FORECASTING THE SERVICE LIFE EXTENSION OF SPECIAL-PURPOSE CLOTHING

Rohila Nuriddinova Pazlitdin kizi
Senior Lecturer, Department of Design, Namangan State Technical University
PhD
E-mail:nuriddinova_a93@mail.ru;
Tel: +9989 97 263 83 63

Abstract. This article proposes a methodology for predicting and extending the service life of special-purpose protective clothing by determining the optimal dimensions of soiling zones and protective areas during the design stage of creating constructive-decorative and technological solutions that correspond to real operational conditions. A method has been developed for assessing the degree of soiling of various parts of special clothing based on changes in the physical-mechanical indicators of the garment material under operational conditions. The method determines the soiling degree through optical assessment, considering the change (darkening) in the surface color of the material due to soiling from acids and oil/fat spills. To ensure rational use of protective materials and extend the product's service life, a design approach based on determining the optimal size of the protective element is proposed.

Keywords: operation, constructive-decorative, technological, physical-mechanical, optical, spectrophotometer.

Annotatsiya. Мақолада ҳимоя кийимларини лойиҳалашда реал эксплуатация шароитларига мос равишда кийимнинг конструктив-декоратив, технологик ечимини яратиш босқичида махсус кийимлар ифлосланиш зонаси ва ҳимоя соҳасининг оптимал ўлчамларини аниқлаш орқали махсус кийим хизмат муддатини узайтириш таклиф қилинган.Эксплуатация шароитида буюм материали физик-механик кўрсаткичларининг ўзгариши бўйича махсус кийим турли қисмларининг ифлосланиш даражасини баҳолаш услуби ишлаб чиқилган. Услуб ифлосланишни кислоталардан, ёғ-мойларнинг кийимга тўқилишидан материал юзаси рангининг ўзгаришини (қорайиши)ни назарда тутиб, ифлосланиш даражаси оптик баҳолаш усул ёрдамида аниқланади.Ҳимоя материалларииоқилона ишлатиш ва буюмнинг хизмат муддатини узайтиришучун ҳимоя элементининг оптималўлчамини аниқлаш орқали махсус кийим дизайнини яратиш таклиф қилинган.

Kalit so‘zlar: Эксплуатация, конструктив-декоратив, технологик, физик-механик, оптик, спектрофотометр.

Аннотация. В статье предложена методика прогнозирования и продления срока службы специальной защитной одежды путем определения оптимальных размеров зон загрязнения и защитных зон на этапе

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проектирования конструктивно-декоративных и технологических решений, соответствующих реальным условиям эксплуатации. Разработан метод оценки степени загрязнения различных деталей специальной одежды по изменению физико-механических показателей материала одежды в условиях эксплуатации. Метод предполагает определение степени загрязнения оптическим методом, учитывающим изменение (потемнение) цвета поверхности материала вследствие загрязнения кислотами и разливами масел и жиров. Для рационального использования защитных материалов и продления срока службы изделий предложен проектный подход, основанный на определении оптимальных размеров защитного элемента.

Ключевые слова: эксплуатация, конструктивно-декоративные, технологические, физико-механические, оптические, спектрофотометр.

Introduction

One of the critical factors ensuring the competitiveness of special-purpose clothing is the utilization of highly efficient technologies in developing design documentation for clothing assortments. In several countries, significant achievements have been made in developing automated methods for designing and manufacturing textile products, improving process management methodologies, and enhancing the production technology of specialized protective materials with special impregnations [1].

To date, criteria and methods for the physiological-hygienic assessment of special clothing have been developed, the relationship between material technical parameters and the garment has been established, and fundamental methodological principles for designing special clothing that meet the requirements of specific operational conditions, as well as industrial production technologies, have been formed, with a substantial volume of scientific material accumulated [1]. Despite this, solving the problem of extending the service life of special clothing requires a scientifically grounded approach at the stage of creating the clothing model sketch.

This article proposes a method for extending the service life of a product by determining the optimal dimensions of soiling zones and protective areas of special garments during the design stage of developing constructive-decorative solutions for protective clothing that correspond to real operational conditions [2-4].

Special-purpose clothing for auto repair shop welder-mechanics, which wears out rapidly under labor conditions due to regular spills of acids and oils/fats, was selected as the research object.

