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KNOWLEDGE-INTENSIVE TECHNOLOGIES TO IMPROVE THE PERFORMANCE OF TEXTILE MATERIALS IN OUTERWEAR

УЛУЧШЕНИЕ ЭФФЕКТИВНОСТИ ТЕКСТИЛЬНЫХ МАТЕРИАЛОВ В ВЕРХНЕЙ ОДЕЖДЕ С ИСПОЛЬЗОВАНИЕМ НАУКОЕМКИХ ТЕХНОЛОГИЙ

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В статье описаны высокие технологии, применяемые для оптимизации эксплуатационных и гигиенических свойств текстильных материалов при использовании их в верхней одежде. В связи с широким внедрением в текстильное производство волокон, полученных при помощи наукоемких технологий, все большую актуальность приобретает оптимизация эксплуатационных свойств текстильных материалов. Существует острая необходимость в применении этих волокон, которые принято называть химическими волокнами нового поколения, поскольку они обладают свойствами, которые можно оптимизировать для текстильных материалов.

High-tech technologies to optimize operational and hygienic properties of textile materials for applications in outerwear are described. Due to the widespread introduction of fibres from knowledge-intensive technologies into textile production, the optimization of operational properties of textile materials is becoming increasingly important. There is an urgent need for the application of these fibres, which are usually called chemical fibres of the new generation, because they have properties that can be optimised for textile materials.

Ключевые слова: наукоемкая технология, химические волокна, текстильные материалы, верхняя одежда, эксплуатационные свойства, износостойкость.

Keywords: knowledge-intensive technology, chemical fibres, textile materials, outerwear, performance properties, wear resistance.

1. Introduction

The rapid development of scientific and technological progress at the end of the twentieth century created new demands for textile materials, such as specific properties required in particular fields of human activity and the ability to change the direction required by consumers under the influence of environmental factors, i.e., to be able to produce a response.

Research of textile material performance used in outerwear and knowledge of the operating conditions are necessary for correct and efficient customer service. The latter is based on performance properties. Detailed research of performance capabilities and quality of textile materials used in outerwear enables consumers to practice informed purchasing and influences the production process to improve product quality and expand the range of products.

Most textile materials used in outerwear exhibit different effects during their wear, namely, a change in their physical and mechanical properties.

To obtain materials with fundamentally new properties, manufacturers are using knowledge-intensive and high-tech technologies (Hi-tech), which has led to the development of so-called smart textiles (Smart textile, Intelligent).

Textile fibres based on advances in knowledge-intensive technologies have unique performance characteristics such as increased strength, elasticity, modularity, and heat and abrasion resistance. Therefore, research into these issues is an urgent need.

An analysis of scientific publications from the last five years identified the following most current areas of textile product development:

- development of new textile materials through recycling previously used materials [1...3];
- development of new textile materials through 3D printing [4], [5];
- combining textile manufacturing methods with electronic devices to create electronic textiles [6], [7];
- developing environmentally friendly biodegradable textile materials.

Thus, the development of textile materials that incorporate the most recent research findings will enhance their performance. The abundance of scholarly publications in the subject of textiles demonstrates the importance of this research. By strategically utilizing innovative technologies it will become feasible to produce clothes with defined performance attributes.

This work investigated the possibility of applying knowledge-intensive technologies to optimise performance properties of textile materials used in outerwear.

To accomplish this goal, tasks were assigned as follows: substantiate the feasibility of introducing advances in knowledge-intensive technology to improve and optimize performance properties of textile materials used in outerwear in areas prone to abrasion and wear and to investigate beneficial effects on the human body of eco-fabrics and yarns derived from algae.

2 Research

Fabrics are subject to damaging effects of abrasion during use, which causes these fabrics to gradually wear out. Consequently, the abrasion resistance index of fabrics is one of the most important performance properties of fabrics and depends on aspects such as the nature of fibres, yarn structure, fabrics, their finishing and operating conditions, and the size and nature of their supporting surface.

