Development of the construction of overalls for oil workers with improved hygienic properties

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Abstract. This article focuses on improving the working conditions of oil and gas industry workers. Safe working conditions of workers working in the open space are largely determined by their provision with their high-quality workwear, which reliably protects from the effects of adverse climatic and production factors. The aim of the study is to develop rational workwear for oil workers in Uzbekistan. To achieve this goal, the following tasks were solved: - analysis of the working conditions of oil workers, existing workwear and the development of scientifically based requirements for the workwear being developed; - research and selection of a rational package of workwear materials. In the oil and gas industry, work is ongoing year-round, but the main work is carried out in a dry, hot climate. The special clothes given out usually to oil industry workers do not correspond to the conditions of their work and cause fair complaints. Therefore, the creation of rational special clothing for oil workers, taking into account the climatic conditions of this zone and the specifics of the oil and gas industry, is an important industrial task facing scientists and workers in the clothing industry.

1. Introduction
The Republic of Uzbekistan, included in the group of countries with a hot climate, located in the so-called “Sun belt” (African, South American, Australian, middle and southern Asian countries), located in the depths of the continents and remote from the seas and oceans, are characterized by a dry, sharply continental climate.

Working conditions in the oil and gas industry are significantly different from industrial conditions. Due to the fact that all the main types of work in the oil and gas industry are performed in the open air, the conditions at the workplace are determined by the climatic conditions of the area. Work in the oil and gas industry is carried out almost all year round - from February to December and weather conditions are very diverse at all types and stages of work.

Changes in the physiological functions of the human body are closely related to the conditions of his work, life and are influenced by environmental factors. Of the whole complex of factors that together constitute the climatic conditions in a particular geographical area, the meteorological indicators such as air temperature, wind speed, humidity and solar radiation have the greatest impact on human sensations. The main factors that cause a person to overheat are air temperature and solar radiation [1].

2. Literature review
In particularly difficult conditions, summer work is underway, when for five months the air temperature rises above 35⁰C, reaching 40 – 45⁰C in the daytime. Due to insolation, the air temperature in this period fluctuates in the workplace within 30 – 40%. In summer, oil workers complain of overheating
(headache, weakness, and fatigue). Objectively, they have an increase in body temperature, sometimes up to 37.5 – 37.8°C, increased heart rate 1 – 2.

Uzbekistan is characterized by high values of total solar radiation. So, the average total solar radiation in this region in May is – 17.7; in June – 19.4; in July – 19.4; in August, 18.1 kcal/m². This is due to the fact that the duration of the sun’s shine on average is 10 hours, reaching in the summer (June) 14 hours a day.

As you know, solar radiation delivers heat both to the human body and to all environmental objects; while a working person receives heat in several ways. He receives the greatest amount of heat directly from direct solar radiation, regardless of the temperature of the surrounding air. This is due to the fact that the heating of the air occurs mainly not by the sun’s rays, but by the heat transfer of the soil, which absorbs and transforms solar radiation. As a result of this, a person receives additional heat due to infrared radiation reflected and emitted by the heated surface of the soil and surrounding objects [2,3].

3. Research methods

3.1. Identification of the most important informative features for designing overalls for oil industry workers using a priori ranking method

The issues of developing a rational design of special clothing for oil workers in Uzbekistan have their own characteristics and require special studies: studying the opinions of oil workers, research and identifying the positive features of work clothing, proven over centuries of experience, etc. In order to identify the most preferred types of clothing used by oil workers in the labor process, a questionnaire survey was conducted. The group of respondents included workers whose activities are related to the issue under consideration [4].

As can be seen from the table 1, the largest percentage of the total number of respondents is occupied by oil workers, who are the main carriers of work clothes.

Table 1. Grouping of experts depending on work experience.

| Employee category | Work experience | Total | % |
|-------------------|-----------------|-------|---|
|                   | Up to 5 years   | 5-10  | 10-15 | 15-20 | 20-25 | From above 25 years old | Man | % |
| Oil workers       | 4               | 16    | 7     | 10    | 8     | 5      | 50 | 50 |
| Welders           | 4               | 12    | –     | 1     | –     | 3      | 20 | 20 |
| Locksmiths        | 10              | 2     | –     | 1     | 2     | 5      | 20 | 20 |
| Executives        | 3               | 2     | –     | 2     | 3     | 10     | 10 | 10 |
| Total             | 21              | 32    | 7     | 14    | 13    | 13     | 100| 100|

After processing a priori information in accordance with the methodology and using the Ranger calculation program on an EC-1033 computer, the sums of ranks for each type of clothing for each season were obtained. The overall average degree of consistency of responses across the totality of characters, taking into account the seasonality of signs, taking into account the seasonality of clothing, was estimated using the concordance coefficient W:

\[ W = \frac{S}{\frac{1}{12}n^2(n^3 - n) - n \sum_{i=1}^{n} t_i} \]

Where S is the sum of the squared deviations.

\[ T_i = \frac{1}{12} \sum_{i=1}^{n} t_i \]

\( t \) – Is the number of related ranks in each row of the matrix.
\( n \) – Is the number of experts in the group.
\( m \) – Is the number of estimated factors.

