UDC 622.411:622.814 DOI: https://doi.org/10.15407/geotm2023.165.027

CRITERION FOR ASSESSMENT OF COMPLIANCE OF WATER CONSUMPTION BY THE IRRIGATION SYSTEM OF IMPORTED ROADHEADERS WITH THE REQUIREMENTS OF UKRAINIAN REGULATIONS

Minieiev S.P., Usov O.A.

M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine

Abstract. Over the past 10 years, the mining conditions of Ukraine's coal deposits have changed significantly. The development of particularly dusty seams has been discontinued and the transition from domestic roadheaders to imported ones has begun. And the normative document governing the requirements for roadheaders' irrigation parameters has not been changed for the last 18 years. This makes the revision of certain provisions of the document a matter of urgency. Of particular relevance is the development of a criterion for assessing the conformity of water consumption by the irrigation system of imported roadheaders to the conditions of Ukrainian coal deposits. A comparison of the dust-generating capacity of seams mined when the normative document was issued in 2005 and those currently being mined showed that the maximum dust generation has now been reduced by 35%. This made it possible to reduce the normative indicator of specific water consumption from 100 l/m^3 to 65 l/m^3 of broken rock. The analysis of the normative methodology for the calculation of the water consumption by the irrigation system of cutter-loaders showed that these calculations take into account an understandable physical law of the reduction of the specific dust generation with the reduction of the coal hardness. However, roadheader calculations do not take this law into account. This leads to an underestimation of the allowable water consumption for hard rock and an overestimation for soft rock. To eliminate this drawback of the methodology for calculating the water consumption of the roadheader irrigation system, a regression dependence of the specific dust generation reduction was obtained when increasing the excavation productivity of weaker rock. The use of this dependency made it possible to determine the value of the equivalent productivity of the roadheader in terms of the dust factor and to formulate the criterion for evaluating the compliance of the water consumption of its irrigation system with the requirements of normative documents. The same dependence can also be used for a rough estimate of the equivalent productivity of shearers.

Keywords: roadheader productivity, mined rock excavation, dust generation, broken rock, dust suppression.

1. Introduction

The Ukrainian coal mining industry is currently undergoing a transition from domestic roadheaders to imported ones. Prior to this transition, the compliance of the irrigation parameters of domestic roadheaders with the normative documents of Ukraine was ensured at the stage of their design. And there was no need for additional verification of compliance of irrigation parameters with the requirements of normative documents by specialists of coal mines and supervisory organisations.

However, the parameters of the irrigation systems of imported roadheaders are unlikely to take into account all the specifics of the complex mining conditions in Ukrainian mines. And for them, additional verification of irrigation parameters in accordance with Ukrainian regulations is required.

This raises the problem of uniform assessment of such conformity. It is caused by two factors which are not directly but indirectly assessed in the current Ukrainian regulations:

– stopping the development of particularly dusty seams;

– reducing specific dust generation with decreasing rock hardness.

We emphasise that all the data required for such an assessment are available in the regulations. All that is required is the correct processing of this data and the formulation of it clearly in the form of criteria.

The analysis of the regulations is carried out only from the point of view of dust suppression during the roadheader operation. The possible impact of safety considerations due to the explosion of a mixture of air with methane and coal dust on the value of the specific water consumption will be considered in the following publications.

2. Methods

The problem was solved by a comparative analysis of the regulatory requirements for roadheaders and cutter-loaders using standard regression methods.

3. Results and discussion

The requirements for irrigation parameters for $q \geq 100$ roadheaders are laid down in NPAOP 10.0-5.23-04 [1]. They are only 2 – water pressure should not be lower than 1.2MPa and its specific flow rate should be

$$q \geq 100, \text{ (l/m}^3 \text{ of broken rock).} \quad (1)$$

It is the requirement (1) that should reflect the specific mining conditions in Ukraine. Therefore, it is this requirement that we will analyse in the future.

It is clear that the specific water consumption for irrigation must somehow correspond to the specific dust generation, measured in g/m^3. The higher is the specific dust generation, the higher should be the specific water consumption for dust suppression and vice versa. Reference materials on specific dust generation of rocks are not available in modern normative documentation. In the “Guidance on Dust Control in Coal Mines” [2], developed more than half a century ago, relates specific dust generation of rocks to specific dust generation of coal seams. The dustiness categories are established for coal seams (Table 2 in the Guidance [2]), which are represented in our Table 1.

