UDC 622.831.1:622.234.5:622.807.4 DOI: https://doi.org/10.15407/geotm2022.162.066

THE POSSIBILITIES TO ESTIMATE HYDROLOOSENING EFFICIENCY BY ASYMPTOTIC FORM OF BARODYNAMIC CURVE.

Minieiev S.P., Usov O.O., Poliakov Yu.Ye.

Institute of Geotechnical Mechanics named by N. Poljakov of National Academy of Sciences of Ukraine

Abstract. The determining criterion for assessing efficiency of hydro-loosening is the nature of the barodynamic curve, and the determining parameter is the final injection pressure. However, it should be noted that the document SOU 10.1.00174088011-2005 say nothing about the presence of two types of barodynamic curves - extreme and asymptotic, which characterize the change of pressure in the process of hydraulic loosening. In the article, a comparative assessment of the determination of hydroloosening efficiency by barodynamic curves is presented. Different calculation models for estimating the length of safe face advance at asymptotic barodynamics are demonstrated, which led to the same result in terms of distance (depth) of safe coal extraction. It is shown that the length of safe face advance at asymptotic barodynamics of hydroloosening is much greater than the depth of sealing. A method for estimating the distance of safe extraction of coal was applied, which indicates that it clearly reflects the existing natural laws. Asymptotic barodynamics, in contrast to the extreme one, provides a much lower final pressure, which can be compared with the final pressure at hydro-pressing, but without the face slip.

That is, the reduction of the final pressure by 80% of the maximum at asymptotic barodynamics compared with its reduction by the normative 30% for the same duration at extreme barodynamics indicates that the unloading of the coal seam at the depth of sealing is significantly greater in the asymptotic case.

It is shown that the efficiency of hydro-loosening can now be easily determined by asymptotic form of the barodynamic curve. It is also proved that the lower is the final pressure of hydro-loosening, the deeper is the unloading zone in the heading area of the coal seam for the asymptotic barodynamic unloading zone, and it reaches its maximum, which can be compared with the depth of sealing.

Keywords: barodynamic curves, asymptotic form of the curve, hydro-loosening efficiency, rock pressure, water injection, sealing depth, rock pressure diagram.

1. Introduction

In the normative document SOU 10.1.00174088011-2005 ([1] clause 9.1.20), hydraulic loosening is considered effective if the active process is completed, the pressure in the hydraulic system has decreased by 30% or more from the maximum achieved, and the resonance frequency of the acoustic signal does not exceed 120 Hz or the coefficient of its variation in time intervals is more than 15%.

But this document say nothing about how close the current efficiency is to the maximum that can be achieved due to the correct choice of hydraulic and geometric parameters of the process. The limits of these parameters changing are partly determined by the requirements and recommendations of the regulatory document [1], partly - by technical capabilities of the equipment, but finally they are determined by the results of research injections.

A great number of studies were carried out on the study of the processes occurred in the coal massif during hydraulic loosening including the set of issues for improving efficiency of this method and increasing the safety of mining operations in hazardous coal seams after its implementation [2-7]. So, hydraulic loosening is carried out in mines once a day - usually during a repair shift. Consequently, the depth of the effective hydraulic loosening zone should be equal to the daily roadway advance. That is, for face driving, it is desirable to effectively develop the coal seams to a depth of ~ 6 m for each cycle of hydraulic loosening, and for highly loaded face - to a depth of ~ 4 m. Today, the main field of application of hydraulic loosening is driving faces at the seam development. The specifics is that hydraulic loosening is always carried out through two borehole located on both sides of the face: this is a requirement of the paragraph 2, clause 9.1.3 of the SOU 10.1.00174088011-2005 [1]. It is also necessary to remember that the width of the driving face does not exceed 6 m, and the wetting radius is taken to be equal to 0.8 of the sealing depth. That is, even with a sealing depth of 4 m, the minimum radius of wetting is 3.2 m, and the maximum distance between the boreholes, which should not exceed twice the radius of wetting, will reach 6.4 m. At the same time, to a large extent the depth of sealing less than 4 m makes hydraulic loosening unprofitable compared to drilling and blasting operations in the mode of shaking blasting (SB), because paragraph 3, clause 9.1.3 of the SOU 10.1.00174088011-2005 [1] requires that coal should be extracted at the depth, which does not exceed the depth of sealing. However, ensuring a high speed of driving face advance with cutter-loader excavation (6 m/day) is possible only with a sealing depth of 6 m. Therefore, with taking into account at least one meter more for the injection chamber, it is necessary to drill a borehole 7 m long.

