Simulation of a Human Operator's Response to Stressors under Production Conditions

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Abstract: The paper investigates an occupational stress phenomenon. The source of stress is an increase in the number of stressful situations during the working process. And the consequence, in turn, is the emergence of diseases inherent in this specific work or suppression of a psychological state of human. The study analyzes the symptoms, obtained from post-stress situations, and provides a stress classification for further determination of stress impact level on the operator during professional activities. The model of professional stress development is given and the factors of occupational disease formation under the influence of stressful situations in the production conditions are investigated. The model of the duration of stay and exit from an extreme situation has improved in the work and decay model to accurately determine the operator's exit from an extreme situation. With the help of the constructed wave of emotional stress, on the basis of G. Selye's concept, the interrelation of levels of working capacity with phases of functional state was investigated. The new method performs 12% better than existing methods of determining stress resistance by interviewing an employee. The main stages of stress development and features of its course in the conditions of automated control systems are also analyzed. The paper presents a list of the main technologies with which the developed system was created; a detailed description of the developed information system software implementation. For clarity of the program interface the user's manual with a division of structure of the system into logical modules is resulted.

Keywords: 1
indicators of organism state, stressful situation, model, information system, automated control system.

1. Introduction

Analysis of human behavior in stressful situations is a constant research object for scientists [1-3]. However, despite the prevalence of this problem, even foreign research is not enough for the realities of modern Ukraine [4-9].

The study of the stress problem and finding ways to overcome it in connection with the development of scientific technology is especially actual. The most difficult task in the field of labor protection is to minimize the impact of stress in a workplace [10]. It is impossible to say only the negative effects of stress [11], however, the occurrence of excessive, constant and prolonged stressful situations during the working day is unacceptable [12].

The published results of EU-OSHA show that about half of the workers in the EU work under stress. Research also shows that stress in the workplace is the cause of 50% to 60% of lost working days [13]. Prolonged exposure to stress in the workplace can lead to the development of chronic diseases and exacerbate pre-existing health problems.

Thus, it is difficult to give an unambiguous definition of occupational stress, as it is associated with a large number of factors that cannot be measured or predicted. Most often, the manifestation of

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emotional instability is in the form of mental and physical reactions to stressful situations, when, for example, the situation is not going according to plan. In the work [14] the model of occupational stress development is given. This model focuses on the negative consequences of the development of occupational stress - the deterioration of employee health. Grouped sources have the same effect on a person, thus preventing from concentrating as much as possible when making a responsible decision. These include those that are more or less related to the work process and external causes that have already been acquired before the start of a working day. All these moments of stress turn into factors that negatively affect the state of health, and then turn into occupational diseases. Of course, the concept of "occupational stress" in different areas of activity has its own characteristics. It is not possible to compare professions with a high level of stress, where the employee is required to have a high level of concentration, the ability to process large amounts of information with a high level of responsibility. However, the detrimental effects of stress to some extent affect workers in any field [15].

Selye distinguishes two types of stress in his works - eustress and distress. Eustress describes a person's desire to achieve a dream. Its effect on the human body is only positive, because with its help to mobilize all forces. Distress is undesirable and usually unpleasant (it is called an indicator of harmful stress) [16]. By the nature of stress origin it is divided into [17]:

1) physiological (excessive physical activity);
2) psychological (complex relationship with the environment);
3) informational (one momentary excessive amount of information or insufficient amount of vital information);
4) managerial (awareness of responsibility for decisions);
5) emotional, the manifestation of which can be clearly traced in terms of threat to human health or life.

Stress can also be classified as acute, in the case of an unforeseen situation that can be life-threatening and chronic, under constant physical and psychological pressure on a person. Acute stress is rapid and accompanied by nervous tension and the release of adrenaline into the blood. The onset of chronic stress does not depend on how strong or weak a stressor is. Post-traumatic stress, which can occur, for example, after acute stress, is singled out [17, 18].

Thus, the concept of "stress" includes the relationship of several complex systems - biological, psychological and socio-psychological. Here, the existence of individual stress thresholds should also be taken into account. Each person is characterized by own stress level, in which exceeding the maximum mark leads to the development of distress. As a rule, melancholics have a lower rate of stress resistance.

The purpose of this work is to create and develop an information system that simulates the human reaction under the influence of a large number of stressors and study stress as a state of mental tension that occurs in the process of human activity.

The methodology for the study of human entry into a state of exhaustion is based on the method of differential diagnosis of depressive states by V.A. Zhmurov [19, 20], which according to the test [21] classifies the current state to a certain category, as well as auxiliary methods of building a model of the duration of the operator in an extreme situation based on the decomposition of the pulse. The object of the study was the human operator and the nature of behavior at the time of information "strike" – the emergence of a situation that requires immediate response.

The subject of the study are biological indicators of human operator state, in particular: systolic pressure, diastolic pressure, pulse, body temperature and their ratio at the appropriate time.

The paper consists of four sections. In section 1, the concept of stress is characterized. On the basis of the considered work of Selye the basic classification of pressure is resulted. Section 2 presents a comparative description of similar systems. Section 3 presents the main tasks to be solved and own method of determining the level of efficiency of the employee in the conditions of storage. The last section concludes this paper containing the user's manual with a division of structure of the system into logical modules.

2. Theoretical Basis

To fully understand the level of emotional stress, should take into account not only physical indicators, but also the criterion of the magnitude of this stressful situation on a person. In other words, its index should be determined.

A major contribution to the study of psycho-emotional stress is the development of methods for instrumental assessment, control, and adjustment of human activity functional states, the work of which is based on the registration of parameters of biologically active points of a body. The effectiveness of these tools in the field of engineering and health care has been experimentally confirmed, which has helped to increase the resistance to the action of stressors, fatigue prevention [22].

This equipment includes: a simulator of mental self-regulation with efficiency registration of autosuggestion on a condition of biologically active points [23], a special computing device for automatic continuous assessment of psychophysiological state by the level of potentials of biologically active points [24], an experimental complex of biopotentials conversion of active points of skin into digital code [25], etc. The usage of these tools allows to trace the relationship between individual characteristics of a person and the reaction to the stimulus. Talking about the quality of a particular system, should pay attention to the following factors: reliability, efficiency, accuracy and pace of work.

During the study of existing analogues, the hardware complex "Vector 01.1" [24, 26] was discovered – indicator of human emotional stress. The operation of this complex is based on the following units – labiliometer, reactor, thermometer and a computer attached to them. Upon receipt, the data is sorted and uploaded as an Excel report for printing. This hardware analogue is specialized for the analysis of emotional state. Registration of changes occurs by fixing the corresponding reaction on the material presented by a psychologist. If a proposed question or image is important to the subject and the mention of this thing leads to changes in the indicators of the emotional background. It is change that is fixed by the hardware complex. Despite the complexity of operation, this device does not require special permission at the legislative level, which allows qualified personnel to use it for various purposes. Also, it should be noted that this complex should be used in human examination or study of the reaction to the presented material. However, to apply such a system in automated production will be somewhat difficult due to its unsuitability for this area and the impossibility of comparative characterization of current and previous results.