Table 1 –Specific dust generation parameters for mine seams

Dustiness group of seams	Specific dust release, g/t		
	minimum	Maxim um	average
1	0	50	25
2	50	100	75
3	100	150	125
4	150	250	200
5	250	400	325
6	400	600	500
7	600	1000	800

At the time of the adoption of NPAOP 10.0-5.23-04 [1] in 2004, mines of Ukraine developed 219 flat seams with dustiness groups 6–7, that made up ~24 % of their total number. The rest of mines were of group 4 and less dustiness (according to “Catalogue of mine seams...” from [2]). It is clear that requirements for irrigation systems were set for very dusty seams not lower than group 6.

To date, there are ~60 mine seams of Group 4 and ~10 mine seams of Group 5 (approximately 15%) remaining in development in Ukraine.

In connection with the occurred decrease of the specific dust-generating capacity of the coal seams developed by the coal enterprises of Ukraine by 35% on average (from 500 to 325 g/t), the M.S. Polyakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine considers it possible to reduce the lower limit of the specific water consumption for irrigation to the value of 65% of the value defined by (1)

$$\dot{q} = 0{,}65q \geq 65\text{, (l/m}^3\text{ of broken rock).} \qquad (2)$$

On the basis of this limiting requirement, the total water flow Q of the roadheader's irrigation system with the breaking productivity P (m^3/min) is determined by the formula

$$Q \geq \dot{q}P\text{, (l/min).} \qquad (3)$$

This formula is the only normative criterion for the adequacy of the flow Q of an irrigation system. It should not contain values that can be interpreted differently by different specialists. However, our experience in estimating the flow Q of an irrigation system shows that this is not the case.

Mines sometimes use the catalogued nominal productivity of their roadheader in formula (3) when verifying the irrigation system flow rate, and sometimes use the actual productivity for their rock formations. It is clear that this results in different estimated irrigation flow rates.

In turn, the catalogue values for the irrigation systems of serial roadheaders do not correspond to formulas (2,3) either. Column 3 of Table 2 shows the catalogue flow rates for the irrigation systems of the various roadheaders. And in the 5th column – the capacities of these roadheaders, which should be taken for calculation by formula (2).

Table 2 – Roadheaders' irrigation parameters

Type of roadheader	Irrigation pressure, MPa	Consumption for irrigation, l/min	Roadheader productivity, m^3/min	
			acc. to catalogue	in the calculation acc. to formula (2)
1	2	3	4	5
1ГПКС	1.5	100	0.26–1.42	1
4ПП-2	1.5	100	0.28–0.53	1
КСП-22	1.5	70	0.25–1.42	0.7
КСП-32	1.5	70	no data	-
КСП-42	1.5	70	0.2–0.5	0.7
П110	1.5–3.5	100	0.3–2,5	1
П220	1.5–3.5	100	0.3–3.0	1

As can be seen from Table 2, when calculating water consumption for irrigation according to formula (2) for different roadheaders it is necessary to take different value of their productivity. For some roadheaders – 1ГПКС, КСП-22, П110, П220 – the calculated productivity corresponds to the middle of the range of catalogued values; for others (4ППП-2, КСП-42) it is higher than the maximum catalogued productivity.

It turns out that the single normative requirement (1) does not give, and the formula (2) derived from it does not allow the regulatory authorities to unambiguously assess the sufficiency of the irrigation consumption for newly developed excavation equipment due to the lack of an unambiguous regulation of the choice of the calculated value of its productivity P.

Therefore, the choice of the roadheader productivity value when calculating the sufficient water flow for the irrigation system is left to the approving organisations. The M.S. Polyakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine proceeds from the following considerations in this matter.

The appropriate water flow rate for the irrigation system depends on the amount of dust generated by the mining operation per unit of time - the greater is the dust, the higher the water flow rate needs to be.