In our opinion, the character of the barodynamic curve is the determining criterion for estimating the efficiency of hydraulic loosening, and the final injection pressure is the determining parameter. However, it should be mentioned that the document SOU 10.1.00174088011-2005 say nothing about the presence of two types of barodynamic curves - extreme and asymptotic, which characterize the change in injection pressure during the hydraulic loosening.

The purpose of the work is to estimate the determination of hydraulic loosening efficiency by barodynamic curves, in particular by its asymptotic form.

2. Methods

The authors of this article in their prior studies [3] obtained the calculated estimate of rock pressure reduction at the end of the hydraulic loosening process:

$$P_{гк} / P_{гп} = 1 - (P_{мах} / P_{гп})\,(1 - P_{к} / P_{мах}),$$

where: $P_{гп}$, $P_{гк}$ - rock pressure in the seam at the depth of sealing before and after its unloading due to hydraulic loosening; P_{max}, $P_{к}$ - maximum and final injection pressure.

This formula makes it possible to make a comparative assessment of the depth of zone of safe coal extraction by different forms of barodynamic curves of the hydraulic loosening process. Since, when deriving this formula, the dependence of coal permeability on rock pressure and injection pressure was chosen in such a way that if they were equal permeability increased indefinitely (hydraulic dissection of coal seam); for further calculations, it is appropriate to assume that the maximum injection pressure does not exceed 0.75 rock pressure value in the ratio of sealing depth value. Then the formula will look like this:

$$P_{гк} / P_{гп} = 1 - 0{,}75\,(1 - P_{к} / P_{мах})$$

$$P_{гк} / P_{гп} = 0,25 + 0,75(P_к / P_{мах}) \quad (1)$$

Let's introduce in (1) the necessary condition for effective hydraulic loosening with extreme barodynamics in accordance with clause 9.1.13 of the SOU 10.1.00174088011-2005 [1], by which it is established that a decrease in the final injection pressure by 30% ($P_к/P_п = 0.7$) is sufficient to reduce the rock pressure at the sealing depth to a safe level $C_б$ and it is allowed to extract coal at a distance from the face to the area where, as a result of unloading the massif, the rock pressure has decreased to a safe level of $P_б$:

$$Pб / P_{гп} = 0,25 + 0,75*0,7$$

$$Pб = 0,775\ P_{гп} \quad (2)$$

According to (2), safe pressure for coal extraction in the unloaded zone $P_б$ is not an absolute, but a relative value - it depends on the initial rock pressure $P_{гп}$, which was in this area before unloading.

For asymptotic barodynamics, the final rock pressure at the sealing depth $P_{гк}$ is calculated by formula (1) on the condition that the final injection pressure $P_к$ is 20% of the maximum $P_{мах}$, and is equal to 0.4 $P_{гн}$. That is, the final rock pressure at the depth of sealing is much lower than the level of $P_б$ for safe coal mining, according to formula (2).

$$P_{гкас} = 0,4P_{гп} \quad (3)$$

This means that the length of the safe face advance at asymptotic barodynamics of hydraulic loosening is significantly greater than the sealing depth.

For determining length of the safe face advance at asymptotic barodynamics, we need to set functions of the magnitude of the rock pressure depending on the distance to the face both before and after hydraulic loosening. However, the question arises as to whether there is vertical pressure in the plane of the face, and what shape the diagram has - convex, concave or close to a straight line. We assume that the diagram has a straight-line character and consider both variants of the stress on the face.

The first variant - when there is no vertical stress on the face (1) - is shown in Figure 1

The top image in the figure shows the rock pressure diagram before and after unloading. The change of the diagram after unloading takes place by turning the original diagram. The bottom image of the figure shows the geometric characteristics of rock pressure diagram before unloading, after unloading, both at extreme and asymptotic barodynamics.