The MIS-DES biomedical system is used to determine the psycho-emotional level of stress. The structural scheme of the system is quite complex, and the biggest drawback is the predominant use in clinical institutions and sanatoriums, diagnostic centers, selection centers, which require an increased level of stress resistance. The output of the system is presented as a combination of analog and digital data on a monitor screen or paper, which requires additional involvement of a professional.

Also, quite popular now is the creation of a mobile application for ease of use. One of the most popular of these is the Welltory app, which allows to measure stress and energy levels in minutes, using only own gadget. Among the advantages that the developer provides is that during the process it is a possibility to see heart rate and after to get a complete general conclusion about the nervous system, heart function, mental stress. The principle of heart study is based on the method of photoplethysmography – a technology that is based on the registration of changes in light intensity after its passage through biological tissue, which causes a change in its volume. In practice, this method is most often implemented to observe pulse waves. That is, with the help of a flash on a smartphone and a camera that records and captures the change in color that occurs due to the difference in the filling of vessels with blood (in the presence and insufficiency of blood). Also, this application captures the intervals between heartbeats, and then interprets this information using the method of heart rate variability. The higher the variability, the healthier a person is. The obtained calculated indicators from this method are interpreted and on their basis the level of stress and energy are determined.

Therefore, the main disadvantages of the above analogues include the limited scope of use, because not every production is able to implement such complexes. It also means that the purchase of such facilities can be costly for small and medium-sized businesses and will not give the desired results, as some of them are based only on the study of one human condition indicator. The results of some of these analogues require the installation of additional software products, such as Microsoft Office.

The software product developed in the work is designed to determine the level of adequacy of human decisions by registering, analyzing and presenting the biological parameters obtained as a result of measurements during the work process and under stress. The system is focused on use in the production environment and outside of it, as it does not require a large number of components to work. The results of the analysis performed by the system can be viewed both directly in the system and uploaded to a file for further printing.

3. Construction of Model

Today, in the context of a large number of reforms, the threat of crisis situations for the population is increasing. In conditions of rapid pace of information change in the environment, personality and information interact closely. Their connection is accompanied by an increase in information, its complexity and non-systemic nature. A person, during the analysis and processing of data, needs critical thinking and quick awareness of events, which leads to constant anxiety, tension, anxiety, fear or stress. In other words, the primary task of a person is to develop coping behavior to adapt as quickly as possible to the requirements of the situation, weaken or mitigate its requirements [27, 28]. In the case of prolonged and regular being in stressful situations, the phenomenon of emotional stress occurs – not only mental but also physical stress, accompanied by mobilization of all systems of an organism and mentality, that is, there is a protective reaction to the operating stimulus.

To achieve the goal of the work it is needed to solve the following tasks:

1) Investigate the main stages of stress development and features of its course in the conditions of automated control systems.
2) Investigate the factors of occupational diseases formation under the influence of stressful situations in production conditions.
3) Investigate the interaction of mental and physiological components in response to a stressful situation.
4) Improve the model of duration of stay and exit of a operator from an extreme situation.
5) Develop the model of surge decline to accurately determine the output of a operator from the tension state.
6) Develop the description of the impact accumulation of final overwork on the activities of a operator.
7) Investigate the relationship between levels of performance and the phases of a person's functional state.

It is also important to study the concept of "stress" from an economical point of view. In 2018, KIIS (Kyiv International Institute of Sociology) interviewed 2,034 respondents across Ukraine. Among them, 52% gave a positive answer about experiencing stress.

In return, the leader among all countries is the United States, where 90% of the total population experiences severe stress, moreover, for 60% its approximate recurrence is 1-2 times a week, for 30% - daily. Statistics from the American Psychological Association reports that 2/3 of all visits to a psychotherapist are caused by stress.

Since the object of study is the human operator, the issue of human adaptation to stress remains relevant. Strong external stimuli disturb the internal balance. This condition is stressful for a body. Prolonged exposure to the stimulus causes a number of special changes. One of them is the release of hormones and changes in the work of various systems. This means that the input data will include information about the change in the value of the measured parameters of the operator during stressful situations and beyond.

The primary studied indicators will include values obtained from donors, such as:

1) pulse,
2) diastolic pressure,
3) systolic pressure,
4) body temperature.

Physiological indicators also include acceleration of respiration, redness or pallor of the skin, sweating, but these are indicators that are not taken into account in this study, as some of them are derived from the primary. On the basis of the above indicators the data on the person-operator at the moment of information "blow" are formed. However, conclusions based only on the results of their research can’t be considered reliable in working conditions, because it is necessary to take into account the indicators before starting work and to carry out their comparative characteristics.

Faced with an extreme situation or interpreting it as such, a person experiences a sharp change in emotional state, a surge of energy, or, conversely, its absence. Determining the limits of the norm in the fluctuations of indicators should also be based not on generally normalized indicators, but on the type of emotional state of a person and personal characteristics.

Formally, the behavior of the operator at the time of the information "blow" can be represented as a rectangular pulse (see Figure 1) with amplitude H, which expresses the magnitude of the operator overwork that occurred at the time t_i, awareness of the situation by the operator, duration $\Delta t = t_{i+1} - t_i$ decision making, and a decreasing nonlinear function $H^* = H \times \varphi(t)$, defined on the interval $t \in [t_{i+1} + 1, T]$. It also includes the duration of normalization of the operator and return to normal state, and at the time t_{i+1}, $\varphi(t_{i+1}) = H$, and when $t \to \infty$, $1 \geq \varphi(t) \geq 0$. That is, a stressful situation is characterized by the reaction of the human operator, his behavior and his personal perception of reality.

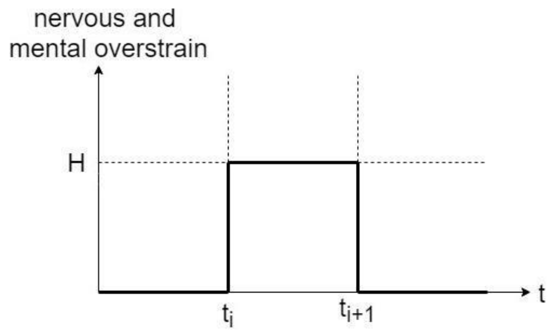


Figure 1: Rectangular pulse

Over time $\Delta t = t_{i+1} - t_i$ there is processing and analysis of the details of the emergency situation, drawing events in the mind, finding several solutions and assessing the further development of events. Also, at this stage, evaluation criteria are formed, solutions are analyzed and the most adequate in this situation is selected. Whenever possible, outside opinion is involved in the process. Awareness of the possible consequences of this decision causes even more nervous tension on the operator, creating additional stress and pressure on his consciousness. The final decision is made at the time t_{i+1}.

