve as an example for new studies.

4. Discussion



The mechanical performances of laminated fabric structures were evaluated before and after the washing-drying process. While no change in bursting strength and abrasion resistance is observed after 50 washing and drying processes, performance losses in tearing, rupture and seam strength are observed. It has been concluded that washing processes cause fiber deformation as a result of detergent and mechanical movements and therefore there are losses in mechanical properties in laminated fabric structures. A decrease in water repellency performance is observed after 50 repeated washing and drying processes. It is thought that the reason for the decrease in water repellency performance is the removal of the water repellent chemical applied to the fabric by the washing effect, as well as the increase in fibrillation on the fabric surface.

Since there was no obvious loss in the physical and mechanical properties of the layered structure after 50 washing and drying processes, resistance tests against chemical penetration were evaluated before washing. It is thought that there is no membrane damage after repeated washing and drying.

As seen in the comparison results, more comfortable and high-performance products can be obtained with laminated fabric structures compared to the commercial disposable products available on the market.

5. Thanks

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