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IDENTIFICATION OF ERGONOMIC HAZARDS AND RISK ASSESSMENT FOR THE WORKPLACE OF OPERATOR OF A BUCKET-WHEEL EXCAVATOR - CASE STUDY

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Abstract The subject of this paper is the identification of hazards for the workplace of the operator of bucket-wheel excavator, as well as risk assessment. The original HRN (Hazard Rating Number) method was used to assess the risk. The modification that has been proposed in this paper consists of determining the MPL_i values for each identified hazard. This means that risk assessment in line with this new approach involves calculating more than one MPL value. In this way, unlike the classical approach, the variety of hazards in intensity or quantity over time is taken into account. In addition, this new approach takes into account the exposure time of workers. In this way, the effect of different consequences on the health of workers for each identified hazard is included. This further allows a preventive/corrective strategy to be developed depending on the calculated HRN_i values. It also opens the possibility to apply adequate corrective action depending on the current situation, which provides significant savings in the system. In this way, the company's management has a number of strategies at its disposal that it can activate in the event of a change in the situation.

Keywords: Hazards; risk assessment; ergonomics; excavator; HRN method.

1. INTRODUCTION

The subject of this paper is the hazards at the workplace of the operator of the bucket-wheel excavator SRs 1200x24/4, which is used for excavating tailings in surface coal mining. This bucket-wheel excavator is used in the Kolubara Mining Basin in Serbia. The Kolubara Mining Basin is a branch of the Electric Power Industry of Serbia that provides coal for thermal power plants, as well as for heating households.

The workplace of the operator who operates the bucket-wheel excavator is in the cab of the excavator. With that in mind, special attention will be paid to the identification of ergonomic hazards. After the first step, which consists in identifying the hazards that are present in this workplace, the second step will assess the risk, taking into account the identified hazards. One of the emphasis will be on improving the risk assessment method that will be used in this paper.

2. METHOD

In order to realize this study, two methods were used. The method of observation was primarily used to identify hazards to the bucket-wheel excavator operator's workplace. The HRN (Hazard Rating Number) method was used to assess the risk for the bucket-wheel excavator operator's workplace.

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However, as mentioned, one modification of this method will be applied, which will be described below.

The HRN method involves, among other things, determining the MPL (Maximum Probable Loss) factor. Usually, for a certain hazard, this factor is determined only for the most severe form of injury or disease that can be caused by the observed hazard. Although not wrong, this approach has certain drawbacks. The main disadvantage is that the previous approach did not take into account the intensity of the source of hazard if it can vary in the specific case (for example, noise level), as well as the exposure time of workers (eg one hour during the working week, or the whole working day of an operator). In cases where variations of hazard are possible in intensity and duration, there are different effects on the health and safety of workers. Therefore, the measures that the employer is obliged to take in order to reduce or eliminate the danger are also different. This also causes different costs of intervention, as well as a different period of time until preventive measures must be taken to reduce the risk.

In order to take into account factors such as changes in the intensity of the hazard source and the time of exposure, the HRN method was modified by determining as many numbers of MPL values for a particular hazard, as it is necessary. For example, if the existing operating mode of the machine induces less dust, the health risk is usually low and includes fewer respiratory problems. In that case, it is necessary to calculate the MPL_1 value. However, if it can be reasonably assumed that in some period there will be a change in the mode of operation of the machine (for example due to higher production or change of material being processed) so that dust increases, then the MPL_2 value corresponding to such operating conditions should be calculated. It is understood that both the type of corrective action and the time of its implementation will be in accordance with the calculated values for MPL_i.

3. RESULTS

The results obtained on the basis of the application of the observation method will be presented here. Figure 1 shows the bucket-wheel excavator that is the subject of this study.

Figure 1. Bucket-wheel excavator SRs 1200x24/4.

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Figure 2 shows the cabin of the operator who operates the bucket-wheel excavator for excavating tailings in surface coal mining.

Figure 2. Control cabin of SRs 1200x24 /4 bucket-wheel excavator.

Figure 3 shows the usual body position of the operator during the operation of the bucket-wheel excavator.

