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The Influence of Disability on the Traumatism Probability at Workplaces

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ABSTRACT

The article is devoted to the issue of workplace safety of persons with disabilities. Workers with chronic illnesses, injuries or other persistent functional impairments in their health status have the right to work as equal with other workers. At the same time, such work activity is entailed the higher risk of injury. The article aims to develop an approach to assess the level of reliability of a worker with disability to make the decisions on ensuring workplace safety. To achieve this aim, a "disability matrix" was formed, which allows describing in a mathematical form the functional state of the employee, taking into account the revealed life disabilities. Considering the disability matrix as a consecutive and parallel irreparable system, the probability to get an injury by an employee is represented as the sum of failure probability for each life limitation with the proper degree of severity. As a result, the probability to get an injury is defined as the individual risk of an event that takes into account the average traumatism level. The probability to get an injury of workers with medium and low levels of disability was determined, which are in the range of $1.6 \cdot 10^{-3}$-$1.9 \cdot 10^{-3}$ and $0.74 \cdot 10^{-3}$-$1.1 \cdot 10^{-3}$ accordingly.

KEYWORDS: *Safety, Disability, Risk, Trauma, Workplace*

INTRODUCTION

According to the World Health Organization, there are more than 1 billion people with disabilities in the world (World report on disability, 2011). Studies conducted as part of the preparation of the World Report on Disability show that as time goes by, the number of people with chronic functional impairments in their health will increase. The objective facts are the reason for this: an aging population, chronic diseases, armed socio-political and military conflicts, natural disasters, accidents, etc. In Ukraine, the number of people with officially registered disabilities is about 2.6 million people (more than 9% of the population aged 15-64 years) (Ukrstat, 2019). The proportion of persons with disabilities in the structure of the working-age population is constantly increasing. This trend can lead to serious demographic and socio-economic problems, as persons with disabilities are among one of the most vulnerable groups of the population, as a rule, are in a state of social exclusion and unable to ensure a deserved financial position, which is often, despite the support from the direction of the government, leads to their marginalization, increasing of the crime and other undesirable socio-economic aspects.

The organization of employment of this population category is an important socio-economic issue, the solution of which allows not only to ensure the inclusion of persons with

disabilities in the social environment but also to improve their financial position. Besides, persons who have a disability as a result of an accident at work or home are often qualified specialists with deep theoretical knowledge and important professional skills. In this case, the issue of returning such workers to workplaces allows ensuring the enterprises with additional qualified human resources.

In practice, employers experience certain alertness associated with hiring a disabled person. Concerns about the possible increasing the level of injuries at the enterprise are causing the discriminatory aspects, as well as the necessity for additional financial costs associated with the re-equipment of the workplace, taking into account the special needs of this category of workers. It is related to the possible decreasing of efficiency of a worker with a disability and increasing of the probability of injury. Determining of the probability of injury of an employee, taking into account the disability, makes it possible to make management decisions regarding to the choosing of a workplace and its adaptation.

REVIEW OF LITERATURE

The reliability of an employee with a disability is one of the main indicators of the effectiveness of his work, which includes indicators that characterize his ability to perform certain production tasks, and the ability to comply with personal and collective safety requirements. For organizing occupational safety at the workplace of workers with certain disabilities, assessment of the ability to fulfill the requirements of the relevant instructions is an important step in the decision-making by the employer regarding the work placement of the employee.

Recently, there has been an increase in occupational injuries in Ukraine with serious consequences: in 2017, 366 fatal accidents occurred in Ukraine, while in 2019 there were 422 such accidents (Public Service Labor in Ukraine, 2019). These figures are higher than those for the European Union countries: for example, in 2017 in Spain the number of fatal accidents at work amounted to 317, Portugal - 140, Czech Republic - 95, Hungary - 80, Belgium - 59, Slovakia - 43 (Eurostat, 2019). At the same time, the employment of a person with a disability at the workplace in the absence of appropriate safety measures and an incorrect assessment of their functional capabilities can lead to a traumatic or emergency and worsen these statistical indicators. In this regard, workers with disabilities are a vulnerable category requiring special attention in terms of safety.

