Ergonomic design of overalls for agricultural workers of Uzbekistan

Sabokhat Pulatova and Nargiza Bebutova
Bukhara Engineering – Technological Institute, Bukhara, Uzbekistan

E-mail: ozod4103@gmail.com

Abstract. This article focuses on the design of workwear based on ergonomic research. Conducted research allowed to obtain the results of the analysis of changes dimensional features and calculate dynamic effects for ergonomic patterns of postures of agricultural workers. The selection of the optimal values of the design parameters of workwear was carried out on the basis of the development of mathematical models using static methods of experiment planning, which makes it possible to implement all kinds of combinations of the considered levels of factors, and the results are evaluated using static analysis. On the basis of the carried out ergonomic researches results of the analysis of changes of dimensional signs and calculation of dynamic effects for ergonomic poses on the basis of which optimum sizes of additions on free fitting were chosen are received and the rational design of overalls for agricultural workers of Uzbekistan is constructed. Novelty of the constructive solution of overalls for agricultural workers is confirmed by the positive decision on issue of the patent of Agency on intellectual property of the Republic of Uzbekistan for the industrial design of overalls under the application No. SAP 2018 0263.

1. Introduction
To develop optimal designs, special data on the size of the signs of work taking into account the dynamics of their labor movements are required. Nowadays, special studies are based on the modern methodology of ergonomic design developed by Uzbekistan and foreign scientists.

2. Literature review

2.1. Analysis of scientific works carried out in this area of research
The development of a systematic approach to the design of special clothing was developed in the work of V.E. Romanov, which reflects ways to improve the ergonomic level of quality, the development of design methods and the concept of forming the flexibility of automated design processes of workwear [1]. Mustafina Z.T. proposed to improve the methodology of designing belt products, which provides anthropometric compliance, and a device has been developed to determine the ergonomic indicator of the quality of the design of belt clothing on the human figure, which ensures high measurement accuracy [2].

It is known that the Russian scientists E.A. Surzhenko proposed a new approach to the ergonomic design of workwear, based on a biokinematic analysis of the interaction of elements of the “man-clothes” system [3]. In addition, the ergonomic design of overalls for various purposes, which made it possible
to determine the appropriate requirements for the construction of overalls and provide comfort for workers to wear, is reflected in works [4-7].

Currently, along with anthropometric methods for carrying out studies on the ergonomics of clothes in statics and dynamics various non-contact methods are offered. The issue of obtaining reliable information about the dimensional characteristics of the human body in statics and dynamics using non-contact measurements based on three-dimensional scanning is reflected in works [8,9].

Besides, Chinese scientists have developed a virtual mannequin, which consists of models of repetitive postures and human movements, on this basis the authors proposed an algorithm for analyzing the Man-Clothing-Environment system [10].

In addition, German scientists developed the CUELA (Elle stat) technology, which is based on the use of a computer and a suit made from the wireless sensors, which provides analysis of workers' movements during the day, and allows them to select optimal motion movements [11]. It is known that the American scientists of the Department of Clothing, Textiles and Interior Design of Kansas State University was established the location of dynamic effects when performing characteristic types of movements in the process of their work [12].

3. Research Methods

3.1. Methods and theoretical principles of ergonomic research

The above scientific developments are aimed at designing work clothes taking into account the mechanical and biomechanical characteristics of movements and the calculation of the optimal values of structural parameters.

However, such approach to solve the ergonomic problem of work-wear entails large material and labor costs for research. To develop an ergonomic and rational design that meets dynamic correspondence, we studied the most characteristic movements of workers during work, which made it possible to identify the necessary dynamic increments to dimensional characteristics when building a work-wear design and to provide workers with freedom of movement, convenience and comfort when performing certain technological operations, respectively reduction of body fatigue and maintenance.

The choice of the labor movement was carried out when carrying out planned daily work for 30 working days. According to the results of studies after 30 days, uncharacteristic movements were excluded and more frequent movements were included, which are shown in figure 1. It was established that the most characteristic movements during the operation of overalls are hand movements, lifting them up and down, turning in the elbow and shoulder joints of the hands, turning legs in the knee joint with a bend of the body [13].