Wear and tear occur in one or more areas with the highest concentration of operational stress, which makes clothes unsuitable for further wear. Therefore, determining the location of the most worn parts in clothes can help to promote the rational design of clothes using textile materials with an improved consumer perception of value. As a result of research using a sociological method into the wear pattern of new generation textile materials, it was determined that most respondents have several spring coats and jackets in their wardrobes made of film-coated cloaks with a polymer product content ranging from a minimum of 2-3% to a maximum of 50-60%.

Dry cleaning cloaks should be avoided due to their polyester coating on the front. Cloaks with a film coating are also not suitable for ironing. In fact, the process of ironing can lead to scorching and holes in the areas of the greatest abrasion. In addition, they have different properties based on how long they are used and stored.

During use, whitish cracks and stains can occur in film-coated products and a loss of gloss and elasticity that reduces durability. These defects can be exacerbated during care of the product.

The following is an example of the most frequently used outerwear when the seasons change: a woman's half coat, a woman's skirt suit, and a woman's trouser suit in wool. The fraying process is the main cause of wear and tear of a women's skirt suits and trouser suits, overcoats, and dungarees. The location of wear and tear on a woman's suit with skirt and trouser suit and overcoat was investigated at the dry-cleaning collection points.

Using an organoleptic method, 150 items were inspected as they arrived and the majority indicated a strong degree of wear and tear on women's skirts, trousers, and parts of half coats made from worsted, woollen, and half wool fabrics, i.e., wool fibre-based fabrics. Women's trousers with an estimated service life of a few months to two years were worn at the hemline, pockets, knee joint, in the area where fittings and trimmings were fastened, and in the step seams. More than half of the skirts with an estimated wear time of 2 months to 3 years had fractures in the seat, fastening of cuts, and fastening of fittings. Half-coats with waistbands suffered damage in the area where the waistband contacted the strap buckle. However, the intensity in these areas was low and wear and tear occurred after extended periods of wear. When examining women's overcoats and other outerwear assortments, wear was evident at the bottom of the sleeve fold, patch pockets, and lapels and at the crease of the coat flange. The approximate wear life of women's jackets and overcoats is shown in Table 1(the wear and tear of women's jackets and overcoats).

These studies suggest that the specificity of wear to total destruction of the textile material varies. In this case, when 40% of the clothing is destroyed, the warp is damaged, the weft is destroyed, and the same amount is also destroyed in the double yarns stated above. There is wear to the outside of the hem in the hemline sleeves of half-coats. In some women's trouser suits, the weft along the warp (both at the front and at the back of the hemline) wears away because the fabric rubs against fabric in the underfold direction.

Table 1

Maximum wear (use) period, in months	Number of items worn out	
	Halfcoat	Jackets
2	-	-
3	-	1
6	-	9
12	1	29
24	1	21
36	2	8
36	2	8

It is also important to note increased abrasion intensity in the front of trousers, skirts, and overcoats due to women's handbags, which create additional conditions for rapid wear on contact points of clothes during the initial wear period.

One exception is outerwear made from new generation fibres. In these garments, frequent alternating or simultaneous exposure to abrasion and hand-stretching forces create wear prerequisites at the entrance and bottom of the side pockets. Main threads in the fabric structure play an important role in structuring the surface. Thus, the surface of the textile material is subjected to abrasion forces. Central to the wear process is the direction of abrasion forces, which occur in both longitudinal and transversal directions related to the core threads of the fabric and mainly from the inside.

Women's trouser suits, specifically side pockets, are often subject to wear at the bottom and failure is caused by a combination of abrasion and stretching forces. Friction forces in trouser suits at the entrance to the side pockets are directed transversely and along warp threads. This can cause the material to break down over time and even cause holes in the warp and weft yarns. In halfcoats, a loss of lustre on the face covering at lapels and collar folds is observed when the wearing period is more than one month. As a result of women's halfcoat, suit, and trouser suit examinations, a loss of lustre on the face covering occurs in edge areas of the collar, collar details, and the middle of the area below the middle of the coat and skirt. There are also irrecoverable creases from the first two weeks of wear on the outer surfaces of sleeves.

Thus, during exploitation of a woman's jacket, wear occurred in the direction of tucking and draping that lifted part of the clothing at the bottom of the shoulder joint and strengthening occurred by ironing the side and collar parts. In women's trouser suits, the bottom side pockets are the most susceptible to wear after long periods of use where both thread systems deteriorate.