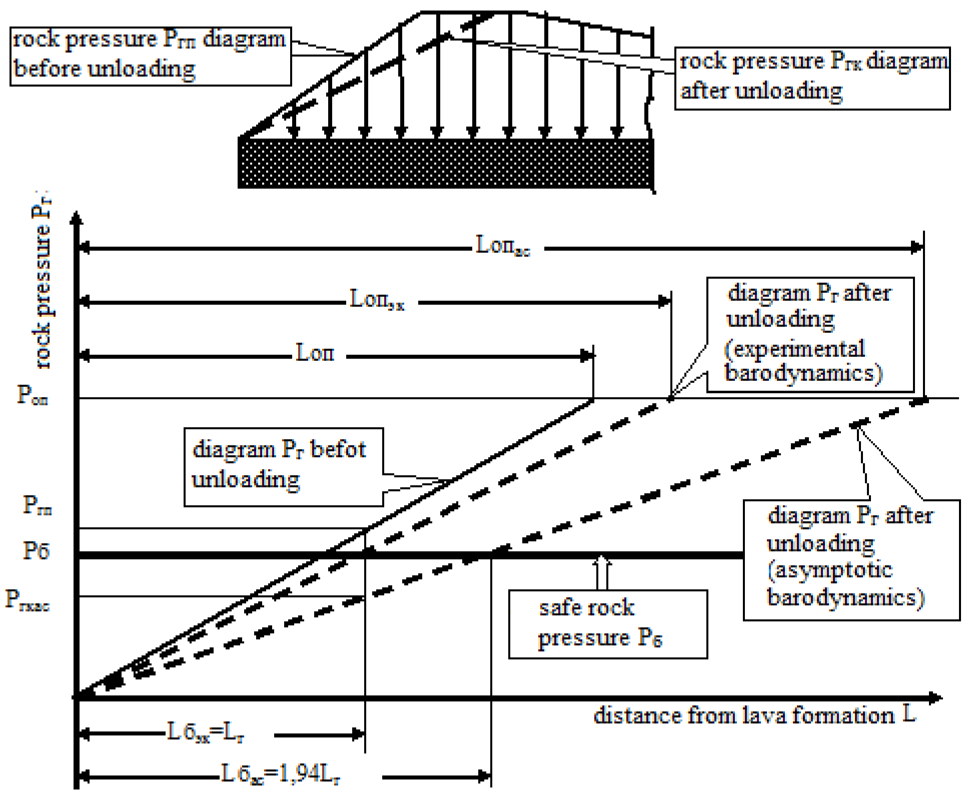
The length of safe coal extraction at asymptotic barodynamics $Lб_{ас}$ is the ordinate of the point of intersection of the unloaded massif diagram with the double horizontal line of safe rock pressure $P_б$:

$$L б_{ас} / Pб = L_г / P_{гкас}$$

$$L б_{ас} = L_г \, Pб / P_{гкас} \quad (4)$$

By taking into account the above relationship $P_{гкас} = 0/4P_{гп}$ and (2) we get that

$$L б_{ас} = 1{,}94 \, L_г \quad (5)$$



$Lб_{ас}$ – the length of safe coal extraction at asymptotic barodynamics; $Lб_{эк}$ – the length of safe coal extraction at experimental barodynamics; $P_б$ - safe rock pressure; $P_{гп}$, $P_{гк}$ - rock pressure in the seam at the depth of sealing before and after unloading due to hydraulic loosening; $P_{гкас}$ - final rock pressure at the sealing depth $P_{гп}$ at asymptotic barodynamics; Lоп, $Lоп_{эк}$, $Lоп_{ас}$ – the distance of the reference pressure to the face for experimental and asymptotic barodynamics

Figure 1 – The scheme for calculating the length of safe extraction of coal at absence of vertical stress in the area of the bottomhole

Thus, when calculating the first variant (absence of stress components in the plane of the face), the length of safe extraction of coal is almost twice the normative value.

The second variant - with the existing vertical component of rock pressure in the plane of the face - is presented in Figure 2.