The function $\varphi(t)$ characterizes the decrease in overwork after making a decision in this situation. However, every extreme situation leaves its mark: feelings, fears, emotional expressions, reactions to them, the processes of analysis and choice of solutions.

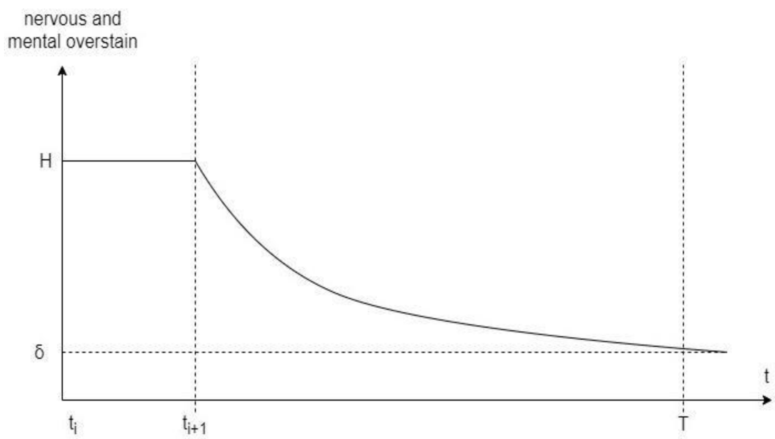


Figure 2: Duration of stay and exit from an extreme situation

Hence the location t_{i+1}, the nature of the extreme situation and personal perception of the operator, which directly affects the development of side effects of emotional stress, at the time T the value of the product $H \times \varphi(T)$ preferably equal to some final overwork δ, as shown in Figure 2.

Presented in Figure 2 model determines the duration of stay and exit from the extreme situation of the operator based on the method of decomposition of a complex pulse, where the duration is determined by the time the operator being in this situation.

Classical theory provides three stages of stress:

1) stage of anxiety;
2) stage of resistance;
3) stage of depletion.

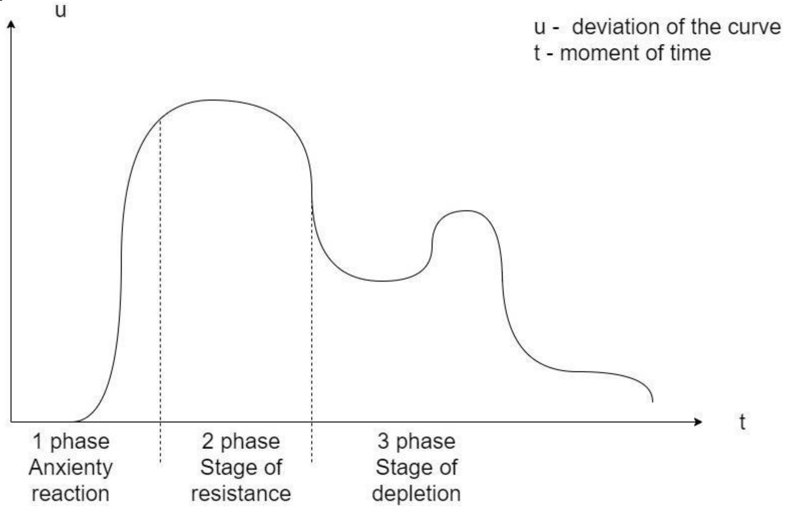


Figure 3: A wave of emotional stress

The first stage (see Figure 3 [18]) of the wave of emotional stress is characterized by the mobilization of forces, the beginning of anxiety feeling depending on the temperament and the degree of operator stress resistance. This stage does not have a fixed duration because it depends on the dynamic indicators, however, in most people it manifests itself in the form of increased efficiency. The next link in anxiety that accompanies the onset of stress in its early stages is fear - an anxiety specified on a particular stressor with a subsequent increase in the intensity of anxiety disorders and the emergence of anxiety-fearful arousal caused by anxiety. Disorganization reaches a maximum and the possibility of purposeful activity disappears. The transition to the resistance stage, or adaptation, means that the body has adapted to a new stimulus, although this adaptation requires increased energy expenditure. Prolonged stress causes distress, hyperstress, which quickly depletes the body's reserves and leads to the destruction of adaptation mechanisms. Stress reactions gradually weaken, they do not reach such a high functional level. The beginning of the third stage of depletion is associated with the depletion of "adaptive energy". This stage occurs only when the stressor acts for a long time or there are a large number of stressful situations in a short period of time. If we delve into the understanding of psychological stress concept, the stage of exhaustion corresponds to the phenomena of despair, helplessness and reckless decisions involving a person in a hopeless situation.

Denote the value of some indicator at the time t_i by Ψ_i, and the value at the time of stress t_S by Ψ_s. Then, to determine the time of overwork stage onset, the following parameters should be calculated:

1) A_0 – amplitude index of stress resistance, is determined from the ratio of indicator value at the time of stress (Ψ_s) to the indicator value at the time of exit from it (Ψ_e). The main purpose is to assess the level of resistance of the stress operator.

$$A_0 = \frac{\Psi_s}{\Psi_e} \tag{1}$$

2) I_s – stress index, is determined from the ratio of indicator value in the next time after a stressful situation to the indicator value at the time of its realization. Gives the opportunity to assess the level of stress on the operator side.

$$I_s = \frac{\Psi_i}{\Psi_s} \tag{2}$$

3) I_{sa} – stress index, which reflects the cost of the human body's reserves for adaptation. It is determined from the ratio of the indicator at the time of decision-making (Ψ_d) to the value of the indicator at the time of awareness of a stressful situation.

$$I_{sa} = \frac{\Psi_d}{\Psi_s} \quad (3)$$

4) I_{as} – actual stress index. Determines the index of current stress among all possible stress options for the current operator.