As a result of a questionnaire survey, it was found that the most commonly used for oil industry workers by the least amount of ranks are: jacket and trousers. The most preferred type of headgear is skullcaps. Obtaining this answer determined the ways for further research: analysis of existing types of workwear, identification of new workwear when developing [5].

3.2. Analysis of existing types of oil industry in Uzbekistan

Safe working conditions for workers in the open space are largely determined by their availability of high-quality workwear, which reliably protects from the effects of adverse climatic conditions.

Currently, oil workers of Uzbekistan, in accordance with the standards and in accordance with the assignment to a certain climatic zone within the country, are given the following types of workwear:

- Men’s suit for protection against the effects of pesticides and mineral fertilizers.
- Semi-overalls.
- Men’s suit for protection against general industrial pollution.

For the dry, hot climate of Uzbekistan, the most appropriate is a suit to protect against general industrial pollution; air exchange under such clothes is more effective, compared with the above types of workwear. However, a number of disadvantages inherent in this suit limit its use during work on cotton fields in the summer heat:

- Work wear materials do not limit the influx of radiation heat from outside to the human body.
- The design of the suit does not provide freedom of movement in the process.
- To improve ventilation and remove moisture from the clothing area in places of the greatest sweating, ventilation openings are not provided.
- Aesthetic appearance does not meet modern requirements (figure 1).

![Overalls for oil workers](image)

Figure 1. Overalls for oil workers.

The analysis of the existing work clothing showed that it was not created at one time specifically for oil workers and naturally does not take into account the climatic features of Uzbekistan and the specifics of production in the oil and gas industry. These costumes are outdated in silhouette, design and appearance, uncomfortable in operation [6,7].
But, in our opinion, when developing new special clothing, it is advisable to use a number of its features, such as a specific cut of the sleeve, a free three-dimensional shape, a rational package of materials that are most justified for the working conditions of oil workers and the climatic conditions of Uzbekistan.

3.3. Improving the workwear design process
When designing special clothing designed for use in a dry hot climate with a significant change in environmental conditions, on the one hand, and with a wide variation in the heat and moisture-physical properties of clothing materials, on the other, significant difficulties arise associated with taking into account the reactions of the human body to change conditions and the need for a long directed experiment on the selection of clothing materials.

As criteria for optimization, we selected single criteria of external $Y_2$ (the range of movements of the hands of a dressed person $P_2$) and internal $Y_1$ (the level of clothing pressure on the human body $P_1$) of dynamic correspondence. Three design parameters were chosen as optimization factors, taking into account the previously performed work and the results of the analysis of existing types of overalls and samples of national clothes: $x_1$ – armhole depth ($V_{pr}$), $x_2$ – increase in free fit to half-circumference of the chest $P_{16}$, $x_3$ – width of the product section, equal to the sum of the widths of the back and armholes ($Sh_{sp}+Sh_{pr}$).

The depth of the armhole ($V_{pr}$) in the existing types of special clothing varies from 24 to 27.2 sm. The depth of the armhole of a household jacket, designed for the conditions of Uzbekistan, is recommended, is 30 sm. The depth of the armhole of national clothing is also 30. To cover the entire limit of variability this parameter varied from 24 to 30 sm.

The recommended values of the increase in free fitting to the half-girth of the chest for summer clothes, according to different authors, range from 7.5 to 15.0 sm. The increase in $P_{16}$ for a summer jacket provided by EMCO CMEA is 12 sm. Based on this, the level of variation for this optimization factor was adopted from 7.5 to 15 sm [8,9].

The length of the structural section, equal to the sum of the widths of the back and armhole ($Sh_{sp}+Sh_{pr}$) in existing types of special clothes, ranges from 36.7 to 39.7 cm. However, studies have shown that products ($Sh_{sp}+Sh_{pr}$) = 41.6 sm provide the best performance dynamic matching. Therefore, the level of variation for this optimization factor was adapted from 36.7 to 41.6 sm.

To determine the optimal design parameters of the work clothes of cotton growers that provide high dynamic matching indicators, the full PFE type 23 experiment was used. The factors varying levels during the implementation of PFE 23 are presented in table 1, the planning matrix is shown in table 2.

### Table 2. The levels of variation of factors in the implementation of PFE 23.

| Factors          | Designation | Levels of variation | Variation Intervals |
|------------------|-------------|---------------------|---------------------|
| Depth of armhole $B_{pr}$ | $x_1$       | 24 27 30            | 3                   |
| The increase $P_{16}$ | $x_2$       | 7.5 11.25 15.0      | 3.75                |
| ($W_s + W_{pr}$)  | $x_3$       | 36.7 29.15 41.6     | 2.45                |

In accordance with the plan of the experiment, jacket designs with different combinations of design parameters were developed. The basis for the design of the summer jacket size 170 – 100 – 88, developed by Tashkent Institute of Textile and Light Industry, with a sleeve built on the armhole of the design according to the method of Bukhara Engineering Technological Institute, was taken as the basis for their development [10].