Figure 3. Usual working position of the bucket wheel excavator operator.

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In Figure 2, on the right side of the control panel, the control organs are arranged, by means of which the operator assigns control actions to the bucket-wheel excavator. On the left side there is a control panel, on which there are displays, which serve to monitor the vital parameters for the operation of the machine. Among others, there is a display that shows the state of overload of the bucket-wheel excavator. In the front center part of the cab, there is an operator's chair that cannot be rotated.

A table with hazards grouped by hazard types was used to identify hazards [1]. Since the subject of consideration is the operator's cabin, the emphasis is on the identification of ergonomic hazards. The first danger that can be noticed in Figures 2 and 3 is the inadequate placement of controls and indicators. The design of the controls and indicators is inappropriate, as the controls and indicators are placed laterally in relation to the operator, at an angle of 90^0 degrees or more in relation to the line of sight of the operator. Some of the controls and displays are out of visual angle, so it is necessary for the operator to turn itself in the chair to activate a command or read a value from a display. In this way, the operator is forced to spend most of his working time in an inadequate body position, which can lead to acute problems in the musculoskeletal system (for example, sciatica). In addition, due to many years of the incorrect position of the torso, neck, shoulder girdle and arms, chronic (tendonitis) and even irreversible changes in the musculoskeletal system (for example scoliosis) can develop.

Figures 2 and 3 show another hazard, which arises from the installation of ordinary glass in the cabin. This glass cannot filter sunlight, and can often penetrate directly into the operator's field of vision. The effect of sunlight on the visual system of the operator is most pronounced early in the morning or in the evening when the sun is low on the horizon. Given this, not only that the operator may be unable to complete the operation and that he can experience an execution error as a result of this, but such a situation may also impair the operator's vision. Blurred vision, sensitivity to light, excessive tearing, blindness are some of the effects of short-term and long-term exposure of the eyes to the action of the sun's rays.

The next hazard is also the consequence of an inadequate design solution for the windows in the excavator cabin. Outdoor weather conditions, such as rain, snow and dust, can lead to reduced visibility and soiling of the cab glass. However, the cabin is not equipped with wipers that could reduce this harmful effect. The cabin has only one small window (Figure 4), which can eventually be used to occasionally wipe dust or falling snow from the glass surfaces of the cabin.

Figure 4. The exterior glass surfaces of the operator's cab are not equipped with wipers to clean them.

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Although impaired visual interaction of the operator cannot cause damage directly to the operator, it can jeopardize the execution of the work task and cause an unsafe situation where the material is unloaded to a location that is not intended for that. Also, in this way, in conditions when the operator is not able to clearly see the details in the external environment, in very rare unfortunate circumstances, a natural person outside the excavator can be injured by part of the excavator or the material being transported.

As already mentioned, the cabin has only one window that can be opened. However, even when opened, a large amount of dust enters the cabin. For this reason, the operator relies on the operation of the air conditioner installed in the cabin as shown in Figure 5.

Figure 5. Air circulation based on the use of air conditioning in the excavator cabin.

The problem, however, is that the air conditioning filter is cleaned only once a year, usually before the start of the summer season. Given that, in the bucket-wheel excavator cabin, we identify a new danger, inadequate air quality with a large amount of carbon dust. These carbon dust particles can have short-term and long-term, serious effects on the health of operators.

Other hazards that must be taken into account include the effects of vibration and noise, which are common for machines of this size and the function they perform. The work of the bucket-wheel excavator is done in two, and usually three shifts.