An analysis of the causes of accidents shows that, to a large degree, their appearance is stipulating the influence of the human factor, which means professional and psychophysiological discrepancy of the characteristics of a person with the requirements that are presented to him by the production process. In the case of employment of a person with a disability, there is initially a discrepancy between the characteristics of the executor and the requirements of the work process and the workplace. In this case, the task is to minimize this discrepancy and increase the level of reliability of a worker with a disability.

The work (Kaygisiz, 2018), emphasizes the importance of ensuring compliance of people with disabilities and the requirements of the working environment, which leads to an increase in safety, health and overall productivity of the production system. Compliance of the workplace and the psychophysiological characteristics of the employee is achieving by using

a complex of organizational and technical measures and means aimed at adapting the working environment based on the studying of special needs.

The problem of ensuring workplace safety for persons with disabilities is a key issue not only for employers but also for workers. The paper (Leber et al., 2018) presents the results of a survey conducted among workers with disabilities in three countries: the United Kingdom, Poland, and Slovenia. The results of the research showed that workers with disabilities are concerned about the working conditions at their workplaces in terms of ensuring their safety, which was confirmed by multiple correlation analysis.

A dangerous trend in the labor market is the fact that technological progress, the constant development of information technologies and the growth of automation leads to a decrease of the number of workplaces where simple operator activity is required, and a constant complication of production processes at workplaces related to maintenance of equipment. Thus, increased demands are placed on the human-operator, not only in terms of the level of qualification but also of psychophysiological characteristics (European Agency for Safety and Health at Work, 2009).

The influence of the human factor on the safety level is determined by several characteristics, the main of which are: psychophysiological characteristics of a person; experience, education, professional skills and technique of carrying out the work; age; the severity and intensity of work, affecting at the fatigue accumulation. In (Newman et al., 2018), based on an analysis of the influence of factors on the level of injuries, it was concluded that the following reasons are prevailing: the intensity of work due to the necessity to ensure a high level of productivity, fatigue and insufficient work experience.

Often the lack of the necessary level of education, production skills, work experience, and effective mechanisms to prevent the realization of dangers connects with the human factor, leads to an increased risk of injury and other adverse consequences. In (Breslin et al., 2018), it is emphasizing that, due to an insufficient level of education, despite significant vulnerability, workers with disabilities often work in adverse conditions, which increases the risk of injury. Therefore, employers should develop and implement efficient procedures to reduce the risk of injury of workers with disabilities.

The development of these procedures should base on researches on the features of the "human-operator with disability - workplace" system, as well as the reliability of the employee as an effective executor of work tasks in the context of industrial safety.

The role of the human-operator in the "human-machine" system (Lys & Soldatov, 2016) describes by such indicators as speed, reliability, and intensity of activity. Moreover, the reliability of the human-operator is characterizing by his ability to perform the functions assigned to him for a preset time without failure. At the same time, the authors consider the failure as a complete or partial loss of workability, as a result of which a person ceases to satisfy the requirements of effectiveness. This approach does not allow considering an employee with a disability as a full-fledged participant of the work process since disability initially implies certain life limitations. Besides, in the article, within the framework of the classification of reliability, along with its types such as psychological and physiological, the term "demographic reliability" is used, which is characterized by the authors as the reliability in the aspect of residual failures (aging, trauma with disability, death). This approach is not only discriminatory but also non-constructive since the reliability of the human-operator is an

integral indicator, which should consider in the context of the potential capabilities of the person performing the operator's actions.

The paper (Khvorost et al., 2018) discusses aspects of the reliability of a human-operator with persistent disabilities, which can be characterized by the probability of no-failure operation. In this case, failure means both a malfunction of production functions and the creation of a traumatic and emergency at the workplace. At the same time, failures are categorized depending on the group of disabilities that are present of an employee with a disability: the ability to self-service, move, orientate, control their behavior, communicate, learn, and perform work.