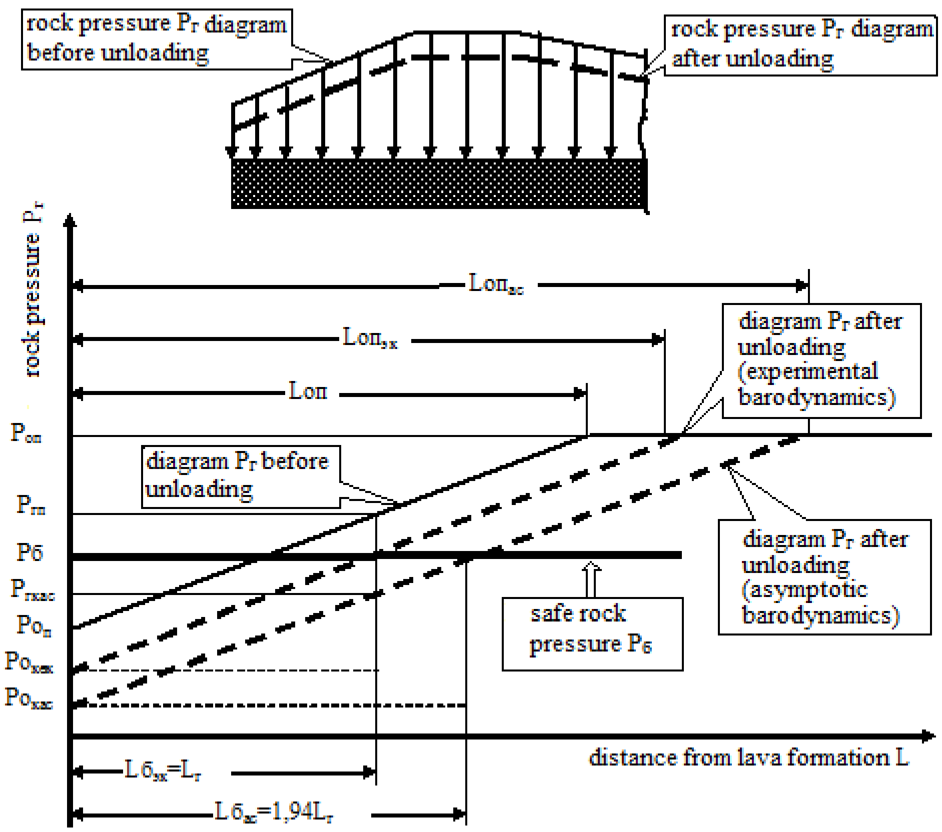
The top image in the figure shows the rock pressure diagram before and after unloading. The change of the diagram after unloading occurs by parallel lowering of the original diagram. The bottom image of the figure shows the geometric characteristics of rock pressure diagram before unloading, after unloading both at extreme and asymptotic barodynamics.

The length of safe coal extraction at asymptotic barodynamics $Lб_{ас}$ is, as in the previous variant, the abscissa of the point of intersection of unloaded massif diagram with the double horizontal line of the safe rock pressure Рб:

$$Lб_{ас} / (Рб - Ро_{кас}) = L_{г} / (Р_{гкас} – Ро_{кас})$$

or

$$Lб_{ас} = L_{г} (Рб - Ро_{кас}) / (Р_{гкас} – Ро_{кас}) \qquad (6)$$



$Lб_{ас}$ - length of safe coal extraction at asymptotic barodynamics; $Lб_{эк}$ - length of safe coal extraction at experimental barodynamics; $Р_{б}$ - safe rock pressure; $Р_{гп}$, $Р_{гк}$ - rock pressure in the seam at the depth of sealing before and after unloading due to hydraulic loosening; $Р_{гкас}$ - final rock pressure at the sealing depth $Р_{гп}$ for asymptotic barodynamics; Lоп, $Lоп_{эк}$, $Lоп_{ас}$ – the distance to the face of the maximum reference pressure for experimental and asymptotic barodynamics; $Ро_{кас}$ – the value characterizing the vertical stress in the plane of the face

Figure 2 – The scheme for calculating the length of safe extraction of coal at availability of vertical stress in the plane of the face