Table 1. Analysis of changes in dimensional characteristics using ergonomic schemes.

| Ergonomic Pose | Description of characteristic poses | Increasing of dimensional signs | Decreasing of dimensional signs |
|----------------|------------------------------------|-------------------------------|--------------------------------|
| A              | Body bent forward under angle of 30° to vertical, arms slightly bent in to elbows and elongated forward | Waist length on the back, the width of the back, the distance from the waistline to the sub-gluteal fold, the distance from the rear corner armpit to the grip line of the wrist, the length of the leg to the ankle, the girth of the arm at the elbow, the height of the shoulder is oblique, the length of the body from the side of the armhole to the waist line | Chest width waist length from the waist line to knee |

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In the course of the research, four characteristic poses and movements that have the greatest influence on the change in the distances along the surface of the body of workers between anthropometric points were identified. Dimensional signs are determined using the contact measurement method. An analysis of changes in dimensional attributes is given in table 1. Changes in the body sizes of workers in dynamics are determined according to the methodology [14].
As can be seen from the data given in table 1, with certain labor movements, significant changes in the size of workers' overalls were found, a number of dimensional signs have a significant increase in parameters that affect the determination of rational allowances for free fitting, which must be taken into account when developing the basic design of overalls for agricultural workers. Labor movements in the course of labor are carried out mainly in a standing position with the body tilted forward, sitting and connected with constant walking [15]. Figure 1 shows a photograph of a farm worker in the process.

In order to assess the change in dimensional signs with the above poses, a dynamic effect was determined. The dynamic effect for each feature is determined by the formula:

\[ d_j = x_j(d) - x_j(S) \]

where:
- \( d_j \) - Dynamic effect,
- \( x_j(d) \) - is the value of the dimensional sign in the dynamics.
- \( x_j(S) \) - Value of the dimensional sign in statics.

Table 2 presents the calculation of dynamic effects for ergonomic posture A.

**Table 2. Calculation of the dynamic effects of ergonomic scheme A.**

| Dimension Designation                                      | Value of a dimensional sign, sm
|-----------------------------------------------------------|---------------------------------|
|                                                           | in statics | in dynamics | Dynamic effect,% |
|                                                           | \( x_j(S) \) | \( x_j(d) \) | \( d_j = x_j(d) - x_j(S) \) | \( d_j / x_j(S) \cdot 100\% \) |
| \( x_1 \) Waist length on the back                       | 53.85      | 59.8        | 5.95               | 11.049210 |
| \( x_2 \) Back width                                     | 42.89      | 52.7        | 9.81               | 22.872997 |
| \( x_3 \) The distance from the back corner of the armpit up to the wrist lines | 60.23      | 67.01       | 6.78               | 11.256848 |
| \( x_4 \) Leg length to ankle                            | 114.41     | 118.5       | 4.09               | 3.574862  |
| \( x_5 \) Shoulder height                                | 60.13      | 66.42       | 6.29               | 10.460668 |
| \( x_6 \) Distance from waistline up to the sub-gluteal fold | 40.22      | 42.15       | 1.93               | 4.798607  |
| \( x_7 \) Girth of the arm in the elbow joint             | 30.23      | 34.17       | 3.94               | 13.033410 |
| \( x_8 \) Chest width                                    | 39.16      | 39.62       | 0.46               | 1.174668  |

As can be seen from table 2, with the ergonomic position of the movement of worker A, when the body is tilted forward at an angle of 30° to the vertical, the arms are slightly bent at the elbows and stretched forward, the maximum dynamic effect belongs to the dimensional characteristic “Back width”, and minimum - “Chest width”.
It is advisable to show the estimate of the change in the magnitude of the dynamic effects of dimensional attributes graphically. At the same time, for constructing a histogram of the value of the dynamic effect of dimensional signs of the ergonomic diagram A of agricultural workers, the technology of diagramming using the MS Excel program was used. Thus, figure 2 shows a histogram with a graph of the linear distribution equation of the dependence of the value of the dynamic effect on the dimensional characteristics of ergonomic circuit A.

![Figure 2. Dimensional signs. A histogram with a graph of the equation of linear distribution of the dependence of the value of the dynamic effect on the dimensional features of the ergonomic scheme A.](image)

As can be seen in figure 2 the dependence of the dynamic effect on the dimensional features of the ergonomic posture A is equal to \( y = 5.714x \).

4. Results and Discussion

4.1. Problem solving and analysis of results

So, on the basis of the research, the results of the analysis of changes in dimensional features and the calculation of dynamic effects for ergonomic patterns pos. The analysis shows that for some dimensional signs the differences in the values of dynamic effects are not noticeable, while for others they are very noticeable. Table 3 presents a comparative analysis of the changes in the dynamic effects of several dimensional signs when performing the above working positions: waist length on the back, back width, distance from the waist line to the sublingual fold, body length on the side of the armhole to the waist line, and distance from the waistline to the fold.