The basis for the calculation of dust emissions during combine harvester operation is given in the "Guidance for Dust Control in Coal Mines". [2]. Below is an excerpt from this document concerning dust emissions from roadheaders:

«*…50. Specific dust emission* q_n *(n/e) when the roadheader operates without dust suppression means in seams of dustiness group VI and air velocity of 0.5 m/s is calculated by the formula*

$$q_n = 300q_k, \qquad (29)$$

where: q_k *– index that takes into account the influence of roadheader design parameters on dust generation and emission.*

51. Indicator q_k *is determined by the formula*

$$q_k = 16,7K_mK_p, \qquad (30)$$

where: K_m *– index of the reduced degree of rock crushing for the roadheader;* K_p *– index that takes into account the change in specific dust emission depending on the configuration of the roadheader …*»

As we see, the effect of combine's design parameters $q_к$ and the reduced degree of crushing $К_м$ do not depend either on productivity, or on the type of cutters or their location on the open cutter-loader of selective action. This strange position is not in agreement with the calculation of dust emissions of the cutter-loaders given in the same document a bit earlier:

«*…28. The index* $q_к$ *is defined by the expression*

$$q_k = 16,7K_mK_p, \qquad (6)$$

where: $K_м$ *is an index of the reduced degree of coal crushing a cutter-loader. The value* $K_м$ *for series-produced cutter-loaders are shown in Table 3…*

Table 3 – The values of the reduction ratio $К_м$, which takes into account the influence of the roadheader's design parameters on dust generation

Roadheader/cutter-loader brand	Tool type	Roadheader productivity, t/min	Index $К_м$
1ГШ-68	ИТ-2С one cutter in line	3.5–6.5	0.036–0.033
1ГШ-68	И-90 МБ two cutters in a line	1.5–6.5	0.070–0.034
КШ-3М	И-79 three cutters in a line	3.6–6.51	0.045–0.032
МК-67	МК-1-1-4-14А two cutters in a line	1.4–4.0	0.095–0.046
2К-52	И-90 МБ one cutter in line	1.0–4.0	0.090–0.045
БК-52	КБ-0,1 and И-90 МБ six and two cutters in a line	1.3–4.0	0.070–0.040
1К-101	ИТ-2С one cutter in line	1.4–5.0	0.130–0.056
1К-101	И-90 МБ one cutter in line	1.4–5.0	0.139–0.063

For cutter-loader, the reduction ratio $К_м$ depends on the cutter-loader's productivity, and quite significantly. As the productivity of the cutter-loader increases, it decreases by a factor of ~ 2. This means that the specific dust generation of the cutter-loader $q_п$ also falls.

Roadheaders do not differ from cutter-loader in terms of the destruction of the rock mass by the cutter. But, for unknown reasons, the reduction of specific dust generation $q_п$ with the increase of roadheader productivity was not taken into account in “Guidance...” [2]. It is for this reason that the normative value of specific water consumption (2) in the irrigation system of roadheaders is not unambiguously interpreted when applying formula (3) to determine sufficient total consumption by the irrigation system.

Considering the importance of the issue, we will assume that the specific dust emission $q_п$ when stripping rock with nominal power also depends on its hardness. Character of this dependence will be determined by data of formulae (5,6) quoted above and *Table.3* of **“**Guidance…” [3] for the operation of in-seam miners.

Substituting *(6)* into *(5)*, we rewrite it as

$$q_p = CK_m . \tag{4}$$

The total dust emission when the cutter-loader is operating at productivity П is then written as

$$G = q_p P = CK_m P , \tag{5}$$

where C – factor of proportionality.

The dependences of *G/C* on *P* for each row in Table 3, plotted against two pairs of values (P_n K_{mn}) and (P_m K_{mm}), the first corresponding to the left values of columns (3, 4) of Table 3, and the second pair corresponding to the right values in those columns, are shown in Figure 1.

The graph shows that the increase in total dust emission with increased fracturing productivity of weaker coals has almost the same character for different cutter-loader.

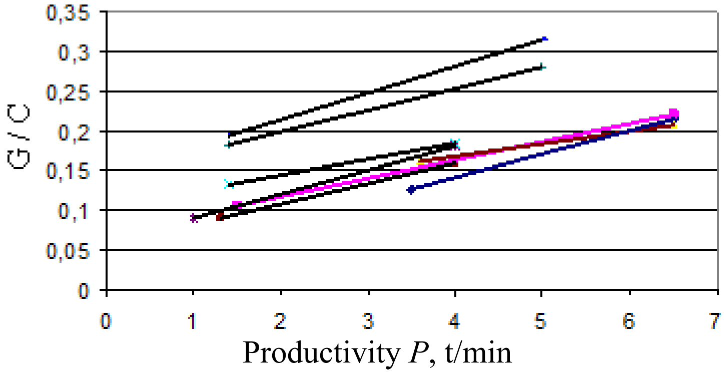

Figure 1 – Dependence of the total dust emission on the productivity of the in-seam miner

Consequently, a further calculation of the dust release dependence on the productivity will be sufficiently accurate for practical estimations.