Disccussion

It is historically important that the production of nanoparticle-filled fibres originated at the end of the twentieth century. Fibres developed at this time are wear-resistant, have minimal shrinkage, are low-combustible, are sufficiently tear- and abrasion-resistant, and have somewhat different and more improved performance properties required by the consumer (depending on which nanoparticles are used and how they are made).

The expediency of introducing textile fibres and materials based on the achievements of knowledge-intensive technologies is explained by the performance of materials that are similarly produced from natural sources of raw materials which are governed by linear density, type of finishing, and the quality of the initial raw materials. It is possible to obtain similar materials with improved performance properties using a minimum number of raw materials when applying the achievements of nano- and bio-technology.

The design of fabrics with improved performance properties in outerwear requires systematic research on the structure of textile materials. Due to the application possibilities of knowledge-intensive technologies in improving the performance properties of textile materials, there has been an increase in their assortment and production. Consequently, there has been a combination of enlargement and novelty in the types of clothing produced. These factors are determined cardinally and are difference from previous requirements such as an increase in the wear period, detailed and in-depth diagnostics of operational properties of outerwear to improve wear resistance, environmental friendliness, and ergonomics that are important components to ensure consumer safety. It is worth noting that chemical fibres are employed as raw materials alongside natural fibres to improve the performance capabilities of textile materials, both to conserve resources and to improve the strength properties of outerwear garments. Among these advances are new chemical fibres such as blacquat and elastane, which have increased performance properties and resistance to UV radiation as well as antimicrobial and antibacterial properties. Therefore, new generation textile fibres have been developed based on chemical fibres that are of special interest and popularity for increasing the performance properties of textile materials for the manufacture of outerwear.

New production technologies can be distinguished during production, for instance, by spinning gelled high-molecular polyethylene with fibre allowing it to stretch up to 30 times. This method is used to manufacture Dyneema SK60 fibres that have a high abrasion resistance, chemical resistance, and are lightweight. With a tenfold strength of steel and a melting point of 145-155 °C, these fibres are employed in flotilla crew apparel. Recently, materials with a unique structure have been developed through a technology that involves spinning from a liquid crystal solution. When crystallised, the polymer molecules in this liquid crystal solution produce a strong material. Spinning from "liquid crystal" is used to create Kevlar, a material with unique physical qualities that makes it ideal for manufacturing special purpose apparel. Mountaineering pants and anorak jackets are made by combining this material with wool or cotton fibres. The development of Fabrican is another revolutionary conceptual collaboration between Imperial College London and Spanish designer M. Torres. Fabrican is a material consisting of cotton fibres and polymers in a liquid state that is applied as an aerosol to the body and instantly cured.

According to many designers, 'liquid clothing' (by expanding the horizons of contemporary fashion with the possibility of creating conceptually distinctive artwork) will make it possible to manufacture a unique approach for both individual costume parts and costume ensembles. As previously mentioned, outerwear must be made of wearable textile materials.

Basic requirements for knitted fabrics used in outerwear include good abrasion resistance, shrinkage not exceeding 5 %, and high elasticity and dyeing resistance. Thus, new knitted fabrics with both knitting properties and widely used fabrics for outerwear are produced. Therefore, it is prudent to use new generation textile fibres, such as "high-tech" (high-tech with unique properties) and lyocell fibres, which are functionally active textiles based on nano- and bio-technology, and multifunctional knitted fabrics with antimicrobial protection and enhanced consumer properties. This occurs by incorporating advanced polymers into outer clothing to increase wear resistance and protection against harmful environmental factors.