$$I_{as} = I_s - I_{sa} \quad (4)$$

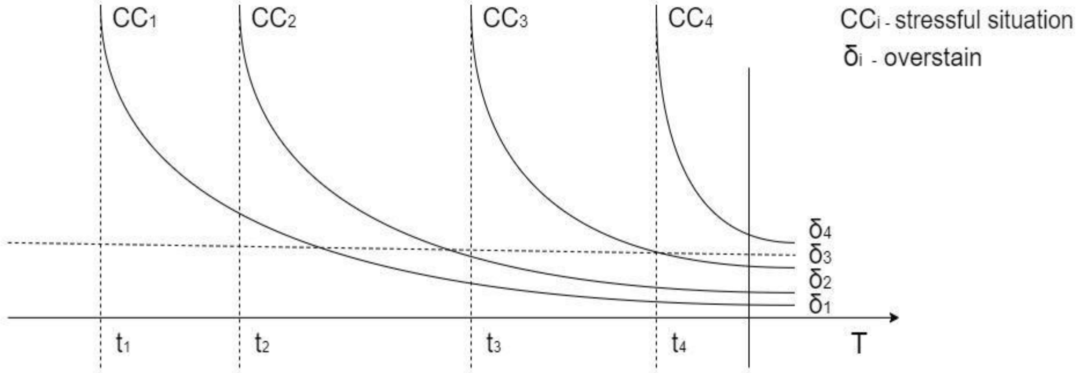


Figure 4: Imposition of final overworks at an exit from an extreme situation

In the process of deciding-making for further action, defined in the time shift system *T*, the nature of its main indicators tends to change especially in the afternoon, when the functional state has the last phases, ie the operator begins to feel tired. In the event of some stressful situations final overworks δ are imposed, the level of "adaptive energy" decreases and the operator's state is approaching overwork, in which the operator's work is inefficient, as shown in Figure 4. Herewith, the natural error due to the operator's characteristics be taken into account. As a result of the total interaction δ_i the psychophysical state of the operator can reach mental stress at the time $t < T$, that is, before the end of the work shift. The state in which the operator is during the work shift is not constant, because it directly depends on the psychological state of the operator and his resistance to stress. Therefore, formally, this state can be represented as a model of time series. In the absence of stressful situations or situations that can be perceived by the human operator as stressful, the trend of its functional state corresponds to the trend of time series $y_1(t)$, as shown in Figure 5. The presence of such situations reflects the trend of time series $y_2(t)$. Let z – the smallest value at which the operator begins to reach the level of the overwork state.

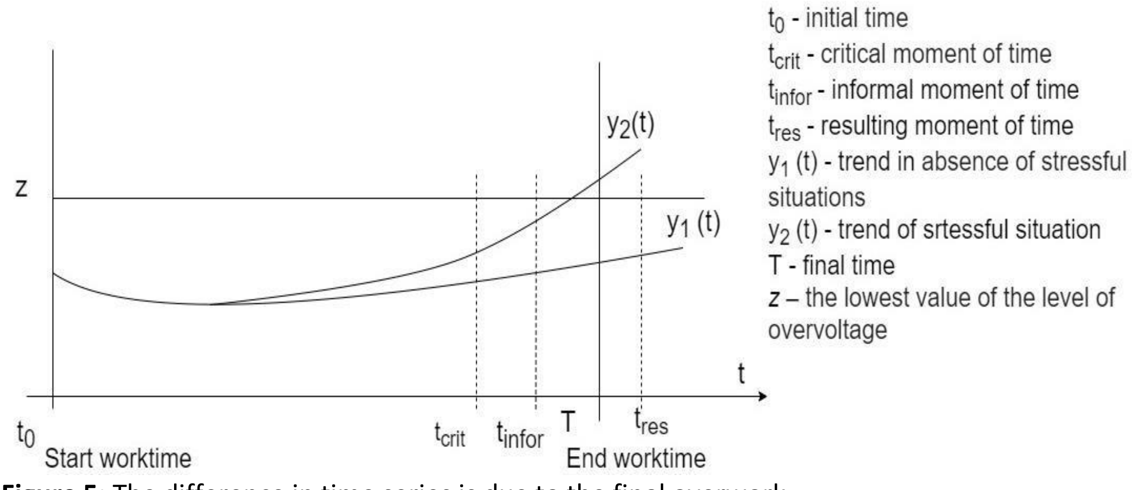


Figure 5: The difference in time series is due to the final overwork

At this level of overwork, the decisions made by the operator may be correct, but the time spent to make them directly depends on the functional state of a person. Also, it can be concluded that the accumulation of overworks during the work shift changes the trend of the operator's efficiency indicator, as shown in Figure 5.

After receiving the indicators at the current time, the method of differential diagnosis of depressive states by V.A. Zhmurov is applied to them. According to the test results, this technique not only classifies a depressed state, but also allows to determine the level of emotional stress.

In particular, there is such a classification [19]:

1) apathy,
2) bad mood,
3) confusion,
4) anxiety,
5) fear.

To determine the affiliation of the operator to one of the phases, it is necessary to calculate the average value of each indicator. Denote the value of the indicator at a particular time by Ψ_i , then, its average value will be determined from the equation:

$$\overleftarrow{\Psi} = \frac{\sum_{i=1}^{n} \Psi_i}{n} \quad (5)$$

The next step is to compare the current value of the indicator with the reference value. Denote the reference value of the indicator as Ψ_r. Then, to determine the *i*-th moment of time for the *i*-th value of the indicator equality must be observed:

$$\Psi_{r_{min}} < \Psi_i < \Psi_{r_{max}} \quad (6)$$

Using mathematical Equations (1) - (4) obtain the stress index, reflection of human adaptation reserves' costs, actual stress index and amplitude index of stress resistance. Based on the actual stress index, the moment determination of operator exhaustion is determined by comparing its value with the method results of determining stress resistance and social adaptation of Holmes and Rage [23]. The scale of methodology contains values from 0 to 300, where 300 - 100%. There are three possible scenarios:

1) The operator is in a state of anxiety and emotional arousal:

$$I_{as} \times 100\% < 66.333\%, \quad (7)$$

$$155 < A_0 < 199. \quad (8)$$

2) The operator is in the stage of resistance:

$$66.666\% < I_{as} \times 100\% < 99.666\%, \quad (9)$$

$$200 < A_0 < 299. \quad (10)$$

This means that his decisions are still considered, however, the operator is already beginning to feel tired.

3) The operator is in a state of exhaustion:

$$I_{\text{as}} \times 100\% > 100\% \ (300\ points) \quad (11)$$

$$A_0 > 300 \quad (12)$$

Since several operators work simultaneously and each of them has its own physiological parameters, then they all simultaneously enter the system from an external sensor. Such a sensor, for example, may be a controller, or even several controllers simultaneously. Their main purpose – to fix the operator’s state and his reaction at the time of information "blow". Based on this, we construct a data flow diagram (Figure 6) to model the functional requirements of future software. We use Heine-Sarson notation to construct the diagram. Using this diagram, we break down all the simulated requirements into functional components (processes) and represent them as a network connected by data flows. This will make it possible to identify the relationship between these processes.