However, it is not practical to construct an empirical formula directly from graph (7) because the slope of these curves and the C-factor are determined from data of different dimensions. And the numerical parameters of these curves are only valid for the dimensions given in the "Guidance..." [2]. Moving to other dimensions, the G/C values and slope angles of the curves will change in an unpredictable way.

To avoid this, it is necessary to operate with dimensionless values. One of these is the relative productivity P_l / P_n. P_l – the cutter-loader's productivity in rock of the mine's typical hardness. P_n – the nominal productivity of the cutter-loader, determined by the hardest rock.

The second dimensionless value is the relative dust generation G_l / G_n. G_l – cutter-loader's dust generation in rocks of the mine's characteristic hardness. G_n – nominal dust generation in the hardest rock at the nominal productivity of the cutter-loader $П_н$.

The values of G_l / G_n in our study are determined by dividing the right values by the left values in columns 3 and 4 of Table 3 of the "Guidance..." [3].

The graph of the dependence of G_l / G_n *om* P_l / P_n is shown in Figure 2.

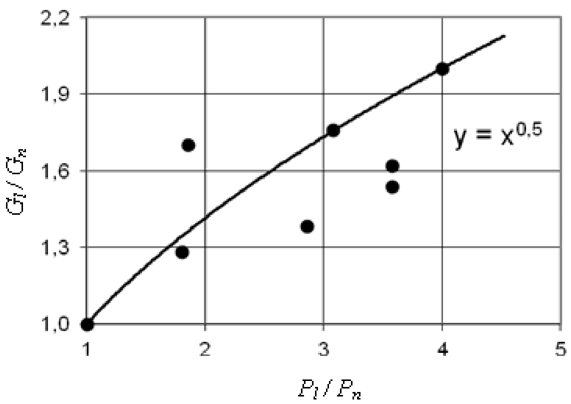

Figure 2 – Dependence of dust generation on in-seam miner's productivity in relative values

The points are more scattered than in Figure 1, but its empirical equation is dimensionless and independent of the choice of dimensions

$$\frac{G_l}{G_n} = \left(\frac{P_l}{P_n}\right)^{0,5}. \tag{6}$$

The convex non-linear graph reflects an understandable physical pattern of decreasing specific dust generation with decreasing rock hardness. This leads to a sharp decrease in the intensity of dust generation growth with increasing excavation productivity of weaker rocks.

Figure 2 shows that with a 4-fold increase in productivity due to the extraction of less hard rock without increasing the productivity of the cutter-loader loader, the dust emission only increases by a factor of 2. And when the productivity increases by a factor of 4 by increasing the cutter-loader's productivity without reducing the hardness of the rock, the dust emission increases by a factor of 4.

Therefore, to determine the irrigation water consumption, one must substitute in formula (3) neither the nominal, nor the actual productivity, but the productivity equivalent in terms of dust generation P_e. It is determined by formula (6) and the following considerations: by formula (5)

$$G_n = q_{pn} P_n \tag{7}$$

and

$$G_l = q_{pl} P_l. \tag{8}$$

Dust generation G_l at productivity P_l in the last formula can be written in terms of equivalent productivity P_e and nominal specific dust emission q_{pn} by formula

$$G_n = q_{pn} P_e. \tag{9}$$

By substituting formula (9) and formula (7) into formula (6), we obtain

$$\frac{G_e}{G_n} = \left(\frac{P_l}{P_n}\right)^{0,5} \tag{10}$$

or

$$P_e = P_n \left(\frac{P_l}{P_n}\right)^{0,5}. \tag{11}$$

This value should be substituted into formula (3) to determine the irrigation water consumption, because the value of equivalent productivity P_e corresponds to the real dust generation during mining rocks of both nominal and lower hardness. As a result, we obtain

$$Q = \dot{q} P_n \left(\frac{P_l}{P_n} \right)^{0,5}, \text{ (l/min).} \qquad (12)$$