LITERATURE REVIEW AND PROBLEM STATEMENT

As an element of human daily attire, special clothing must be comfortable in all aspects. To ensure its competitiveness, it is essential to use high-quality fabrics

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with good air permeability and resistance to soiling. For some formal clothing items, fabrics are impregnated with special substances to impart specific protective properties. An analysis of materials used for producing oil- and acid-protective clothing revealed that the current wide assortment of protective fabrics, while aimed at improving the quality of the designed item, complicates the selection of a specific fabric sample. Furthermore, fabrics with high oil-acid protection properties are expensive, making their practical use in production for enterprises nearly unprofitable, and the addition of extra components significantly increases the garment's overall weight [5-6].

The number of company leaders wishing to provide their staff with unique, market-identifying workwear designs is growing, and clothing designs are proposed considering the customer's preferences. To determine the impact of the artistic-constructive solution on the service life of oil-protective special clothing for auto repair shop welder-mechanics, an analysis of existing analogues was conducted. To identify the predominant parameters of fabrics and special clothing constructive-technological solutions, the wear topography of worn-out special workwear for auto mechanics from the "ToshAvtoServis" service center was studied based on visual inspection results. A wear topography scheme was developed by analyzing photographs of 100 suits (jackets and trousers), classifying zones into highly soiled, moderately soiled, and relatively soiled areas based on the distribution variance of soiling degree on the garment surface. According to the developed scheme, an analysis of the artistic-constructive features of existing analogues was performed – analyzing 43 models from the "Line of Defense" company for 2018-2020 regarding garment cut, silhouette, segmentation, collar shape, fastener type, pocket types, jacket length, details, and other design elements. Analysis results revealed that in special clothing design, straight silhouette garments constituted 80%, semi-fitted silhouette garments 20%; regarding segmentation, mixed horizontal and vertical segmentation was present in 43.3% of garments; regarding cut, 93.3% had a raglan cut; and primarily zippered and buttoned fasteners were predominant. Furthermore, based on a survey, it was found that typical special clothing often does not meet the service life specified in regulatory documents (service life: jacket – 1 year, trousers – 8 months), with jackets actually wearing out in 6 months and trousers in 4 months.

MATERIALS AND METHODS

In the process of developing special clothing design, determining the optimal size of the protective element for cost-effective use of protective materials creates the possibility of predicting the product's service life. We have developed a method for assessing the degree of soiling of different parts of special clothing based on changes in the physical-mechanical indicators of the garment material. This method

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determines the degree of soiling through optical assessment, considering the change (darkening) in the surface color of the material due to soiling from acids and oil/fat spills. As a result of soiling, oil and dirt particles settle on the fabric surface, altering its structure and color, which is visually perceived as darkening or discoloration of the fabric surface. The degree of darkening and the area of darkening can indicate the level of soiling. The material's color affects the visual perception of soiling: the lighter the material, the more clearly the darkening is detected.

$\Delta C = (R - R^*)$ - be the change in the brightness degree of the studied material surface, where R is the brightness of the soiled surface, R^*- is the brightness of the unsoiled surface.

Assuming $C = R$, the relative indicator of soiling can be determined by the following expression:

$$I = (\Delta C/C) * 100\%, \quad 0 \le I \le 100\% \qquad (1)$$

The degree of soiling can be assessed more accurately using instruments.

The degree of soiling is determined by the optical method using a spectrophotometer, for example, using the FO-1 device as a measure of the change in the fabric's reflection capability in different parts of the spectrum, by measuring the reflection coefficients of the material surface in the blue-457 nm, green-520 nm, and red-620 nm spectral regions::

$$\Delta C = \sqrt{((R_b - R_b^*)^2 + (R_g - R_g^*)^2 + (R_r - R_r^*)^2)} \qquad (2)$$

where R_b, R_b^* are the values of reflection coefficients in the blue region of the spectrum for the initial and soiled material,

R_g, R_g^* are the values of reflection coefficients in the green region of the spectrum for the initial and soiled material,

R_r, R_r^* are the values of reflection coefficients in the red region of the spectrum for the initial and soiled material.

The relative soiling indicator can be determined by the following expression:

$$I = (\Delta C/C) * 100\%, \quad 0 \le I \le 100\% \qquad (3)$$

where $C = \sqrt{(R_b^2 + R_g^2 + R_r^2)^2}$.

The value $I = 0$ corresponds to the absence of soiling, $I = 100\%\ $ corresponds to absolute soiling..