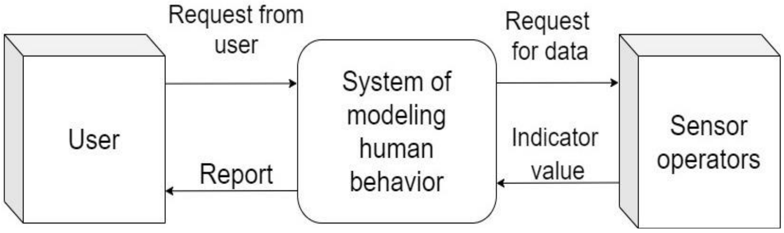


Figure 6: Description of data flows between the future system and external entities

From the "User" essence, information flow is a request to obtain the value of the selected operator. The result is an output flow in the form of a report. From the "Operator Sensor" essence, input stream is a request to obtain data for a particular operator. The result of user interaction with the designed system is a report. The report is both graphical and presented in tabular form information. Graphic information in this case is a simulated graph with the values of a selected indicator, tabular – the values of indicators and values found by the system using mathematical Equations (1) - (4).

4. Results

In this section, Experimental results are presented in particular those related to the proposed framework performance. The dataset is used from open sources to study the performance of employees at the airport. The proposed method is tested on hardware: Intel Pentium N3700 2.4 GHz, 4 GB RAM, HDD WD 1 TB 7200 RPM.

The proposed method provides good accuracy for a maximum number of operators up to 100. Method of photoplethysmography gives the closest results.

The main purpose of the developed system is to study the duration of the operator's stay in an extreme situation (see Figure 2). During the work process and the classification of its current state belonging to one of the three stages of stress (see Figure 3).

The main technology for the system's development was the .NET Framework – a cross-platform technology for creating regular programs and web applications. In this case, a significant advantage is the practical implementation of the principle "any entity is an object".

The architecture of the developed software product is client-server and provides such basic components as: client, server, network, which provides interaction between client and server. "Client" means the client computer from which the request is made in the form of an HTTP request to obtain data. The server that receives HTTP requests from the client issues an HTTP response along with the HTML page. The connection between the client and the server is made using the API. To do this, the software implementation uses the namespace System.Net.Http to connect the following components:

1) HttpClient — the main class for sending and receiving requests over HTTP;
2) HttpClientHandler is an HTTP handler for creating HTTP response messages.

Login to the developed system is carried out by means of the authorization form (Figure 7).

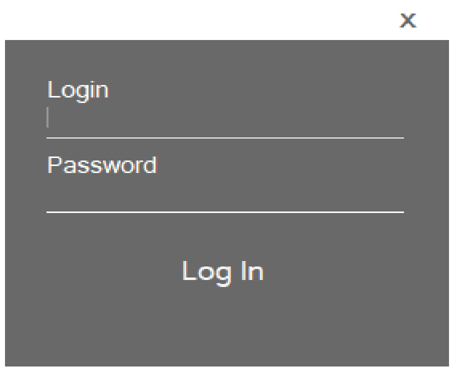


Figure 7: Login

To successfully log in, the user must specify a valid login and password. It is not possible to register in the system, as only the responsible person is able to grant the user access rights to the system.

After logging in, the user has the opportunity to change personal data (see Figure 8). The list of personal data includes:

1) Login;
2) Password;
3) Password confirmation (in case of password change);
4) Date of birth.

After editing any of the above parameters, the changes must be saved using the "Edit" button.

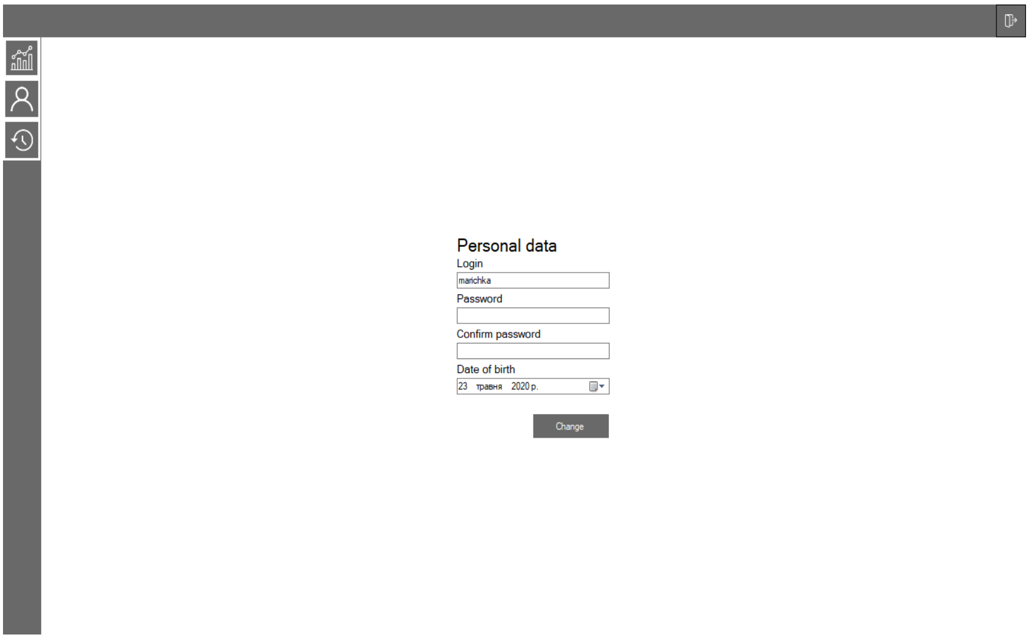


Figure 8: Personal user’s account

To graphically represent the graphs, go to the simulation section (see Figure 9). If this section is sellected, the shift manager has the opportunity to graphically examine the dependence of operator’s state on the sensor at any time. To do this, the calibration of indicator’s values is placed vertically, and the time scale is displayed horizontally. In the case when the value of the indicator exceeds the norm (Equation 6) – the graph will be displayed in red, otherwise – in blue.

