Modeling of the process of safe functioning of a mechanized feed production complex

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Abstract. The article deals with the concept of the safe production process of forage by improving the means of mechanization in order to reduce injuries to workers and improve working conditions. A modern feed mill is an industrial complex and is quite specific, characterized by the peculiarities of the developing factors that affect the health of workers, as well as the nature and level of their morbidity. Sources of hazards are power plants (transformers, electric motors, distribution panels and points, compressor stations, boiler plants, etc.), a significant number of various technological, transport and auxiliary equipment; mobile and self-propelled means of mechanization. A large number of different types of raw materials, often with specific properties, finely dispersed, with tendency to caking, dust releasing, pass through the communications of the enterprise, are stored in silos, bunkers, floor-type warehouses. With the effective implementation of the developed model, the process becomes explosion and fire safe, safe for the environment and comfortable during operation.

1. Introduction

Effective mechanization of the process reduces the risk of accidents to the minimum acceptable risk, while the risk of exposure to harmful and / or hazardous production factors arising in connection with an emergency situation and due to it does not exceed the acceptable one. These factors include moving parts of equipment, dustiness of the air, increased noise and vibration, increased temperature of equipment surfaces, explosion and fire hazard, electric shock, unfavorable microclimate [1].

The authors’ obtaining quantitative estimates of the impact of working conditions in the process of operation of mechanized complexes (MC) for the production of feed on safety and labor productivity is intended [1].

The authors’ obtaining quantitative assessment of the impact of working conditions in the process of mechanized complexes (MC) operation for feed production on safety and productivity is intended:

First, to achieve some rational according to the criterion of the maximum comprehensive assessment of the state of labor protection (Kcomplex) - a combination of sanitary and hygienic parameters of working conditions (O ≤ Kcomplex ≤ 1) and ensure the probability of work without injuries and accidents (O ≤ P ≤ 1);
Secondly, to obtain the highest average shift productivity - P(t) MC with its minimum fluctuations, assessed statistically by the standard deviation σ or variance Dσ.

To obtain a mathematical description, let us consider a model of the MC normal functioning, which includes the workstation of the operator-driver of the raw material drying unit AVM-1.5, the OPK-2 press operator and the diesel engine operator.

1. Model of the functioning of a mechanized processing complex.

Taking into account the recommendations [2], the scheme of functioning (the model) is built on the principle of “input-output”, in the first approximation we will accept the linear model (figure 1).

In this model, F(t) is the vector function of disturbing (external) influences on the unit. These include the processes V(t), changes in time, respectively, of air mobility, relative humidity and air temperature, illumination level, as well as Y(sh), Y(vib), which have constant values of noise, vibration and dust content in the air.

The transforming properties of the MC in relation to the input actions are determined by some operator AΣ. To reveal the internal structure of the operator AΣ, the following prerequisites must be taken into account [3]:

\[
\begin{align*}
&f_1(t) \\
&f_2(t) \\
&f_3(t) \\
&f_4(t)
\end{align*}
\]

\[
\begin{array}{c}
\text{MC} \\
\text{(AΣ)}
\end{array}
\]

\[
P(t)
\]

\[
\text{Figure 1. Block diagram of the mechanized complex functioning.}
\]

The state of labor protection at MC is assessed by the complex indicator Kcomplex according to the formula:

\[
K_{\text{complex}} = \sqrt[3]{K_1 \cdot K_2 \cdot K_3},
\]

(1)

where K1 - indicator of the state of labor protection at the workplace of the operator-driver of the raw material drying unit AVM-1.5; K2 - indicator of the state of labor protection at the workplace of the OPK-2 press operator; K3 – an indicator of the state of labor protection at the workplace of a diesel engine operator. In turn, K1, K2, K3, ... and so on are defined as geometric mean values:

\[
K_{1,2,3,\ldots n} = \sqrt[n]{\prod_{i=1}^{n} K_i}
\]

(2)

or in more detail:

\[
K_{1,2,3,\ldots n} = \sqrt[n]{d_1 \cdot d_2 \cdot d_3 \cdots \cdot d_n}
\]

(3)

where d1, d2, d3, ..., dn - dimensionless performance indicators representing the sanitary and hygienic parameters of working conditions at workplaces.
2. Methods
To determine these indicators, the methodology [4] is used, the essence of which is that the control effect on the system includes a certain set of factors. That is, each variant of the control action on the system is accompanied by a certain set of factors that interact with each other and lead it to the goal. By reducing this set to a generalized indicator of efficiency, a quantitative assessment of the control impact on the system is obtained, expressed by the following scale of assessments (table 1).

Table 1. Scale for assessing the level of efficiency of working conditions.

| Efficiency level | Level characteristic                                      |
|------------------|-----------------------------------------------------------|
| 0...0.20         | Inappropriate level of efficiency                          |
| 0.20...0.37      | Undesirable but sometimes acceptable level of effectiveness|
| 0.37...0.60      | Acceptable and sufficient level of efficiency              |
| 0.60...0.80      | Good level of efficiency                                  |
| 0.80...1.00      | Excellent level of efficiency                              |
| 1.00             | Highest possible level of efficiency                       |

To convert the numerical value of any factor into an indicator of the effectiveness of working conditions, the function is used [5]:

\[ Y = d = e^{-e^x} \]  \hspace{1cm} (4)

at \( X = 0, Y = d = 0.37 \), so the graph of the function (4) has the following form (figure 2).