To estimate the risk of production activities in an article (Kasianov et al., 2016), at analyzing the components of the concept of "production system", it proposes to use the failure intensity rate indicator as to the most convenient for determining quantitative reliability indicators by the criterion of the probability of their failure-free operation. It notes that this approach is consistent with the recommendations of the International Labor Organization on improving the OSH management system for all types of production activities to manage production risks.

When assessing the reliability of a human operator, in an article (Yasynetskyi et al., 2018) it is proposed to use the following aspects of his activity: purposeful behavior in the human-operator activities; a variety of elements that are involved in the technological process; correlation of mental planning and performing functions; the ability to choose a different algorithm of actions when changing the production situation. The criterion for the optimal construction of the "human-machine" system is the permissible density of the incoming information stream. This criterion can be selected based on the condition that the waiting time for signal processing by the operator with a given probability does not exceed the permissible value.

Thus, the concept of human-operator reliability in the "human-machine" system is multifaceted and can be considered both for optimizing the production process and to ensure the system safety.

PURPOSE AND RESEARCH TASK

To reduce the risk of an emergency or accident, it is necessary to assess and ensure the appropriate level of reliability of a person with a disability as an executor of certain production functions and to prevent the realization of dangers associated with the human factor.

To achieve the necessary indicators of the reliability of the human operator, it is important to his capabilities adequately assess to carry out work activities safely and effectively.

The study aims to assess the functional state of an employee with a disability according to criteria characterized the limitations of his life activity, and characterize his level of reliability as a human-operator to form an information base for making managerial decisions on choosing a workplace and adapting it to ensure the safety of work processes

METHODOLOGY

In the aspect of studying the safety and work efficiency of persons with disabilities, as the basic reliability indicator can use the non-failure indicator, but, from a practical point of view, it is more reasonable to consider the probability of failure as an indicator that characterizes a decrease the safety level and efficiency of the work process.

In the concerned case, when researching the safety issues of the operator activities of a disabled employee, failure means an erroneous action that is associated with the risk of injury to the employee or other persons, as well as other unfavorable outcomes due to the functional state of the employee.

In a situation where it is necessary to assess the state of a person with a disability, a three-stage system for assessing persistent functional disorders of a human can be used according to the degree of manifestation of vital functions criteria, including the ability to (Danova, 2018): self-service, which means the ability to perform effectively the social and domestic functions without the help of others; movement (the ability to move effectively in surroundings (walking, running, overcoming obstacles, using personal and public transport)); orientation (the ability to navigate independently in space and time, to have an idea of the surrounding objects; the main orientation systems are vision and hearing (on conditions that the normal state of mental activity and speech)); control of behavior (the ability to demonstrate behavior following the moral, ethical and legal norms of the public environment); communication (the ability to make contacts with other people and maintain social relationships (excepting communicative disorders associated with a disorder of mental activity)); studying (the ability to perceive, assimilate and accumulate knowledge, to form skills and abilities (domestic, cultural, professional and others) in a focused learning process); carrying out of work activity, i.e. the totality of the physical and spiritual capabilities of a person, determined by the state of health, which allows fulfilling various types of work activity.

This approach bases on determining the degree of disability. The degree of limitation of life activity is the amount of deflection from the norm of human activity according to the criteria described above. Three degrees of disability can be using: moderately pronounced, pronounced, significant, that is conditioning a certain disability group.

A moderately pronounced limitation of life activity causes by malfunctions of organs and systems of the body, which lead to a moderate restriction of learning, communication, orientation, and control over one's behavior, movement, self-care, and participation in work activity.

Pronounced limitation of life activity is causing by malfunctions of organs and systems of the body, which consists of a pronounced malfunction of the possibility to learn, communicate, orientate, control of one's behavior, move, self-care, and participation in work activity. When moderately pronounced or pronounced life restriction, a person can perform professional activities in the conditions of production, but, as functional disorders are pronouncing, the workplace and the work process will require the implementation of adaptation and safety measures.