**Table 3.** Comparative analysis of the dynamic effects of dimensional signs of 4 types of ergonomic schemes.

| Name of dimensional sign | Dynamic effect, (S) \( d_j / x_j (S) \cdot 100\% \) |
|--------------------------|-----------------------------------------------|
|                          | A     | B     | C     | D     |
| Waist length on the back | 11.05 | 11.25 | 7.97  | 6.18  |
| Back width               | 22.87 | 26.25 | 27.53 | 23.81 |
| Distance from the back corner of the armpit up to wrist lines | 11.25 | 11.26 | 11.62 | 13.58 |
| Distance from waistline up to the sub gluteal fold | 4.79  | 30.85 | 27.77 | 2.31  |
From table 6 it can be seen that the dimensional sign - “Waist length on the back” has a range from 11.25 to 6.18 %, “Back width” from 27.53 to 22.87 %, “Distance from the back corner of the armpit up to wrist lines” from 13.58 to 11.25 %, “Distance from waistline up to the sub gluteal fold” from 30.85 to 23.1 %.

Figure 3. Changing of the dynamic dimensional effect sign “Waist length on the back”.

Figure 4. Changing of the dynamic dimensional effect sign “Width of the back”.

Figure 5. Changing of the dynamic dimensional effect sign “Distance from the rear corner of the armpit to the line wrist girt”.

Figure 6. Changing of the dynamic dimensional effect sign “The distance from the waistline to the fold”.

As can be seen from figures 3-6, the linear equations obtained on the basis of the ergonomic study of the dynamic correspondence of parameters for agricultural workers, they are quite significant indicators of the influence on the dimensional signs of work-wear. It should be noted that the values of the dynamic effects of the dimensional signs “Waist length on the back”, “Width of the back”, “Distance from the rear corner of the armpit to the line wrist girt”, “The distance from the waistline to the fold” in position C are too high, therefore the dynamic effects cannot be used completely [16].

Taking the above said into consideration, the choice of the optimal values of the structural parameters of the work-wear was carried out on the basis of the development of mathematical models using static methods of experiment planning, which makes it possible to implement all sorts of combinations of the considered factor levels, and the results are evaluated using static analysis. To obtain the dependences between the indicators Y (relative dynamic effect of the dimensional characteristic) and X (range of dimensional characteristics), we used methods of regression analysis, including linear functions of multiple regression.

The task of regression analysis is to experiment determining regression coefficients b by observing the character of changes of input variables (factors) and output size (effective indicator).
Table 4 shows the linear equations of the dependence of changes in the dynamic effects of dimensional features on the most common repetitive movements of agricultural workers in different ergonomic poses A, B, C and D.

### Table 4. Linear equations of dynamic change effects of dimensional signs from labor movements.

| Dimensional sign                                                   | The linear equation of the function of the dynamic effect of dimensional dimension |
|-------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Waist length on the back                                         | \( Y = 17.43X \)                                                                |
| Back width                                                        | \( Y = 27.11X \)                                                                |
| Distance from the back corner of the armpit up to wrist lines     | \( Y = 17.63X \)                                                                |
| Distance from waistline up to the sub gluteal fold                | \( Y = 3.602X \)                                                               |

5. **Experiment and Result**

The following experiments were carried out under the production conditions of «Equatorial TEKS» LLC (Bukhara region):

- Visual assessment of the overalls fit in dynamics and statics.
- Evaluation of the ergonomics of the design of work-wear in dynamics when performing characteristic movements.
- Evaluation of the ergonomic design of work-wear in static.

The results of the experiments showed that the developed design of overalls, taking into account the results of the above ergonomic studies, provides a good fit in statics and dynamics, provides freedom in the performance of working movements, helps to reduce fatigue and maintain efficiency.

6. **Conclusions**

Thus, on the basis of the carried out ergonomic researches results of the analysis of changes of dimensional signs and calculation of dynamic effects for ergonomic poses on the basis of which optimum sizes of additions on free fitting were chosen are received and the rational design of overalls for agricultural workers of Uzbekistan is constructed. Novelty of the constructive solution of overalls for agricultural workers is confirmed by the positive decision on issue of the patent Of Agency on intellectual property of the Republic of Uzbekistan for the industrial design of overalls under the application No. SAP 2018 0263.

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