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IDENTIFICATION OF HAZARDS AND RISK ASSESSMENT FOR THE WORKPLACE OF MAINTENANCE WORKER 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 maintenance worker bucket-wheel excavator SRs 1200x24/4, as well as the risk assessment for that workplace. In addition to the hazards arising from the design of the machine itself, ergonomic hazards have been identified, as well as hazards arising from the working environment. The HRN (Hazard Rating Number) method was used to assess the risk. The emphasis of the paper is on the comparison of the original HRN method with two modifications of this method. The mentioned modifications refer to the tabular values of the influencing factors used in the risk assessment. It was concluded that the original HRN method still represents a solid basis that allows its application in practice for risk assessment.

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

1. INTRODUCTION

The subject of this paper is the hazards at the workplace of the maintenance worker of the bucket-wheel excavator SRs 1200x24/4, which is used in surface coal mining to excavate tailings. In Serbia's Kolubara Mining Basin, this bucket-wheel excavator is in daily use. The Kolubara Mining Basin is a sector of Serbia's Electric Power Industry that provides coal for both thermal power plants and residential heating.

The workplace of the maintenance worker who operates the bucket-wheel excavator involves several locations, but the main location refers to the drive part of the machine. Special attention will be paid to the identification of ergonomic hazards. Following the initial phase of identifying the hazards in this workplace, the second step will assess the risks taking into account the discovered hazards. One of the emphasis will be on the comparison of several versions of the HRN method for the risk assessment.

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2. METHOD

In order to realize this study, three methods were used. The methods of observation and interviewing were primarily used to identify hazards to the bucket-wheel maintenance worker's workplace. The HRN (Hazard Rating Number) method will be used for the risk assessment of the bucket-wheel excavator maintenance worker's workplace. However, different versions of this method will be used, so that the versions themselves and the results of their application can be compared.

For each hazard, the HRN method requires the determination of the next values: LO (Likelihood of Occurrence), FE (Frequency of Exposure), DPH (Degree of Possible Harm) and NP (Number of Persons at risk). The risk assessment is based on the calculated value for HRN = LO x FE x DPH x NP, while taking into account the tabular values for LO, FE, DPH, and NP.

The HRN method was devised by Chris Steel in 1990 [1]. Values for PE (LO), FE, MPL (DPH), and NP were then defined. Note that PE is the original term (Probability of Exposure) used by Steel. LO (Likelihood of Occurrence) is the term that has the same meaning in the calculation sense as PE, and it is used in [2]. The same explanation is for the relation MPL - DPH. The tabular values are given in Tables 1, 2, 3 and 4. Risk assessment is performed based on Table 5.

Table 1. Values for PE according to the original HRN method created by Chris Steel [1].

Probability of exposure to/contact with hazard (PE)		
0	Impossible	Cannot happen under any circumstances
1	Unlikely	Though conceivable
2	Possible	But unusual
5	Even chance	Could happen
8	Probable	Not surprising
10	Likely	Only to be expected
15	Certain	No doubt

Table 2. Values for FE according to the original HRN method created by Chris Steel [1].

FE (Frequency of Exposure)	
0.1	Infrequently
0.2	Annually
1	Monthly
1.5	Weekly
2.5	Daily
4	Hourly
5	Constantly

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Table 3. Values for MPL according to the original HRN method created by Chris Steel [1].

Maximum Probable Loss (MPL)	
0.1	Scratch or bruise
0.5	Laceration or mild ill health effect
1	Break of minor bone or minor illness (temporary)
2	*Break of major bone or minor illness (permanent)*
4	*Loss of 1 limb/eye or serious illness (temporary)*
8	*Loss of 2 limbs/eyes or serious illness (permanent)*
15	Fatality

Table 4. Values for NP according to the original HRN method created by Chris Steel [1].

NP (Number of Persons at risk)	
1	1-2 persons
2	3-7 persons
4	8-15 persons
8	16-50 persons
12	50+ persons

Table 5. Risk assessment levels according to the original HRN method created by Chris Steel [1].