A significant limitation of life activity is causing by malfunctions of organs and systems of the body, which leads to the impossibility of significant malfunction of the ability to learn,

communicate, orientate, control one's behavior, move, self-care, participate in work activity, and is accompanied by the necessity of outside care (outside help). Employment of persons with significant disabilities can be carried out at home or in specialized institutions.

For each of the above criteria, the degree of limitation of life activity determines, which characterizes the magnitude of the deviation from the norm of human activity. In this case, the conclusions of the corresponding medical commissions, as well as various test methods, can be used.

Thus, a person who has significant functional impairment according to the criteria of self-care, movement, orientate in the surrounding, control of his behavior, communication, training, as well as employment, will have a disability group I, while persons with moderate and severe restrictions may be assigned to II or III groups according to the results of the assessment of their functional state.

This information is documented and is available to the employer, as well as to another person making managerial decisions on the organization of the workplace and the technological process of an employee with a disability in production conditions.

In the process of assessing the functional state of a person, depending on the degree of manifestation of the criteria, the degree of loss of professional ability in percent can be determined (Table 1).

Table 1: Determination of the degree of loss of professional ability

Functional state	Disability group	Percentage of loss of professional ability, %
Complete loss of self-care ability and the necessity in constant care or assistance	I	85 - 100
Pronounced malfunctions of the body, leading to a significant limitation of life activity at the maintaining the ability to self-care, and the absence of necessity of constant outside care or help	II	65 - 80
Moderately pronounced malfunctions of the body with the maintaining the ability to continue professional activity	III	30 - 60

For an employer who needs to organize a workplace for an employee with a disability and ensure the safety of the work process, it is important to have information about the degree of discrepancy of the employee with requirements that are determined by the specifics of work tasks, equipment, and the risk of injury. On the one hand, the degree of discrepancy can be judged directly by the disability group, but it is not enough since persons assigned to the same disability group are different in functional indicators.

Table 2: Matrix of life activity limitations for worker with disabilities

Categories of life activity limitations, u_p	Degree of manifestation of criteria of life activity limitations, k_j		
	degree I – moderately pronounced, k_1	degree II– pronounced, k_2	degree III– significant, k_3
Self-service, u_1	$u_1\ k_1$	$u_1\ k_2$	$u_1\ k_3$
Unassisted movement, u_2	$u_2\ k_1$	$u_2\ k_2$	$u_2\ k_3$
Orientation, u_3	$u_3\ k_1$	$u_3\ k_2$	$u_3\ k_3$
Communication, u_4	$u_4\ k_1$	$u_4\ k_2$	$u_4\ k_3$
Control of behavior, u_5	$u_5\ k_1$	$u_5\ k_2$	$u_5\ k_3$
Ability to studying, u_6	$u_6\ k_1$	$u_6\ k_2$	$u_6\ k_3$
Ability to work activity, u_7	$u_7\ k_1$	$u_7\ k_2$	$u_7\ k_3$

Thus, the system for assessing the functional state of a person, which includes the criteria of life activity and the degree of their manifestation, can be represented in the form of a matrix $\|E_{pj}\|$ (Danova & Malysheva, 2018):

$$\|E_{pj}\| = \{u_p, k_j\}, \quad (1)$$

u_p - categories of life activity limitations
k_j - degree of manifestation of criteria of life activity limitations.
This disability matrix can useindication functional state of a particular employee with disabilities. For example, following the conclusions of the medical and social expert commission for a worker who has a disability group II with a diagnosis of discirculatory encephalopathy due to internal brain injury, the following life activity restrictions are defining: the degree of restriction on self-service - I, on movement - I, on communication - II, on the ability to work – II. Using table 2, this functional state of the employee can be represented:

$$E_{pj_1} = \{1u_1, 1u_2, 2u_4, 2u_7\}. \quad (2)$$

Similarly, for the second employee, who had also had as the second disability group for general illness due to ischemic heart attack, the following life activity restrictions were determined: the degree of restriction on self-service - II, on movement - II, on the ability to work - II, the functional state is characterizing by the formula:

$$E_{pj2} = \{2u_1, 2u_2, 2u_7\}. \quad (3)$$

Thus, with the same disability group, these workers have differences in the number and degree of manifestation of criteria to limit life activity, which affects their reliability as operators, as well as the safety level of production activities.
The matrix of life activity limitations for an employee with a disability (Table 2) can represent a consecutive and parallel irreparable system (Figure 1).