By substituting in (6) the values of Сб and $Р_{гкас}$ from formulas (2, 3) we obtain

$$Lб_{ас} = L_{г} (0,775\ Р_{гп} - Ро_{кас}) / (0,4\ Р_{гп} – Ро_{кас})$$

$$Lб_{ас} = L_{г} (0,4\ Р_{гп} - Ро_{кас} + 0,375\ Р_{гп}) / (0,4\ Р_{гп} – Ро_{кас})$$

$$L\text{б}_{ас} = L_г\,[1 + 0{,}375\,P_{гп} / (0{,}4\,P_{гп} - Po_{кас})] \quad (7)$$

The denominator in the second component of the right-hand side of the last formula contains the unknown value of $Po_{кас}$, which characterizes the vertical stress in the plane of the face. We do not need to determine its value. It is enough to consider that the second component decreases when value of $Po_{кас}$ decreases. Since the minimum value of $Po_{ка}$ is zero, we can substitute this zero value in formula (7) and find the minimum distance of safe coal extraction

$$L\text{б}_{ас} = L_г\,[1 + 0{,}375\,P_{гп} / 0{,}4\,P_{гп}] \approx 1{,}94\,L_г \quad (8)$$

It coincides with the result of the calculation according to the first variant (5) - without the vertical stress component in the plane of the face. Thus, different calculation models led to the same result in terms of distance (depth) of safe coal extraction. This indicates that the applied method of determining the distance of safe coal extraction clearly reflects the existing natural laws, although we do not imagine them sufficiently well.

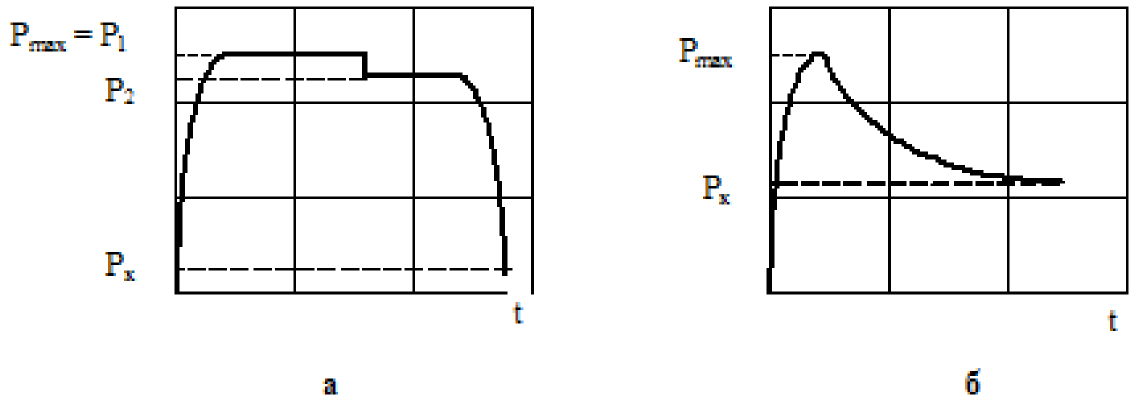
It should be remembered that a whole complex of mechanisms, starting with hydropower and ending with deformation, affects the process of the heading area unloading [8,9].

3. Results and their discussion

At the stages of the performed work, which analyzed experimental mine studies, it was established that there were two forms of the barodynamic curve: asymptotic - with a pronounced section of pressure stabilization, and extreme, in which such section was absent, and the pressure rose to a maximum for 1-2 minutes with further gradual decrease over tens of minutes. Basically, the pressure drop coincides with the appearance of a leak observed on the exposed surface of the seam.

If barodynamic curve has an asymptotic character (a pronounced area of pressure stabilization), then the leak occurs in one place, and the final water pressure, excluding losses in the sealer, does not exceed 1-2 MPa. At the same time, in the middle of the process of hydro-loosening (by duration), the average pressure of P2 is reduced - not more than 10 - 15% of the initial P1, and its drop to the end value of $P_к$ lasts not more than 1-2 minutes - figure 3a.