Dynamic matching studies were performed using the above procedure. The quantitative values of the indicators of external and internal dynamic correspondence were determined by modeling real human activities. As a working movement, the lifting of both hands forward and up was chosen.

The natural values of the optimization criteria $P_1$ (Pa) and $\alpha$ (grad) were determined as the arithmetic mean of the values noted at two control points for three series of parallel experiments.
Table 3. Planning matrix and experiment results.

| Planning matrix | Working matrix | Natural values $f^2$ of optimization parameters | Dynamic Matching Score |
|-----------------|----------------|-----------------------------------------------|------------------------|
| $x_1$ $x_2$ $x_3$ | $x_1$ $x_2$ $x_3$ | $P,(Pa)$ | hail | $K_1$ | $K_2$ | $K_3$ |
| + + + | 30 | 15 | 41.6 | 3084 | 139 | 1.225 | 1.183 | 1.12 |
| + - - | 30 | 7.5 | 36.7 | 9874 | 95 | 0.507 | 0.75 | 0.62 |
| - - - | 24 | 7.5 | 36.7 | 11056 | 84 | 0.450 | 0.716 | 0.57 |
| + + - | 30 | 15 | 36.7 | 4476 | 132 | 1.06 | 1.08 | 1.06 |
| + - + | 30 | 7.5 | 41.6 | 8620 | 95 | 0.575 | 0.833 | 0.68 |
| - + + | 24 | 15 | 41.6 | 7878 | 105 | 0.641 | 0.916 | 0.76 |
| - - + | 24 | 7.5 | 41.6 | 10628 | 83 | 0.493 | 0.666 | 0.56 |
| - + - | 24 | 15 | 36.7 | 9034 | 96 | 0.549 | 0.791 | 0.65 |

An assessment of the homogeneity of the dispersions of parallel experiments by the Kochen criterion G showed that all dispersions are homogeneous, since $G_P = 0.497 < G_T = 0.516$ (for $P, Pa$) and $G_P = 0.281 < G_T = 0.516$ (for $\alpha, \text{deg}$) with a confidence probability of 0.95, the number of degrees of freedom $f^2 = 8$.

Calculation of linear regression coefficients characterizing pair interactions of factors, estimation from significance, and checking the adequacy of the linear model were performed in accordance with the methodology.

Table 4. Regression coefficients ($b_i$) according to unit $Y_1$ and $Y_2$ optimization criteria.

| Optimization criterion | $b_1$ | $b_2$ | $b_3$ | $b_4$ | $b_5$ |
|------------------------|-------|-------|-------|-------|-------|
| $Y_1$                  | 104   | 11.42 | 14.42 | 1.83  | 5.83  |
| $Y_2$                  | 8.21  | -1.44 | -1.84 | -0.41 | -0.65 |

Based on the regression coefficients, mathematical models for optimizing the design parameters of the jacket were compiled:

By the criterion “Level of clothing pressure on the human body”.

$$Y_1 = 0.69 + 0.17x_1 + 0.19x_2 + 0.03x_3 + 0.13x_{12}$$

According to the criterion “Range of movement of the hands of a dressed man”.

$$Y_2 = 0.79 + 0.08x_1 + 0.11x_2 + 0.01x_3 + 0.04x_{12}$$

By a comprehensive optimization criterion.

$$Y = 0.74 + 0.12x_1 + 0.15x_2 + 0.02x_3 + 0.09x_{12}$$

An analysis of the design lines of equal response values, constructed taking into account the unit $Y_1$, $Y_2$ and complex $Y$ optimization criteria, made it possible to identify the interaction between the studied structural parameters and determine the region of their optimal values. So, the maximum possible value of the complex optimization criterion ($Y = 0.98 ... 1.02$) with Forward = const = 30 sm corresponds to the region of optimal values of design parameters $P_{16} = 14.0 ... 15.0$ sm, ($W_{sp} + S_{pr}$) = 40.0 ... 41.6 sm.

With a constant value of the second parameter $P_{16} = \text{const} = 15$ sm, the highest value of the complex optimization criterion $Y = 0.97 ... 1.1$ is achieved with the value of the design parameters $B_p = 29.0 ... 30.0$ sm, ($W_{sp} + S_{pr}$) = 36.7 ... 37.0 sm.

Thus, as a result of the studies, the optimal values of the design parameters of the jacket of special clothes are determined, which provide a high level of dynamic compliance. The established optimal values were used in the future to develop the basic framework for the construction of workwear for working in the open in dry hot climates.
4. Conclusions
Based on the concept of targeted design of workwear and analysis of the “man-clothing-environment” system, the article developed the design of workwear, selected materials, determined their quality indicators. The problems of placement and cutting of workwear parts have been solved, which allow for the optimal placement of patterns of workwear parts on fabric. Workwear models have been developed and are recommended for implementation in industrial production.

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