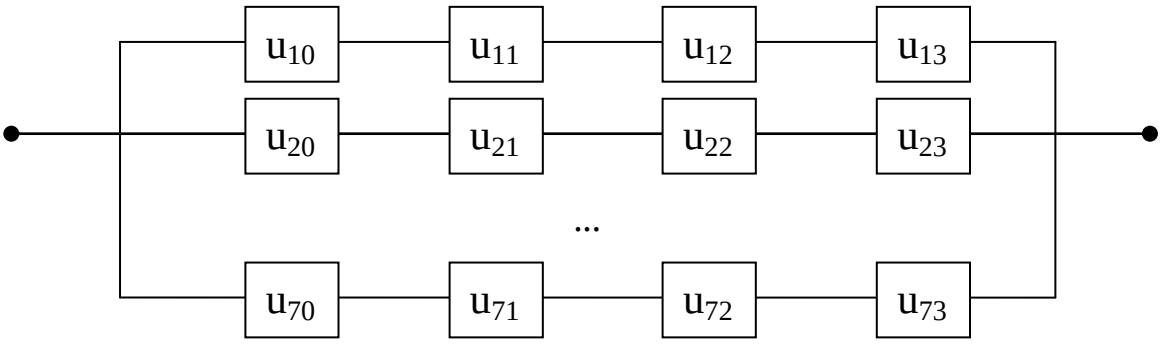

Figure 1: The block diagram characterized the functional state of a human-operator

In the block diagram (Fig. 1), blocks u_{10} - u_{70} characterize the employee's lack of persistent functional changes in the state of health recorded by the medical and social expert commission. The remaining blocks correspond to the matrix of disabilities for an employee with special needs (Table 2).

The probability of failure of a human-operator with a disability considers as an independent random event, which is defined as the sum of the probabilities of failure according to the criteria of life activity, describing the functional state of an employee with a disability. For the scheme (Fig. 1), the failure characterizes by the formula

$$Q_u(t) = \sum_{p=1}^{7} \sum_{j=1}^{4} \left(1 - P_{u_{pj}}(t)\right), \quad (4)$$

where P_{upj} – the probability of failure of a human-operator with disabilities over a period of time t;

p – category of life activity limitation of a human-operator;

j – degree of manifestation of the criteriaof life activity limitation of the human-operator.

This approach can be used to assess the probability to get an injury by an employee, using the example of enterprises in the processing industry.

The processing industry, which includes metallurgical and machine-building enterprises, light industry, and other industries related to the processing of raw materials, is one of the five most traumatic areas in Ukraine. Technological processes and equipment used in enterprises represent a significant danger for workers. Significant physical and moral aging of equipment, the imperfection of technological processes creates the preconditions to get the injury for employees, maiming and occupational diseases, therefore the employment of workers with disabilities in enterprises in this industry must be carried out taking into account heightened precautionary measures.

In the general case, using the available statistical information on cases of injuries associated with the influence of production factors at processing enterprises (Ukrstat, 2019), it can be determined that the probability of injury by an employee is determining by individual risk and calculates as

$$Q_h = R = \frac{n}{N}, \quad (5)$$

where n – the number of people injured in accidents, 1106 persons in a year;
N – the average annual number of workers employed in the industry, is taken equal to 1355.75 thousand people.

Thus, the probability of injury of an industry employee is $8.2 \cdot 10^{-4}$, accordingly, the probability of work without injury is P = 0.99918.

Using the table 1, the values of the coefficients k_j are predetermined as the median of the range of the percentage of loss of professional workability for each disability group:

$$k_j = d_{1j} + \frac{d_{2j} - d_{1j}}{2}, \quad (6)$$

where d_{1j}, d_{2j} – beginning and end of the j-range of the percentage of loss of professional work ability; $k_0 = 0$; $k_1 = 0.45$; $k_2 = 0.73$; $k_3 = 0.93$.