Synthetic fibres filled with metal oxide nanoparticles (TiO_2, AlO_{23}, ZnO, and MgO) are being intensively researched and produced based on which fibres acquire important characteristics such as antimicrobial, dirt-repellence, and light-weather resistance. Based on fibres from knowledge-intensive technologies, such as nanotechnology and bionics for sewing garments, the diagnosis of performance properties of textile materials is gaining unprecedented momentum. Currently, breakthroughs in biotechnology (bionics) are being applied to the manufacturing and modification of fibres. The goal is to develop ways for creating chemical fibres with somewhat different qualities compared to natural fibres to fulfil current consumer wants and requirements. This is to recreate the present technology in a variety of natural things such as spider web weaving with greater strength, elasticity, and protein content. Spiders have protein synthesis genes and these genes are being grafted onto the cells of fungi; microscopic mould fungi can also weave fibres capable of synthesizing enzymes that break down cellulose by proliferating on cotton waste. Thus, cotton waste could become one of the primary textile materials for the production of fabric via biotechnology. Through biotechnology methods, organic waste, agricultural products, and raw materials of animal origin can now become new sources of eco-fibre and yarn-based fabrics for manufacture. For instance, research has enabled the development of fibres from maize and soya, which is termed soybean protein fibre and SPF, and this provides a novel method of crop utilization. These fibres are produced with the utmost ecological purity, which has the added benefit of being biodegradable. NatureWorks PLA polymer, which is made from free plant carbon, is used to produce Ingeofibre. Ingeofibre is a biodegradable material that has a rapid degradation rate, whereas with oil-based materials this process would take many decades. In the future, sugar beet and rice will be used as raw materials for this fibre. There has also been a positive trend in the livestock industry. Presently, Japanese scientists are attempting to use New Zealand milk as a raw material to produce milk fibre. In 2003, a polymer made from maize grains, named Sorona Farina, was produced. Corn is used to produce maize yarn, which is not entirely a natural fabric as it is partly synthetic, but it is biodegradable and has many advantages such as increased resistance to light weathering that reduces durability. It is also comfortable to wear and hygroscopic and hypoallergenic. Moreover, it is simple to clean and rapidly dries.

Currently, Chinese ramie nettle is used for the production of expensive textiles to make delicate fabrics that are as soft and delicate as natural silk. However, it is often used in combination with cotton or woollenfibres to produce fabrics that are hard-wearing, durable, and dense. Icelandic algae are another modern raw material for producing eco fabrics, the value of which is given by their unique characteristics due to amino acids, minerals, microelements, useful fats, and vitamins contained in the algae. Icelandic algae have a positive effect on human skin and a restorative effect by activating metabolism at the cellular level and improving blood circulation and cell regeneration. Moreover, it has antibacterial and antimicrobial properties because of silver enrichment and they are resistant to repeat washing. Fibres from crab shells are made from chitin-rich extracts from which chitin viscose is produced by a special technology that is distinguished by its durability, hypoallergenicity, and antibacterial and medicinal properties. In fact, fibres from crab shells retard ageing, activate cells, and strengthen the immune system. Soy fibre is one of the exciting new raw materials for nextgeneration fabrics as this natural fibre is extremely environmentally friendly and is produced using biotechnology. This fabric is highly functional (resistance to repeated washing and colour retention), sanitary, antibacterial, has a high hygroscopicity, is entirely biodegradable, and protects against damaging effects of electromagnetic and UV radiation. Bamboo has emerged as a primary fibre material for the textile industry and serves as the raw material for everyday apparel, lightweight sweaters and socks, and coats and jackets with a hint of wool fibre. Bamboo fibre fabrics have exceptional performance characteristics, are very resistant to wear, are durable and crease-resistant, and do not have a substantial negative impact on the environment. The cottonization of linen fibre and the addition of up to 10% linen fibre decreases the fabric's electrifying quality, reduce creases, and promotes ductility.

Thus, the introduction of biotechnology is a feasible way to enhance the performance qualities of textile materials.

CONCLUSIONS

The use of high-tech, economical, environmentally friendly, functionally active textiles and biodegradable chemical fibres is recommended for use in outerwear that aims to improve durability and performance properties. The specific recommended material is lyocell fibres. Through biotechnology, organic waste, agricultural products, and raw materials of animal origin that were irrelevant to the world of fashionable textiles and fabrics have now become new sources of textile materials based on eco-fibres and yarns. The use of such textile fibres results in high-performance, sanitary, and antibacterial fabrics and provides greater electromagnetic safety and high hygroscopic qualities. To boost abrasion resistance at abrasion spots, a combination of fibres is recommended (natural fibres and new generation fibres), which results in increased abrasion resistance of clothes.

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