To avoid negative values of the generalized efficiency indicator, function (4) is written in the following form:

\[ Y = d = e^{-e^{-x}} \]  \hspace{1cm} (5)

The graph of this function is shown in figure 3.
The most used for work is considered to be the middle part from \( X_A = X_{\text{min}} \) to \( X_b = X_{\text{max}} \). At that \( X_A = 3.53 \) and \( X_b = 5.5 \). To determine the scale of this segment \( M_x \), the formula is used:

\[
M_x = \frac{X_{\text{max}} - X_{\text{min}}}{X_A - X_B},
\]

where \( X_{\text{max}} \) - the maximum value of the \( i \)-th factor; \( X_{\text{min}} \) - the minimum value of the \( i \)-th factor.

The current values of the coefficient of efficiency of individual factors are [4]:

\[
X_1^n = X_A + (X_1 - X_{\text{min}}) / M_x
\]

\[
X_2^0 = X_B + (X - X_{\text{min}}) / M_x
\]

By substituting the current values of the coefficient in (5), the values of \( d_1, d_2, \ldots, d_n \) are found. As an example, let us define for the workplace of the operator-driver for control of the raw material drying unit AVM-1.5 (table 2) and evaluate it.

**Table 2.** Initial data for determining the complex indicator for the operator's workplace for controlling the raw material drying unit AVM-1.5.

| Name of factors        | Flange scale (M_i) | Current coefficient values | Numerical values of the function |
|------------------------|--------------------|----------------------------|----------------------------------|
| 1. Air temperature     | 19.28              | 3.85                       | \( d_1 = 0.25 \)                 |
| 2. Noise               | 27.91              | 4.25                       | \( d_2 = 0.34 \)                 |
| 3. Vibration           | 30.96              | 4.18                       | \( d_3 = 0.32 \)                 |
| 4. Dustiness           | 59.89              | 5.31                       | \( d_4 = 0.44 \)                 |
| 5. Humidity of air     | 30.45              | 3.99                       | \( d_5 = 0.27 \)                 |
| 6. Mobility of air     | 2.48               | 3.9                        | \( d_6 = 0.25 \)                 |
|                        |                    |                            | \( K_1 = 0.31 \)                 |

It can be seen from the table that \( K_{\text{complex}} = 0.326 \) is very low, if we take into account that the ideal value of \( K_{\text{complex}} = 1 \). \( K_{\text{complex}}(t) \) is an intermediate output parameter of the PMK dynamic system, which determines the quality of its functioning. On the other hand, this process largely determines the nature of the process \( P(t) \) of changes in the MC productivity.

### 3. Results

Taking into account the foregoing, the model of MC functioning, from the point of view of the safety of operators of technological equipment, can be represented by the diagram shown in figure 4.
The operators $A_1$, $A_2$, $A_3$ in their physical essence represent the dynamic characteristics of the environment from the MC contour to the working area, respectively: the operator-driver of the raw material drying unit AVM-1.5, the OPK-2 press operator and the diesel engine operator.

Due to the fact that at the inputs of blocks 1, 2, 3 there are parameters that comprehensively characterize meteorological conditions, and at the output, parameters that comprehensively characterize the sanitary and hygienic parameters of working conditions at workplaces, the operators $A_1$, $A_2$, $A_3$ in form and modulus depend from the distances from the MC contour to a particular workplace. This distance does not depend on the MC operation time, which speaks in favor of the premise of the linearity of models with the operators $A_1$, $A_2$, $A_3$.

Depending on the functional purpose of the working areas 1; 2; 3; ...; n, the vector function of external influences on them in each case consists of a different set of input processes. Since in section 1 of the operator-driver of the AVM-1.5 raw material drying unit act, proceeding from the specifics of the technological process, the following disturbing factors: $W(t)$ - air humidity; $T(t)$ - air temperature; $Y_{sh}$ - noise level; $Y_{vib}$ - vibration level; $Y_{lig}$ - illumination level; $V(t)$ - air speed. At section 2 of the OPK-2 press operator act the following disturbing factors: $W(t)$ - air humidity, $V(t)$ - air speed; $T(t)$ - air temperature, $Y_{sh}$ - noise level; $Y_{vib}$ - vibration level; $Y_{lig}$ - light level. At section 3 of the diesel engine operator - $T(t)$ - air temperature; $Y_{sh}$ is the noise level; $Y_{vib}$ - vibration level; $W(t)$ - air humidity; $V(t)$ - air speed.

Based on the accepted designations, the function of the goal of our research will be written in general as follows:

$$K_{\text{complex}}(t) = \sqrt{F_1(t)A_1(t) \cdot F_2(t)A_2(t)F_3(t)} \rightarrow 1$$

(9)

or in the frequency domain

$$SK_{\text{complex}}(w) = \sqrt{SF_1(w)A_1(w)^2 \cdot SF_2(w)A_2(w)^2 \cdot SF_3(w)A_3(w)^2} \rightarrow \text{max}$$

(10)

For the process $P(t)$ we have
In equations (9) and (10), the following designations are adopted:

- $A_i(t)$ - the current value of the corresponding operator in time coordinates;
- $[A_i(w)]^2$ - the square of the modulus of the amplitude-frequency response of the $i$-th dynamic path;
- $S_i(w)$ - spectral plane of the 1-st disturbing or output process.

To substantiate rational according to the criterion of compliance with the tolerances for the parameters of sanitary and hygienic working conditions during the MC normal functioning, it is necessary to conduct their probabilistic and statistical assessment.

4. Conclusion
The introduction of the proposed model for the MC safe operation will increase the reliability of the technological process and proportionally reduce the level of professional risk, although, at the same time, there may be a sharp decrease in the number of maintenance personnel.

References
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