Using formulas (4-5), the formula that characterizes the probability of a human operator's failure is written taking into account the limitations of life activity that affect the functional state, in the form

$$Q_u(t) = Q_h(t) \sum_{p=1}^{7} (k_1 u_{pI} + k_2 u_{pII} + k_3 u_{pIII}), \quad (7)$$

where u_{pI}, u_{pII}, u_{pIII} – the p-th significant category of the limitations of life activity I, II and III degrees, respectively.

Using this formula, the probability of failure could define for the cases of disability of workers considered above, the functional state of which is characterizing by formulas (2-3). In the first case the probability of failure, accompanied by injury to the employee, will be 0.0019, and in the second case, 0.0018.

In the situation of employment and matching a workplace for an employee with a disability, the employer or other person who makes a managerial decision should assess the functional state of the person and the risk of injury, which increases as a result of the employee's life activity limitations, according to which disability is establishing.

RESULTS

The proposed approach in assessing the influence of the functional state of a human-operator on the probability of failure, which is understood to mean injury or mutilation of a significant degree of severity, which is the basis of investigation of an accident at an enterprise, allows obtaining and forming a certain information base for making managerial decisions. Having a list of categories of disabilities, as well as the degree of their manifestation, it is possible to present this information in the form of a mathematical tuple (formulas 2-3) and in the future, using formula (7), determine the probability of failure.

Formula (7) characterizes the contribution of each of the life activity limitations to the probability of failure of a human-operator, accompanied by injury, taking into account the basic level of injury in the industry.

On fig. 2 in a graphical form, the information about the change in the probability of injury of a worker with a disability depending on the increase of the number of life activity limitations of I or II degree is presented. The III degree of life activity limitation is not considered due to the fact that people with significantly expressed life activity limitations are practically not involved in performing work in real production conditions.

The graph shows that increasing the degree of manifestation of life activity limitations leads to an increase in the probability to get an injury by 1.6 times. However, the situation presented in Fig. 2, can only be theoretically. In practice, an employee may be observed with the cases of disability of various degrees of manifestation.

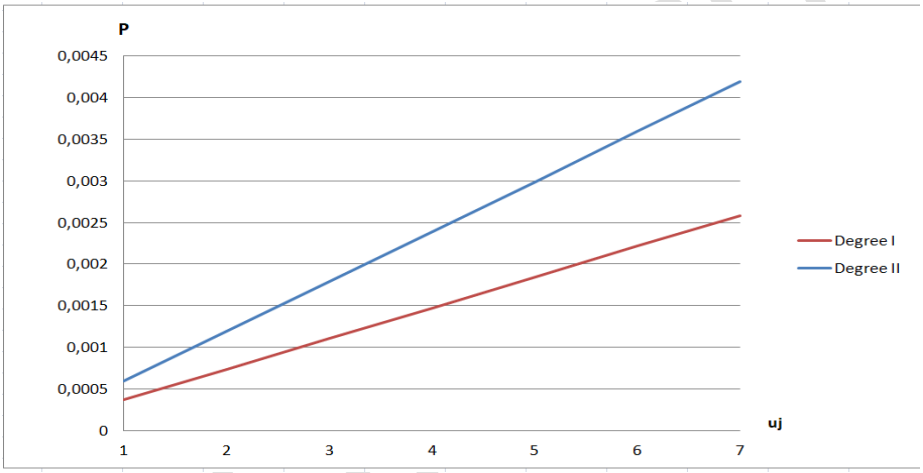

Figure 2: The probability of injury of a worker with a disability, depending on the manifestation of the categories of life activity limitations

This makes it difficult to make managerial decisions when it is necessary to compare the functional conditions of two or more persons with disabilities of the same disability group, but with different combinations of categories of life activity limitations and degrees of their manifestation.

Examples of using this methodology are given in the table. 3.