When the barodynamic curve had an extreme (falling) character (Fig. 3-b), several leaks from the seam were observed. And the final pressure was much higher (~ 50% of the maximum). Analysis of the conditions, in which barodynamic curves of different forms were observed, showed that such parameters as injection pressure and sealing depth did not affect it. For example, in the Tatsynska mine, the asymptotic (pressure 14-16 MPa) and extreme (pressure 18-20 MPa) forms of the barodynamic curve were observed at almost the same values of sealing depth (~ 1 m) and pressure. An exclusively asymptotic barodynamic curve was observed at the Zhdanivska 3/4 mine at the same depth of sealing, but in a much wider range of pressure (12-22 MPa).



a) - asymptotic; b) - extreme

Figure 3 – Possible forms of barodynamic curves

The influence of the roadway shape also does not have a determining effect. Both forms of barodynamic curve were observed in the driving faces, as well as in the upper corners of the benches of steeply falling longwall.

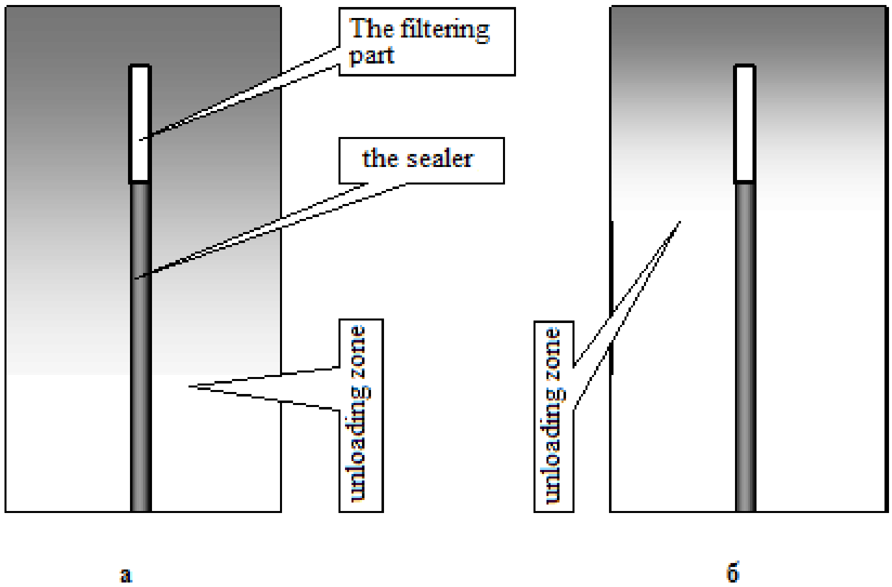
Most likely that form of barodynamic curve can be explained by coincidence of several geomechanical, hydraulic and geometric factors. In particular, by the above-mentioned dynamics of changes in the rock pressure diagram in the process of unloading the heading area of the seam, as well as by suffosion-clogging effects [10] of water flowing through the pores and cracks, which have not been sufficiently investigated.

While studying unloading of the heading area of the seam, it is possible to analyze the efficiency of hydraulic loosening from hydromechanical positions. Leaks of water from the seam at the final stage of the process are the indisputable evidence of a hydraulic connection between the borehole cavity and the roadway contour. Since the pressure on the roadway contour is atmospheric, the pressure in the borehole at the final stage of hydraulic loosening shows the hydraulic resistance of the filtration channels (cracks) that connect the borehole cavity with the roadway contour. That is, the lower is the final pressure the greater is permeability of the seam zone located between the borehole cavity and the roadway contour. And since the permeability of the seam greatly depends on the value of rock pressure, it can be stated that with the asymptotic barodynamic curve, the rock pressure in the face zone is less than with the extreme form of the barodynamic curve.

If we add this thesis with the argument about the decrease in hydraulic pressure as the distance to the borehole cavity increases, then it can be stated that the lower is final pressure of the hydro-loosening the deeper is zone of unloading of the heading area of the seam. With an asymptotic barodynamic curve, depth of unloading zone reaches its maximum, which can be compared with the depth of sealing.

The scheme of the unloading zone at the final stage of hydraulic loosening is presented in Figure 4, where the loading zone of the heading area of the seam is shown in dark color.