4. ANALYSIS OF RESULTS

The aim of this analysis of the results is to perform a risk assessment for the workplace of the 1200x24/4 bucket-wheel excavator operator, taking into account changes in the quantity (intensity) of the hazard source and the duration of exposure. As already mentioned, the HRN method will be used for this purpose, with the mentioned modification of the MPL factor. Therefore, for each identified hazard, one or more MPL_i values will be determined, depending on whether more levels of intensity or quantity of harmful effects of the hazard source can be predicted over time (or already exist), or

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depending on the operator's exposure in a shorter or longer time period. Due to these factors, the effects on operator health can vary, from mild to fatal. For the purpose of estimation, the values from the tables given in [2] will be used to determine the values for PE (Probability of Exposure), FE (Frequency of Exposure), MPL (Maximim Probable Loss) and NP (Number of Persons at risk). The risk assessment is based on the calculated value for HRN = PE x FE x MPL x NP, in accordance with the tabular values that are used for the assessment of risk levels that are also given in [2]. For identified hazards and determined values for PE, FE, MPL and NP, Table 1 gives also the calculated values for HRN_i, as well as the risk assessment for each hazard based on the obtained values.

Table1. Risk assessment table based on original HRN method.

Hazard	FE	PE	NP	MPL	HRN	RISK LEVEL
Body posture	5	5	2	$MPL_1 = 0.5$	$HRN_1 = 25$	Significant risk
		8		$MPL_2 = 2$	$HRN_2 = 160$	Very high risk
Sunlight	1.5	8	2	$MPL_1 = 0.1$	$HRN_1 = 2.4$	Very low risk
		2		$MPL_2 = 4$	$HRN_2 = 24$	Significant risk
Poor visibility (due to dirty windows of the cabin)	1.5	1	2	MPL = 15	HRN = 45	Significant risk
Dust in the air	5	10	2	$MPL_1 = 0.5$	$HRN_1 = 50$	Significant risk
		1		$MPL_2 = 15$	$HRN_2 = 150$	Very high risk
Vibration	5	8	2	$MPL_1 = 0.5$	$HRN_1 = 50$	Significant risk
		8		$MPL_2 = 2$	$HRN_2 = 160$	Very high risk
Noise	5	8	2	$MPL_1 = 0.5$	$HRN_1 = 50$	Significant risk
		8		$MPL_2 = 2$	$HRN_2 = 160$	Very high risk

All MPL_2 values were selected for the more serious health consequences that the identified hazard may have. As can be seen from the table, when the effect on health changes, the probability of the occurrence of such a condition changes almost without exception, which as a rule decreases in the case of more severe health effects. The reason for this is that certain preventive measures are expected

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to be taken, or it can be assumed that the worker himself will be able to avoid the danger (when possible). One such drastic example can be seen from the table for the hazard associated with dirty cab windows and the inability of the operator to visually monitor details outside the cab (such as a person who is, contrary to regulations, within the reach of excavators or material that is transferred).

5. CONCLUSION

The subject of this study is hazard identification and risk assessment for the SRs 1200x24/4 bucket-wheel excavator operator workplace. The following hazards were identified: improper body position of the operator due to inappropriate design solutions in the excavator cabin, sunlight due to the absence of glass surfaces of the cabin that have the possibility of filtration, dirty cabin windows due to lack of wipers which negatively affects visibility outside the cabin, poor air quality with a large presence of coal dust particles, vibration and noise. A partially modified HRN method was used for risk assessment. The modification consisted of determining a greater number of MPL_i values for each hazard identified, if there was a real need for it. The classical approach provides for the determination of only one MPL value for an individual hazard. In this way, the possibility of variation of hazards in intensity and quantity over time is not taken into account. In addition, the time of exposure of workers to that hazard is not taken into account. As a result, different health effects that may be caused by the same hazard are not taken into account. This further leads to the fact that the gradation of preventive measures is not taken into account, ie the different options that can be applied depending on the damage that can be caused by the hazard. Therefore, the costs of preventive measures may be unnecessarily high. For example, rotating workers and limiting workers' exposure to certain hazards during working life can prevent the most serious health consequences, which is certainly a cheaper option than installing complex and expensive technical solutions that are responsible for the complete elimination of harmful effects. Of course, the best solution is to absolutely eliminate the danger, but in practice, it is a rare option for economic and other reasons.

Determining the MPL_i value for each hazard allows preventive and corrective actions to be developed depending on the current state of the system. If the state of the system changes, the preventive/corrective action provided for that state is automatically activated, depending on the MPL_i value corresponding to that state. In this way, the company's management has at disposal a number of adequate options for managing the system of safety.

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