HRN	Risk	Action Timetable
0-1	Acceptable risk	Accept risk/consider action
1-5	Very low risk	Action within 1 year
5-10	Low risk	Action within 3 months
10-50	Significant risk	Action within 1 month
50 - 100	High risk	Action within 1 week
100 – 500	Very high risk	Action within 1 day
500 - 1000	Extreme risk	Immediate action
Over 1000	Unacceptable risk	Stop the activity

After 25 years since the publication of the HRN method, Derek Coulson performed an analysis of the original HRN method [3]. He states that this method is still valid, that it is in accordance with the EN ISO 12100 standard, and that he personally, including many companies, often uses it in practice. Coulson proposes only one correction compared to the settings of the original HRN method, which refers to the determination of minimum values for PE. This correction is proposed in order to further

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increase the accuracy of the assessment and is shown in Table 6 (other values for PE are identical to those in Table 1).

Table 6. Correction of values of PE according to Coulsen [3].

Probability of exposure to/contact with hazard (PE)		
0.05	Almost impossible	Possible in extreme circumstances
0.5	Highly unlikely	Though conceivable
1	Unlikely	But could occur

However, in [2] a number of value corrections for LO, FE, DPH are presented, as well as of the criteria on the basis of which the risk assessment is performed. The values for NP are identical in [1] and [2]. The following tables show only the changed tabular values, which are given in [2] (other values in the tables are identical to those in [1]).

Table 7. Corrected values for PE (LO) according to [2].

Probability of exposure to/contact with hazard (PE)		
0.033	Almost impossible	Only in extreme circumstances
1	Highly unlikely	Though conceivable
1.5	Unlikely	But could occur

Table 8. Corrected values for FE according to [2].

FE (Frequency of Exposure)	
0.5	Annually
1	Monthly

Table 9. Corrected values for MPL (DPH) according to [2].

Maximum Probable Loss (MPL)	
1	Break – minor bone or minor illness (temporary)
2	Break – major bone or major illness (temporary)
4	Loss of 1 limb/eye or serious illness (temporary)
8	Loss of 2 limbs/eyes or serious illness (permanent)

Table 10. Criteria for risk assessment according to [2].

HRN	Risk
HRN < 5	Preferable
5 ≤ HRN < 10	Acceptable
10 ≤ HRN ≤ 50	Acceptable under circumstances
HRN > 50	Unacceptable

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As previously stated, all three versions of the HRN method will be used to assess risks in order to compare them in a practice case.

3. REULTS

The regular production process requires the maintenance worker to control the operation of machine assemblies throughout the excavator, as well as to eliminate minor defects. The results obtained on the basis of the application of the observation and interviewing methods will be presented here. Figure 1 shows the excavator's rotating parts, which are under the supervision of the maintenance worker.

Figure 1. Rotating parts of the excavator.

Among other things, the maintenance worker monitors the condition of the reducer coupling and brake linings on a daily basis, and on that occasion, injuries can occur due to the close proximity of the rotating parts. Rotating parts have their own protection. However, in order to diagnose a fault, this protection is often removed while the machine is running, which is hazardous.

Figures 2 and 3 show the position of the opening of the chamber of the drive part intended for lifting the breaking part of the unloading strip (marked by an arrow) and the entrance to that chamber.

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Figure 2. Opening of the chamber of the propulsion part intended for lifting the break part of the unloading lane.

Figure 3. Entrance to the chamber.

Ergonomic hazards related to inaccessibility can be seen in figures 2 and 3. In addition, Figure 1 also shows parts that are very difficult to access. Due to the existence of poorly accessible locations, the worker often has to take an inappropriate body position. In addition, tripping, slipping and falling on hard-to-reach parts are possible.

In the event of the need to replace the reducer unit (weighing approx. 35 kg), the crane can only lift the reducer unit to the approach to the chamber opening (Figures 2 and 3). Further manipulation of the reducer is performed by a maintenance worker. The reducer must first be inserted into the chamber through the said opening. That opening is the only opening for human entry (in this case maintenance

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workers). After the reducer unit is in the chamber, the maintenance worker should raise the reducer unit to a height of approx. 1 m (Figure 4). The same reducer must be moved during regular maintenance and inspection.

Figure 4. Interior of the chamber and position of the machine reducer.

Due to the manipulation of a load of heavier weight in a cramped space, in addition to inadequate body position, the maintenance worker is exposed to an effort of greater intensity, which is also a hazard. In addition, the maintenance worker is exposed to dust (Figure 5), noise and vibration.

Figure 5. Dust on the platform.