Similarly, low values of the final pressure of hydraulic loosening with the asymptotic barodynamics curve practically coincide with the values of the final pressure of hydro-pressing, which are specified in the normative document [1]. But this coincidence is not a reason to attribute hydro-processing with asymptotic barodynamic curve to hydro-pressing, because the main feature of hydraulic pressing - the face slip to the normative distance [1] - was not observed during the mine studies.



a) - extreme; b) - the asymptotic form of the borodynamic curve

Figure 4 – Scheme of the unloading zone at the final stage of hydro- loosening

The absence of hydraulic pressing at asymptotic barodynamics of hydraulic loosening is explained by the influence of the increased length of the filtering part of the borehole (i.e., by a decrease in the flow rate). This prevents the formation of excess pressure in the cavity of cracks that move from the contour of the borehole in the direction parallel to the face. Thus, asymptotic barodynamics, in contrast to extreme barodynamics, provides a much lower final pressure, which can be compared with the final pressure during the hydro-pressing, but without the face slip. That is, the reduction of the final pressure by 80% of the maximum at asymptotic barodynamics compared to its reduction by the normative 30% with the same duration at extreme barodynamics shows that the seam unloading at the depth of sealing is significantly greater in the asymptotic case.

To improve reliability, the depth of safe coal extraction after hydraulic loosening at asymptotic barodynamics is recommended to take as the average between its minimum values of the sealing length (Lг). That is, the recommended depth of safe coal extraction after hydraulic loosening at asymptotic barodynamics is 1.5 Lг.

4. Conclusions

1. According to the indicator of the distance (depth) of safe coal extraction, different calculation models have led to the same result. This indicates that the applied method for determining distance of safe coal extraction clearly reflects the existing natural laws and allows to estimate the efficiency of hydraulic loosening by barodynamic curves. It is also shown that efficiency and productivity of hydraulic loosening

in accordance with the current rates of the seam development correspond exactly to the asymptotic form of the barodynamic curve.

2. Unloading of the seam to the depth of sealing is significantly greater at asymptotic form of the barodynamic curve compared to extreme barodynamics: it is evidenced by the decrease in its final pressure by 80% of the maximum compared to the decrease by the standard 30% at the experimental form over the same time. As a result, with asymptotic barodynamics of hydraulic loosening, the length of the safe face advance is much greater than the sealing depth.

3. It is possible to recommend the depth of safe coal extraction after hydraulic loosening at asymptotic barodynamics be equal to 1.5 Lг

REFERENCES

1. Standard of the Minvuglеprom of Ukraine (2005), *SOU 10.1.00174088.011-2005.* Pravyla vedennya hirnychykh robit na plastakh, skhylnykh do hazodynamichnykh yavyshch. Standart Minvuhlepromu Ukraïny [10.1.00174088.011-2005. Rules for conducting mining operations on layers prone to gas-dynamic phenomena], Ukraine Ministry of Coal Industry, Kiev, Ukraine.

2. Mineev, S.P., Potapenko, A.A., Mhatvari, T. Ya., Nikiforov, A.V., Kuzarya, S.V. and Timofeev, E.I. (2013), *Pidvushenya efektuvnosti gidravlichnogo rozpushuvanya vukudonebezpechnuh vugilnuh plastiv* [Increasing the efficiency of hydraulic loosening of hazardous coal seams], Skhidnyy vudavnuchuy dim, Donetsk, Ukraine.

3. Mineev, S.P., Usov, O.A. and Poliakov, Yu.E. (2021), *Napirna filtraciyu u vugleporodnomu masuvi* [Pressure filtration in a coal massif], Bila, Dnipro, Ukraine.

4. Koptikov, V.P., Bokiy, B.V., Mineev, S.P., Yuzhanin, I.A. and Nikiforov, A.V. (2016), *Udoskonslenya sposobiv ta zasobiv bezpechnoyi rozrobku vugilnukh plastiv, shulnukh do gazodunamichnukh yavush* [Improvement of methods and means of safe development of coal seams prone to gas-dynamic phenomena], Promin, Donetsk, Ukraine.

5. Mineev, S.P., Rubunskuy, A.A., Vitushko, O.V. and Radchenko, O.G. (2010), *Girski robotu u skladnukh umovakh na vukudonebezpechnukh vugilnukh plastakh* [Mining operations in difficult conditions on hazardous coal seams], Skhidnyy vudavnuchuy dim, Donetsk, Ukraine.