Table 3: Examples of assessing the probability to get injury depending on the functional state of the employee

Disability group	Disease	Formula of functional state	Probability to get injury
II	Diabetes mellitus of I type with affection of internals	$\{2u_1,1u_2,2u_7\}$	$1.6\cdot10^{-3}$
II	Oncological illness of larynx	$\{2u_1,2u_2,2u_7\}$	$1.8\cdot10^{-3}$
II	Dyscirculatory encephalopathy of 2 degree	$\{1u_1,1u_2,2u_4,2u_7\}$	$1.9\cdot10^{-3}$

III	Dyscirculatoryencephalopathyof 2 degree	$\{1u_1,1u_2,1u_7\}$	$1.1\cdot10^{-3}$
III	Insulin-dependent diabetes	$\{1u_2,1u_7\}$	$0.74\cdot10^{-3}$

The presented table shows that, with the same disease, workers may have different disability groups and different probabilities of failure due to differences in the number and degree of manifestation of life activity limitations criteria.

Thus, the use of the proposed methodology for assessing the functional state of a human-operator allows obtaining the values of the probability of failure, characterized by injury, depending on the number of life activity limitations criteria and the degree of their manifestation. This information can be used when deciding on the employment of an employee with a disability at the workplace to reduce the probability of origin in the traumatic situation.

DISCUSSION

When decision-making about choosing the workplace for an employee with a disability, it is important to take into account his functional state to reduce the possibility of occurrence of a traumatic or emergency caused by a mismatch between the requirements of the workplace and the technological process to the state of human health.

The approach proposed in the article allows creating an information base regarding persons with disabilities who work at the enterprise to ensure rational employment and reduce injuries level.

It should be noted that it is advisable to adapt this technique according to the context of the enterprise since it is necessary to take into account the particular requirements for the human operator from the side of the workplace and the technological process. For this, the enterprise can establish ranges of acceptable failure probabilities for each workplace technological process or structural unit.

Also, this technique can be developed in the direction of identifying the employee's discrepancy with the requirements of the workplace and technological process. In this case, it is possible to specify the weights of certain categories of life activity limitations and obtain the result that takes into account not only the functional state of the human operator but also the requirements of the production process. This approach can be implemented, for example, in the form of neural networks.

CONCLUSIONS

The problem of ensuring the employment of persons with disabilities, as well as older people, is one of the central issues in the context of existing demographic trends. Therefore, studies aimed at improving the reliability of executors of production tasks, including persons with persistent functional impairments in their health state, are in the focus of the attention of the scientific community.

The employment of a person with a disability is associated with an increased risk of injury, therefore, it should organize taking into account the life activity limitations that are due to his health state.

The functional state of the employee plays an important role in ensuring the safety of production processes. International law guarantees the employment of persons with disabilities, while the employment of a person with life activity limitations at the workplace creates the prerequisites for an increase of the level of accidents and injuries.

Assessment of the functional state of a person with a disability can be proceeded according to a list of criteria that determine the life activity limitations, taking into account their manifestation. The employer, who is generally responsible for ensuring the safety of workers at the workplace, based on this limited information, must make a deliberate managerial decision on the employment of a person with a disability in a particular workplace, as well as the necessity to equip with additional protection frames. This determines the necessity of developing the new approaches in decision making on the organization of employment of an employee with a disability.

The article proposes a methodology for assessing the functional state of a human-operator by forming a disability matrix that takes into account the life activity limitations of a person with a disability and degree of its manifestation.

Basing on this matrix, it is possible to compile a functional characteristic of a person with a disability in the aspect of life activity limitations in the form of a mathematical tuple. In the future, by setting the degree of manifestation of the criteria of life activity limitations by coefficients characterizing the percentage of loss of professional workability, taking into account the average probability of injury by an employee, determined by the amount of individual risk, it is possible to obtain the probability of an employee with a disability injuring at the workplace.

As a result of applying the methodology on the example of processing industry enterprises, it determined that increasing the degree of manifestation of the category of life activity limitations from I to II leads to an increase of the probability of injury on average 1.6 times, which must be taken into account when choosing a workplace to reduce the probability of injuries and accidents at the enterprise.

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