4. ANALYSIS OF RESULTS

The results will first be analyzed using the original HRN method. After that, the risk will be assessed based on the two previously described modifications of the HRN method. In order to make these three approaches easier to compare, the risk will, in this case, be assessed according to the instruction of the original HRN method which predicts only one value for MPL, according to the concept of "maximum probable loss" (ie in this case, for one the danger, it will not be determined a larger number of MPL values). Table 11 shows the risk assessment based on the application of the original HRN method.

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Table11. Risk assessment table based on the original HRN method.

Hazard	FE	PE	NP	MPL	HRN	RISK LEVEL
Body posture	4	8	1	0.5	16	Significant risk
Effort (heavy object manipulation)	2.5	8	1	1	20	Significant risk
Rotating parts of the machine	2.5	2	1	8	40	Significant risk
Poor access	2.5	8	1	0.5	10	Low risk
Dust	4	8	1	4	128	Very high risk
Vibration	4	8	1	2	64	High risk
Noise	4	8	1	2	64	High risk

Risk assessment with the application of Coulsen correction, in this case, gives identical results as the original HRN method. Therefore, the calculation table is omitted, because it is identical to Table 11. The risk assessment in tabular form will be given below, based on the corrections given in [2].

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Table12. Risk assessment table based on corrections [2] of the original HRN method.

Hazard	FE	LO (PE)	NP	DPH (MPL)	HRN	RISK LEVEL
Body posture	4	8	1	0.5	16	Acceptable under circumstances
Effort (heavy object manipulation)	2.5	8	1	1	20	Acceptable under circumstances
Rotating parts of the machine	2.5	2	1	8	40	Acceptable under circumstances
Poor access	2.5	8	1	0.5	10	Acceptable under circumstances
Dust	4	8	1	4	128	Unacceptable
Vibration	4	8	1	2	64	Unacceptable
Noise	4	8	1	2	64	Unacceptable

5. CONCLUSION

The subject of this paper is the identification of hazards and risk assessment for the workplace of maintenance worker bucket-wheel excavator SRs 1200x24/4. Based on the application of the interview and observation methods, it was determined that there are the following hazards: inadequate body position, exposure to significant physical effort due to handling heavy objects, rotating machine parts, cramped and inappropriate access to maintained parts, dust, vibration and noise.

The risk assessment was based on the use of the original HRN method, as well as two modifications of this method. The risk assessment according to the original method and according to the original method with value adjustment of Coulsen for PE, gave identical results in this case. However, a comparison of the original HRN method and the corrected HRN method based on the corrections

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given in [2] provided information, on the basis of which certain conclusions can be drawn. First of all, if we compare the numerical data from Tables 11 and 12, at first glance we can say that there are no differences. However, from Table 12 it can be noticed that for noise and vibration the two numerical values are underlined, in the column related to the values for DPH. The problem is this. In the case of noise and a maintenance worker of that machine, it is estimated for existing working conditions that permanent but mild damage may occur due to partial hearing loss. Similarly, it has been estimated that the effect of vibration on this worker may have lasting but milder consequences (changes in tendons, muscles, etc.). So, these are permanent consequences. However, this category of damage does not exist in the table for DPH [2]. This table predicts only serious illnesses in the form of permanent damage. In order not to make a mistake in the assessment, recognizing this problem, the value 2 was selected from the corrected table that most closely corresponds to the actual situation.

However, despite the fact that the values in Tables 11 and 12 are formally identical, the final risk estimates according to the original and corrected approach [2] are quite different. In essence, the mentioned corrected HRN method for the same numerical HRN values in a descriptive sense assesses the risk as higher (compared to the original method). Since this workplace includes ergonomic risks, from an ergonomic point of view, it can be said that risk assessment according to the original method gives more realistic values. The reason for this may be that the correction of the HRN method in [2] is proposed for robotic systems, so it can be assumed that in this case good results are obtained (which was not the subject of consideration in this paper).

Having in mind the results obtained in this study, the authors of this paper agree with Coulsen's view that the original HRN method is a quality method for risk assessment, although it is possible that it can be further improved.

References

[1] Steel C., 1990, Risk estimation, *The safety & health practitioner*, June, pp. 20-21.
[2] Hippertt MP,, Junior ML., Szejka AL. et al., 2019, Towards safety level definition based on the HRN approach for industrial robots in collaborative activities, *Procedia Manufacturing* , Vol. 38, pp:1481–1490.
[3] Coulsen D., 2015, Risk Estimation: 25 years on, *The safety & health practitioner*, June, https://www.shponline.co.uk/blog/risk-estimation-25-years/