6. Chernov, O.I. (1975), *Pidgotovka shahtnukh poliv iz gazovubrosonebezpechnumu plastamu* [Preparation of mine fields with hazardous coal seams], Nadra .

7. Krukovskuy, O.P., Krukovskuy, V.V. and Usov, O.O. (2020), "The influence of coal treatment with water and antipyrogens on the formation of the stress field around the mine", *Geotekhnicheskaya Mekhanika* [Geo-Technical Mechanics], no 150, pp 116-126. https://doi.org/10.15407/geotm2020.150.116

8. Pikhachov, G.B. and Isaev, R.G. (1972), *Pidzemna hidravlika* [Underground hydraulics], Head helper, Nadra.

9. Usov, O.O. (1985), Establishing regularities of liquid filtration, increasing the efficiency of coal seam hydration, Abstract of Cand. Tech. dissertation, Sciences: 05.15.11, M.S. Poljakov Institute of Geotechnical Mechanics under NAS of Ukraine, Dnepropetrovsk, Ukraine.

10. Usov, O.O. (2020), "The assessment of compliance with the linear law of filtration leads to the real dynamics of changes in its pressure during injection into the coal seam", *Geotekhnicheskaya Mekhanika* [Geo-Technical Mechanics], no. 150, pp 93-101.

About authors

Minieiev Serhii Pavlovych, Doctor of Technical Sciences (D.Sc.), Professor, Head of the Department of Pressure Dynamics Control in Rocks, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM 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, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, usov.o.a@gmail.com

Poliakov Yurii Yevhenovych, Doctoral Student, Junior Researcher in Department of Pressure Dynamics Control in Rocks, Institute of Geotechnical Mechanics named by N. Poljakov of the National Academy of Sciences of Ukraine (IGTM NAS of Ukraine), Dnipro, Ukraine, poliakovyurii488@gmail.com

МОЖЛИВІСТЬ ОЦІНКИ ЕФЕКТИВНОСТІ ГІДРОРОЗПУШУВАННЯ ЗА АСИМПТОТИЧНОЮ ФОРМОЮ БАРОДИНАМІЧНОЇ КРИВОЇ

Мінєєв С.П., Усов О.А., Поляков Ю.Є.

Анотація. Визначальним критерієм для оцінки ефективності гідророзпушування є характер бародинамічної кривої, а визначальним параметром - кінцевий тиск нагнітання. Проте слід зазначити, що у документі СОУ 10.1.00174088011-2005 не відображається наявність двох видів бародинамічних кривих – екстремальної та асимптотичної, які характеризують зміну тиску нагнітання протягом тривалості гідророзпушування. У статті наведено порівняльну оцінку визначення ефективності гідророзпушування по бародинамічним кривим. Продемонстровано різні розрахункові моделі оцінки довжини безпечного просування вибою при асимптотичній бародинаміці, що призвели до однакового результату за показником відстані (глибини) безпечного вилучення вугілля. Показано, що довжина безпечного руху забою при асимптотичній бародинаміці гідророзпушування значно більша за глибину герметизації. Була застосована методика оцінки відстані безпечного вилучення вугілля, яка вказує на те, що вона чітко відображає існуючі природні закономірності. Асимптотична бародинаміка, на відміну від екстремальної, забезпечує значно менший кінцевий тиск, який можна порівняти з кінцевим тиском при гідровіджимі, але без наявності віджиму вибою. Тобто зниження кінцевого тиску на 80% від максимального при асимптотичній бародинаміці в порівнянні зі зниженням його на нормативні 30% за той же час при екстремальній бародинаміці свідчить, що розвантаження пласта на глибині герметизації істотно більше в асимптотичному випадку.

Продемонстровано, що ефективність гідророзпушкування в даний час можна легко визначити за її асимптотичної формою бародинамічної кривої. Так само доведено, що чим нижчий кінцевий тиск гідророзпушування тим глибше зона розвантаження привибійної частини пласта для асимптотичної бародинамічної зони розвантаження і вона досягає максимальної, яку можна порівняти з глибиною герметизації.

Ключові слова: бародинамічні криві, асимптотична форма кривої, ефективність гідророзпушування, гірський тиск, нагнітання води, глибина герметизації, епюра гірського тиску.

The manuscript was submitted 14.06.2022