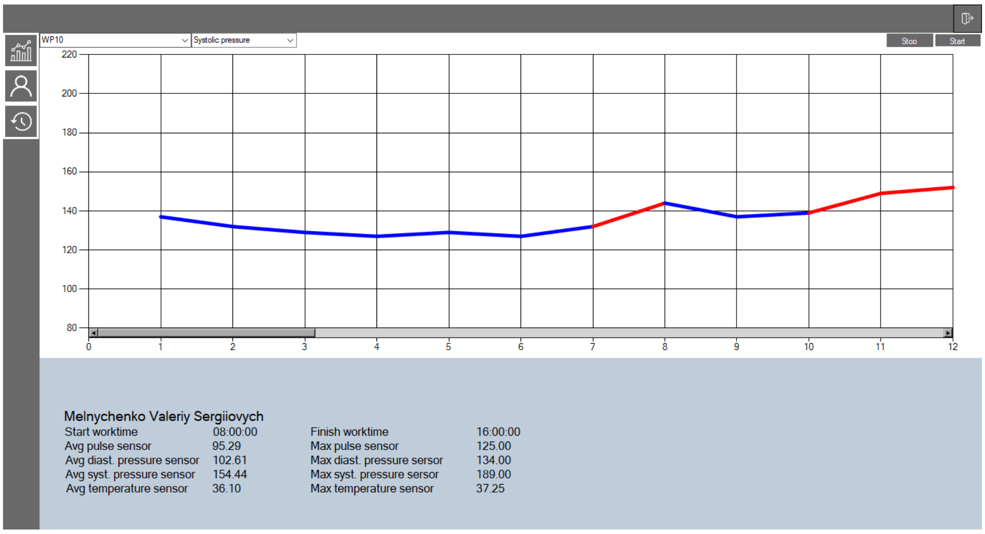


Figure 9: Modeling module

The developed system loads real-time operators into the workplace selection field. From this list it should be chosen the required workplace and specify the sensor’s indicator, then click "Start". The developed system will make a graphical representation of the data from the database, which had been already contained in it before. The pattern of a graph changes in real time according to the data received from a corresponding sensor.

The main purpose of creating this section in the system was to provide an opportunity to quickly assess the operator’s state during the work shift. Statistical data is more suitable for reporting, however, having received such a large amount of data, the manager will not be able to process them quickly and make a decision about efficiency.

In Figure 10 shows the state of the operator in which he is no longer able to make decisions and perform his duties. In this case, the shift manager should make a decision about further work.

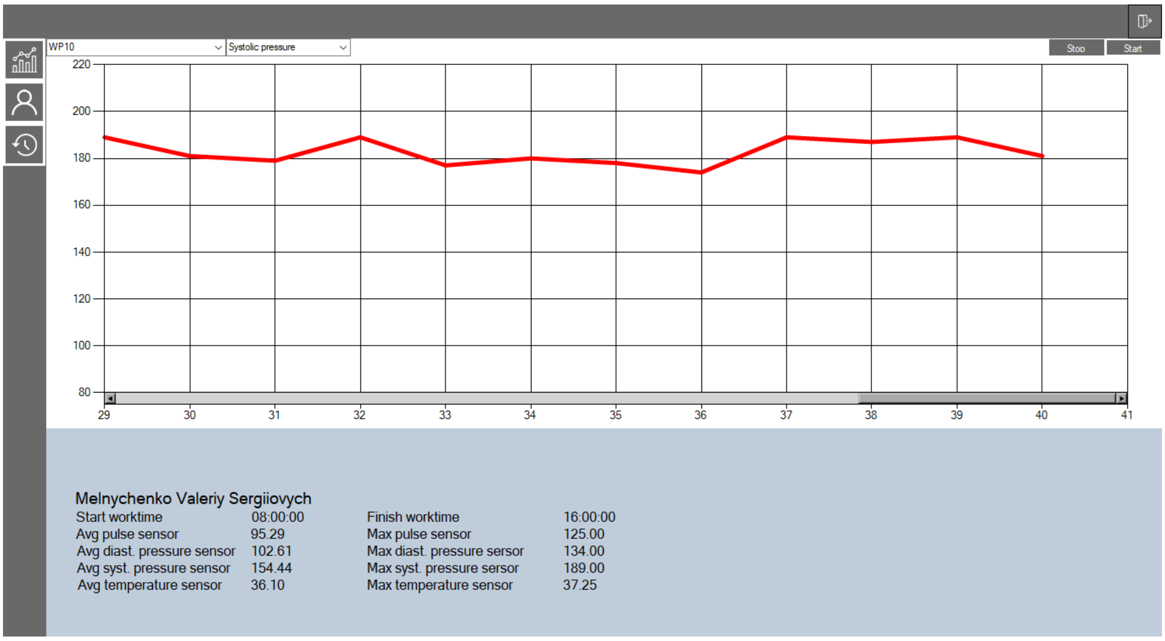


Figure 10: Critical indicator of the operator's state

In case of a stressful situation for a system user will be displayed a notification about the workplace of the operator responsible for resolving this situation and a brief description of the event (see Figure 11). Also, the notification will be displayed when the system decides that the operator's state is not suitable for further work. The workplace number in the notification acts as a pointer to the operator. During system development, was made a decision on the inexpediency of displaying operator's name and surname in this block due to text cumbersomeness and ambiguous identification.