In practical application of the method, it is necessary to utilize an integral assessment of soiling and consider the spatial distribution of fabric soiling observed during garment operation. In this case, the soiling degree of certain parts of the garment will be high, while the soiling degree of other parts will be low. It is

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advisable to use an integral indicator for an integral assessment of the garment's soiling degree.

The soiling indicators $\Delta S, I$, at a specific point with coordinates x, y on the materials, correspond to a local assessment of soiling. The values of these indicators measured at each point of a specific garment area allow for creating a general view of the garment's soiling.

The overall degree I_S of the material soiling area S is determined by the following expression:

$$I_S = \sum_{i=0}^{n=1} i * S_i/S \qquad (4)$$

where S_i is the area of fabric with soiling degree i.

Let us denote the permissible soiling degree as I_g, i.e., soiling that is not critical for the use of the material.

Then, the set of numerous points of materials having the value I_g defines the boundary G_g of the soiled area in the image of the corresponding material location.

Let us denote the area of the fabric soiled zone bounded by the G_g contour as S_g, and S_0 as the total area of the studied materials. Then, the total relative soiling of the fabric is determined as follows:

$$I_S = (S_g/S_0) * 100\%, 0 \leq I_S \leq 100\% \qquad (5)$$

Thus, the assessment of the degree of soiling is carried out using optical instruments.

A conclusion about the material's unsuitability for service is made when the soiling area I_S (in percentage) exceeds the predetermined value of the permissible soiling degree I_S^*.

RESULTS AND DISCUSSION

When calculating the optimal sizes of soiling areas and protected parts of special clothing, the parameters of the cost of protective elements and the extension of the service life of the protected special clothing are taken into account. For special clothing for auto repair shop workers dealing with oils, acids, and alkalis, unlike, for example, firefighters' special clothing, it is not advisable to manufacture the entire garment from protective material.

It is proposed to determine the optimal size S_{opt} of the protective element according to the following criterion:

$$S_{opt} = \{S | T_\text{h} = T_0 + t_S\} \qquad (6)$$

where T_h is the service life of the protected clothing, T_0 is the service life of the unprotected clothing, t_S is the increase in service life due to the use of protective clothing elements of size S.

The identification of soiled areas of special clothing and the assessment of the degree of soiling are based on the analysis of photographic images of clothing

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obtained as a result of operation. Requirements for photographic images of soiled special clothing have been developed [1]. Taking into account the labor conditions of workers, the wear topography of special clothing, and parameters from the analysis of existing model analogues, a special clothing model was developed using protective materials, and a prototype was prepared at "Golden Ring" LLC. Photographic images are being collected monthly to analyze and assess the identified soiled areas and the degree of soiling of the proposed clothing sample made from local protective material and the special clothing made from imported protective material used in the enterprise under operational conditions.

The proposed design methodology for protective clothing, based on determining the optimal dimensions of soiling zones and protective areas during the stage of creating constructive-decorative and technological solutions that correspond to real operational conditions, enables the rational use of protective material and creates the possibility of extending the service life of special clothing.

For auto repair shop workers under various operational conditions, the task of developing information and software support for creating products of various designs that allow extending the service life of special clothing through the use of protective materials offers the possibility of increasing the efficiency of preparing design documentation.

The application of the optical soiling assessment method allows for an objective quantitative analysis of wear, moving beyond subjective visual inspection. The formula for calculating the optimal protective element size (S_{opt}) provides a practical tool for designers to balance material cost with projected service life extension, a crucial economic factor for enterprises.

CONCLUSION

In designing protective clothing, determining the optimal dimensions of the soiling zone and protection area of special garments at the stage of creating the constructive-decorative and technological solution of the garment according to real operational conditions contributes to the rational use of protective material and extends the service life of special clothing.

The developed methodology for assessing soiling degree based on optical parameters and the criterion for determining the optimal size of protective elements provide a scientific and practical foundation for forecasting and extending the service life of special-purpose workwear. This approach not only improves the economic efficiency of protective clothing use for enterprises but also addresses the practical need for durable, cost-effective, and well-designed workwear that meets real-world operational demands.

Further research will focus on the longitudinal tracking of the developed prototype's performance compared to standard issue clothing, refining the

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mathematical models based on accumulated operational data, and exploring the integration of this methodology into automated clothing design (CAD) systems.

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