As an example, we calculate the minimum allowable water consumption for dust suppression by the cutter-loader irrigation system П315:

Specific water consumption $\dot{q}$ for mines in Ukraine (V Group of dustiness of seams) is accepted according to formula (2) to be 65 l/min. The cutter-loader's nominal productivity (at a rock strength of 140MPa) is equal to 0.28 m^3/min (17 m^3/h). The maximum productivity of the cutter-loader (at a rock strength of 30MPa) is 1.64 m^3/min (98 m^3/h).

And the minimum allowable water flow rate for dust suppression by the П315 combine irrigation system is determined by formula (14):

$$Q = 65 \times 0,28 \times \left(\frac{1,64}{0,28} \right)^{0,5} = 44 \text{ l/min.}$$

4. Conclusions

As Ukrainian mines have stopped mining the dustiest coal seams, the standard value of specific water consumption for dust suppression can be reduced from 100 l/m^3 to 65 l/m^3 of crushed rock (formula 2) for explosion-proof seams.

The minimum required water consumption for dust suppression by the roadheader's irrigation system (formula 13) is estimated by multiplying the adjusted specific water consumption (formula 2), the nominal productivity of the roadheader on the hardest rock (roadheader specifications) and its actual productivity (formula 12).

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About the authors

Minieiev Serhii Pavlovych, Doctor of Technical Sciences (D.Sc.), Professor, Head of the Department of Pressure Dynamics Control in Rocks, M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine), Dnipro, Ukraine, sergmineev@gmail.com.

Usov Oleh Oleksandrovych, Candidate of Technical Sciences (Ph.D.), Senior Researcher in Department of Pressure Dynamics Control in Rocks, M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine), Dnipro, Ukraine, usov.o.a@gmail.com.

КРИТЕРІЙ ОЦІНКИ ВІДПОВІДНОСТІ ВИТРАТИ ВОДИ СИСТЕМОЮ ЗРОШЕННЯ ІМПОРТНИХ ПРОХІДНИЦЬКИХ КОМБАЙНІВ ВИМОГАМ НОРМАТИВНИХ ДОКУМЕНТІВ УКРАЇНИ.

Мінєєв С.П., Усов О.О.

Анотація. Останні 10 років гірничотехнічні умови розробки вугільних родовищ України суттєво змінилися. Припинено розробку особливо запорошених пластів та почався перехід від вітчизняних прохідницьких комбайнів до імпортних. А нормативний документ, який регламентує вимоги до параметрів зрошення прохідницьких комбайнів, не змінювався останні 18 років. Ця обставина робить актуальним перегляд його окремих положень.

Особливої актуальності набуває розробка критерію оцінки відповідності витрати води системою зрошення імпортних прохідницьких комбайнів умовам українських вугільних родовищ. Порівняння здатності пластів до пилоутворення, які були у розробці на момент виходу нормативного документа 2005г. та розроблюваних у теперішній час показав, що зараз максимальне пилоутворення зменшилося на 35%. Це дозволило зменшити нормативний показник питомої витрати води із 100 до 65 л/м^3 відбитої породи. Аналіз нормативної методики розрахунку витрати води системою зрошення видобувних комбайнів показав, що у цих розрахунках враховано зрозумілу фізичну закономірність зменшення питомого пилоутворення при зменшенні міцності вугілля. А у розрахунках прохідницьких комбайнів ця закономірність не враховується. Це призводить до заниження допустимої витрати води для міцних порід та її завищення для слабких порід. Для усунення цього недоліку методики розрахунку витрати води системою зрошення прохідницьких комбайнів було отримано регресійну залежність зменшення питомого пилоутворення зі збільшенням продуктивності виїмки слабших порід. Використання цієї залежності дозволило визначити величину еквівалентної продуктивності прохідницького комбайна за пиловим фактором та сформулювати критерій оцінки відповідності витрати води його системою зрошення вимогам нормативних документів. Цю ж залежність можна використати і для приблизної оцінки еквівалентної продуктивності очисних комбайнів.

Ключові слова: продуктивність комбайна, відбійка гірської маси, пилоутворення, відбита порода, пилопридушення.