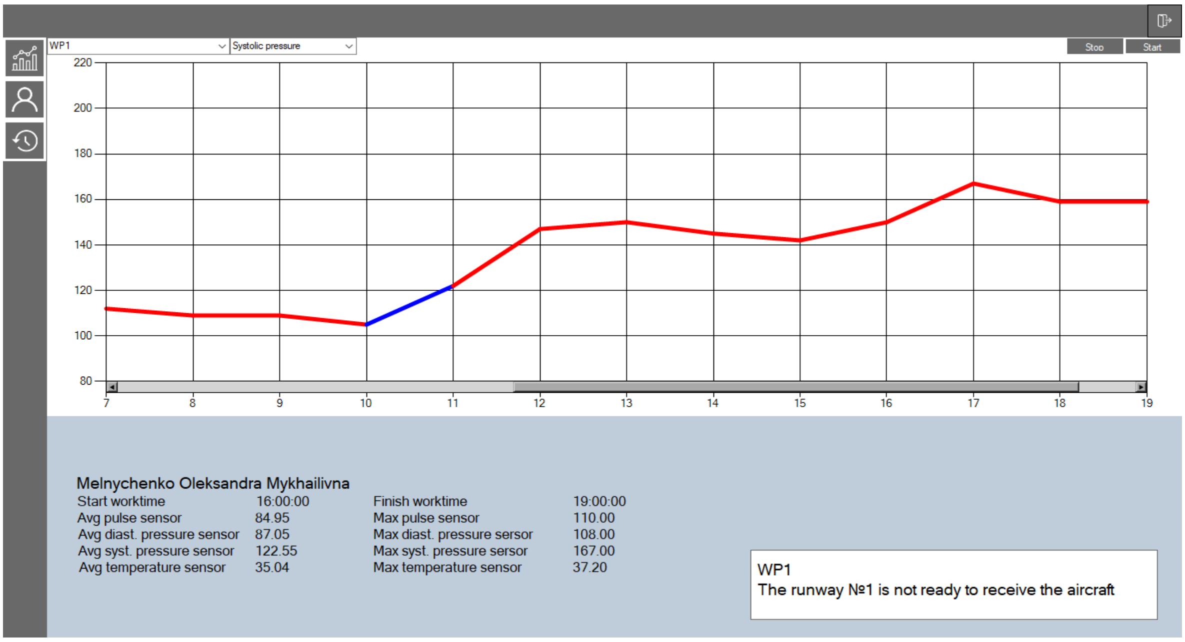
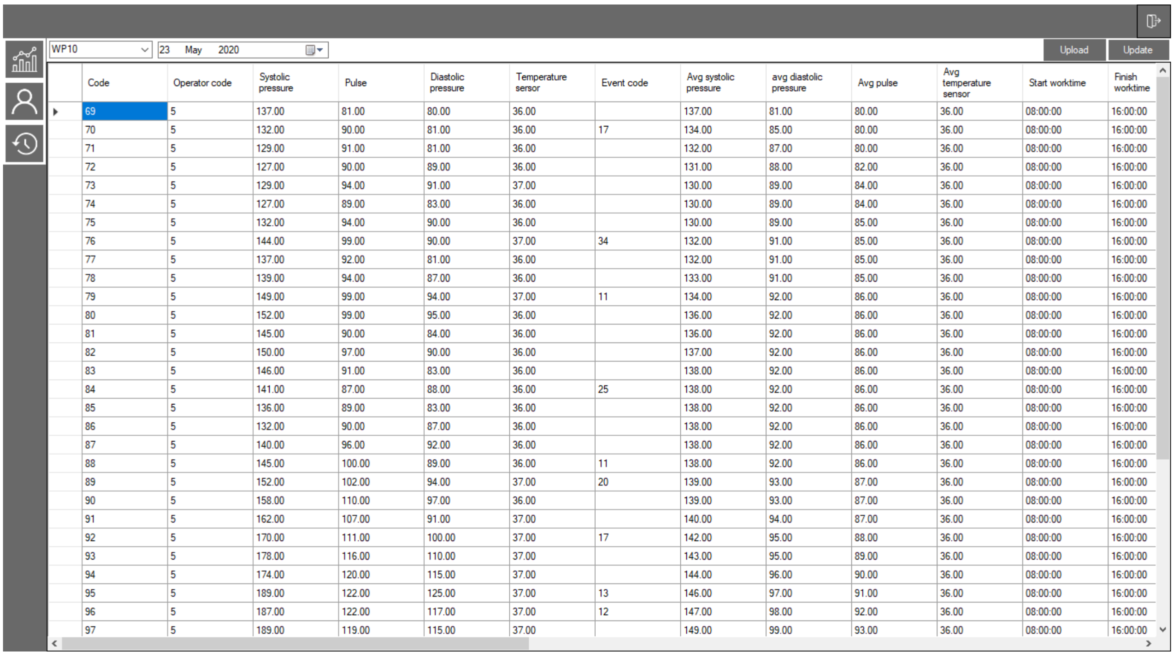


Figure 11: Notifications

The main purpose of the module is to present data in tabular form (see Figure 12) and their grouping by the specified date and operator. By using the scroll bar it is easy to view all the columns in the table.



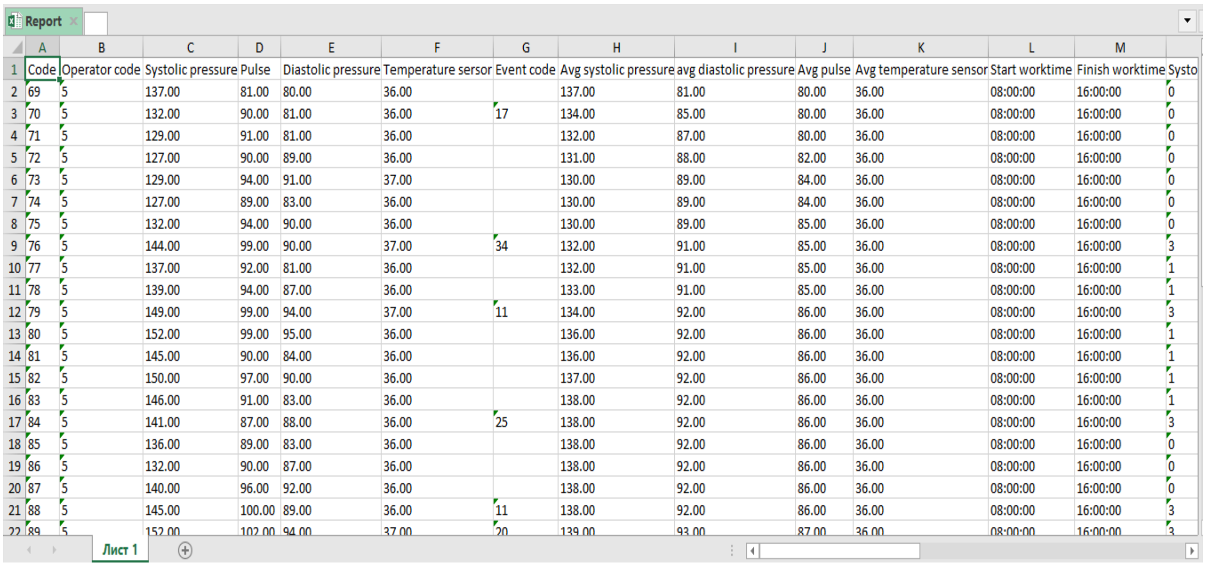
WP10 | 23 May 2020 | Upload | Update

Code	Operator code	Systolic pressure	Pulse	Diastolic pressure	Temperature sersor	Event code	Avg systolic pressure	avg diastolic pressure	Avg pulse	Avg temperature sensor	Start worktime	Finish worktime
69	5	137.00	81.00	80.00	36.00		137.00	81.00	80.00	36.00	08:00:00	16:00:00
70	5	132.00	90.00	81.00	36.00	17	134.00	85.00	80.00	36.00	08:00:00	16:00:00
71	5	129.00	91.00	81.00	36.00		132.00	87.00	80.00	36.00	08:00:00	16:00:00
72	5	127.00	90.00	89.00	36.00		131.00	88.00	82.00	36.00	08:00:00	16:00:00
73	5	129.00	94.00	91.00	37.00		130.00	89.00	84.00	36.00	08:00:00	16:00:00
74	5	127.00	89.00	83.00	36.00		130.00	89.00	84.00	36.00	08:00:00	16:00:00
75	5	132.00	94.00	90.00	36.00		130.00	89.00	85.00	36.00	08:00:00	16:00:00
76	5	144.00	99.00	90.00	37.00	34	132.00	91.00	85.00	36.00	08:00:00	16:00:00
77	5	137.00	92.00	81.00	36.00		132.00	91.00	85.00	36.00	08:00:00	16:00:00
78	5	139.00	94.00	87.00	36.00		133.00	91.00	85.00	36.00	08:00:00	16:00:00
79	5	149.00	99.00	94.00	37.00	11	134.00	92.00	86.00	36.00	08:00:00	16:00:00
80	5	152.00	99.00	95.00	36.00		136.00	92.00	86.00	36.00	08:00:00	16:00:00
81	5	145.00	90.00	84.00	36.00		136.00	92.00	86.00	36.00	08:00:00	16:00:00
82	5	150.00	97.00	90.00	36.00		137.00	92.00	86.00	36.00	08:00:00	16:00:00
83	5	146.00	91.00	83.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00
84	5	141.00	87.00	88.00	36.00	25	138.00	92.00	86.00	36.00	08:00:00	16:00:00
85	5	136.00	89.00	83.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00
86	5	132.00	90.00	87.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00
87	5	140.00	96.00	92.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00
88	5	145.00	100.00	89.00	36.00	11	138.00	92.00	86.00	36.00	08:00:00	16:00:00
89	5	152.00	102.00	94.00	37.00	20	139.00	93.00	87.00	36.00	08:00:00	16:00:00
90	5	158.00	110.00	97.00	36.00		139.00	93.00	87.00	36.00	08:00:00	16:00:00
91	5	162.00	107.00	91.00	37.00		140.00	94.00	87.00	36.00	08:00:00	16:00:00
92	5	170.00	111.00	100.00	37.00	17	142.00	95.00	88.00	36.00	08:00:00	16:00:00
93	5	178.00	116.00	110.00	37.00		143.00	95.00	89.00	36.00	08:00:00	16:00:00
94	5	174.00	120.00	115.00	37.00		144.00	96.00	90.00	36.00	08:00:00	16:00:00
95	5	189.00	122.00	125.00	37.00	13	146.00	97.00	91.00	36.00	08:00:00	16:00:00
96	5	187.00	122.00	117.00	37.00	12	147.00	98.00	92.00	36.00	08:00:00	16:00:00
97	5	189.00	119.00	115.00	37.00		149.00	99.00	93.00	36.00	08:00:00	16:00:00

Figure 12: History module

To optimize the analysis process, the manager changes the operator's state in the history table with the values calculated by Equations (1) - (4). These formulas were applied to all values from the sensors to tabulate the operator's state.

If the user views the information received in real time, it is enough to click the "Refresh" button to update it. If needed, it is also possible to upload a file in Excel format (see Figure 13) for further operations by clicking "Upload".



Report

	A	B	C	D	E	F	G	H	I	J	K	L	M	
1	Code	Operator code	Systolic pressure	Pulse	Diastolic pressure	Temperature sersor	Event code	Avg systolic pressure	avg diastolic pressure	Avg pulse	Avg temperature sensor	Start worktime	Finish worktime	Systo
2	69	5	137.00	81.00	80.00	36.00		137.00	81.00	80.00	36.00	08:00:00	16:00:00	0
3	70	5	132.00	90.00	81.00	36.00	17	134.00	85.00	80.00	36.00	08:00:00	16:00:00	0
4	71	5	129.00	91.00	81.00	36.00		132.00	87.00	80.00	36.00	08:00:00	16:00:00	0
5	72	5	127.00	90.00	89.00	36.00		131.00	88.00	82.00	36.00	08:00:00	16:00:00	0
6	73	5	129.00	94.00	91.00	37.00		130.00	89.00	84.00	36.00	08:00:00	16:00:00	0
7	74	5	127.00	89.00	83.00	36.00		130.00	89.00	84.00	36.00	08:00:00	16:00:00	0
8	75	5	132.00	94.00	90.00	36.00		130.00	89.00	85.00	36.00	08:00:00	16:00:00	0
9	76	5	144.00	99.00	90.00	37.00	34	132.00	91.00	85.00	36.00	08:00:00	16:00:00	3
10	77	5	137.00	92.00	81.00	36.00		132.00	91.00	85.00	36.00	08:00:00	16:00:00	1
11	78	5	139.00	94.00	87.00	36.00		133.00	91.00	85.00	36.00	08:00:00	16:00:00	1
12	79	5	149.00	99.00	94.00	37.00	11	134.00	92.00	86.00	36.00	08:00:00	16:00:00	3
13	80	5	152.00	99.00	95.00	36.00		136.00	92.00	86.00	36.00	08:00:00	16:00:00	1
14	81	5	145.00	90.00	84.00	36.00		136.00	92.00	86.00	36.00	08:00:00	16:00:00	1
15	82	5	150.00	97.00	90.00	36.00		137.00	92.00	86.00	36.00	08:00:00	16:00:00	1
16	83	5	146.00	91.00	83.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00	1
17	84	5	141.00	87.00	88.00	36.00	25	138.00	92.00	86.00	36.00	08:00:00	16:00:00	3
18	85	5	136.00	89.00	83.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00	0
19	86	5	132.00	90.00	87.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00	0
20	87	5	140.00	96.00	92.00	36.00		138.00	92.00	86.00	36.00	08:00:00	16:00:00	0
21	88	5	145.00	100.00	89.00	36.00	11	138.00	92.00	86.00	36.00	08:00:00	16:00:00	3
22	89	5	152.00	102.00	94.00	37.00	20	139.00	93.00	87.00	36.00	08:00:00	16:00:00	3

Лист 1

Figure 13: Unloaded Excel file

6. Discussions and Conclusions

In conditions of constant stressors influence on human consciousness, a decision can be ill-considered and made under the influence of emotions. In order to avoid such a situation in the workplace, the head of the enterprise should monitor the condition of an operator. To simplify this process, the information system was developed.

A conceptual model was built to identify causal relationships and properties of system objects using Chen notation. Analyzing the subject environment, the factors of occupational disease formation and the interrelation of working capacity levels with phases of a functional state of a person were investigated.

Based on the conducted numerical experiments, the model of overwork decline was developed to accurately determine the exit from the tension state and the impact of final overworks accumulation on activities of a human operator was described. Based on the proposed Selye's stress classification, a detailed analysis of stress peculiarities and the development of occupational diseases has been developed.

To assess the state of an operator during a work process, the amplitude index of stress resistance, stress index, stress index of reserve costs, the actual stress index are calculated.

The main advantages of the developed system include ease of use, division of functionality into logical sections, presentation of data in graphical and tabular form, the ability to view generated reports and download for further printing. The information system allows to view real-time simulated graphs, which are based on values from the selected sensor. Also, there is the function of analyzing the state of an operator and outputting notifications in case of overwork. The notifications module also displays notifications for the user in case of a stressful situation.

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