

Variability of rock pressure along the length of the working face

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Abstract

Introduction. Common deepening of mining causes problems with maintaining the achieved production capacity. The ability of the mechanized supports to withstand rock pressure in such conditions is questioned. Modern supports equipped with pressure sensors will make it possible to control and prevent the negative impact of the increased rock pressure and visualize the results.

Research aim is to determine the rock pressure variation rate along the length of the longwall in order to avoid its negative impact and to plan the capacity of the cutter-loader and load upon the working face in various mining and geological conditions in a more substantiated way.

Methodology. The use of the Surfer software to visualize the processes of displacement and construct the geomechanical structure diagram of the coal-bearing disintegrated rock mass in the form of geomechanical layers hierarchy makes it possible to forecast the sites with the increased rock pressure upon the coal bed and the longwall support.

Results. Timely and well-grounded determination of the sites with the increased rock pressure upon the coal bed and the powered support at the longwall face advance is the technical results of the research.

Analysis and discussion. The geomechanical structure diagram shows the sequence of disintegrated rock displacement arches development. Overburden and bearing pressure acts upon the coal bed between the displacement arches and depends on the depth of coal bed occurrence, working face advance speed and the strength of the roof rock. It is the sum of the overburden and bearing pressure that is reflected on the state of the coal bed ahead of the face of the longwall; their impact is wave-like.

Summary. The diagram will make it possible to forecast the sites subject to the negative impact of rock pressure along to length of the longwall and improve the effectiveness of coal bed mining by means of more accurate calculation of load upon the working face and the capacity of the cutter-loader; specify the force of cutting machine working elements during coal bed breaking, choose the support of the longwall according to the load-carrying capability, plan some measures to eliminate the negative impact of rock pressure at particular sites, and strengthen the marginal part of the bed in order to reduce visible coal sloughing.

Key words: rock pressure; coal bed; enclosing rock mass; rock; longwall face.

Introduction. Within the last decades working areas capacity has increased by a long way. Due to the tendency towards increasing mining depth and increasing gas content of the developed coal beds, the issues of maintaining the achieved coal production levels and further growth of productivity have become relevant. Rock pressure and gas-oil ratio are known to be the main factors restricting effective development of coal fields. It is impossible to develop equipment and technology without taking into account modern knowledge on the processes occurring within the rock mass when cutting the coal beds. Numerous scientists both in Russia [1, 2] and abroad [3–8] deal with the issues of coal mining safety. As it has been stated in [9], the processes of displacements and gas emission out of the rock mass are closely connected. It is beyond doubt that investigation of rock pressure generation processes is relevant at the present time.

Research aim is to determine the rock pressure variation rate along the length of the longwall in order to avoid its negative impact and to plan the capacity of the cutter-loader and load upon the working face in various mining and geological conditions in a more substantiated way.

Methodology. Research [10] proved the waviness (nonlinearity) of the geomechanical process as applied to the coal bed mined by the room and pillar method. Conclusion on the nonlinearity of the geomechanical processes is based on the application of gas dynamics methods. Nonlinearity of the working area methane-bearing capacity variation has been shown with the period which is incommensurably larger than the caving step of the main roof. The data on the pressure in the posts of the powered support [11] are presented, which also prove the wave-like character of the process, but the area near the face and possible consequences of wave-like rock pressure effects are not considered in details. Reference to the data on pressure in power support posts can be found in the works of foreign authors. Pressure variation wave-like character has been registered but there have been no recommendations on practical implementation of the registered variation of rock pressure. The whole matter comes down to stating the observed features.

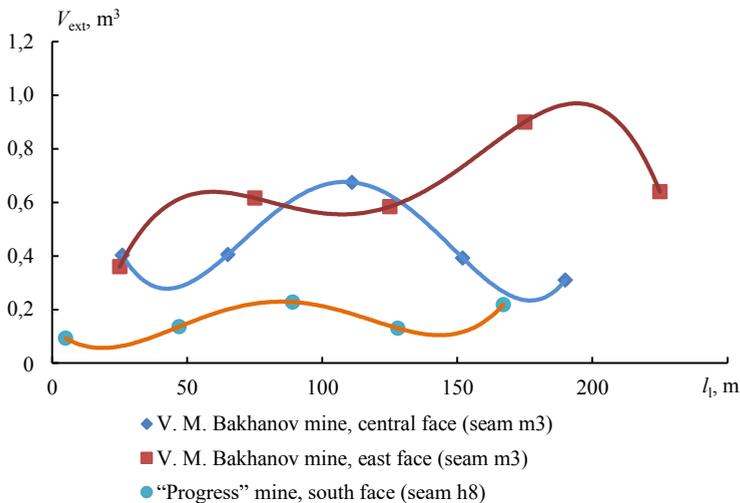


Fig. 1. Sloughed coal volume alternation along the length of the working face
Рис. 1. Изменение объема отжатого угля по длине очистного забоя

There are some investigations of rock pressure effect on the coal bed along the length of the working face [12] and on coal massif weakening [13]. Research [14] considers alternation of sloughed coal volume V_{ext} along the length of the longwall face l_1 (fig. 1).

It can be seen at fig. 1 that the volume of the sloughed coal along the length of the longwall changes in waves, i.e. rock pressure, which has an effect on the coal bed, is of the wave-like character. Research [15] attributes the wave-like alternation of rock pressure to the technogenic structuring of the rock mass when cutting the coal bed.

Having counted pressure indicators in the posts of the powered support according to the formulae (1)–(3), let us determine the height of the rock layer which has an effect on the support; for this let us accept the mean density of rock equal to 2.5 t/m³ (fig. 2). *Surfer* software is used to construct the pressure area.

The force response of the powered support posts, MN:

$$P_p = P_{p1}S_{p1} + P_{p2}S_{p2}, \quad (1)$$

posts pressure distributed along the area of the roof timber, MPa:

$$P_r = P_p/S_r, \quad (2)$$

the height of the rock layer which has an effect on the support, m:

$$h_{layer} = P_r/0.025, \quad (3)$$

where P_{p1} , P_{p2} – fluid pressure in the posts of the powered support, MPa; S_{p1} , S_{p2} – the squares of the powered support posts piston, m²; S_r – the square of the roof timber, m.

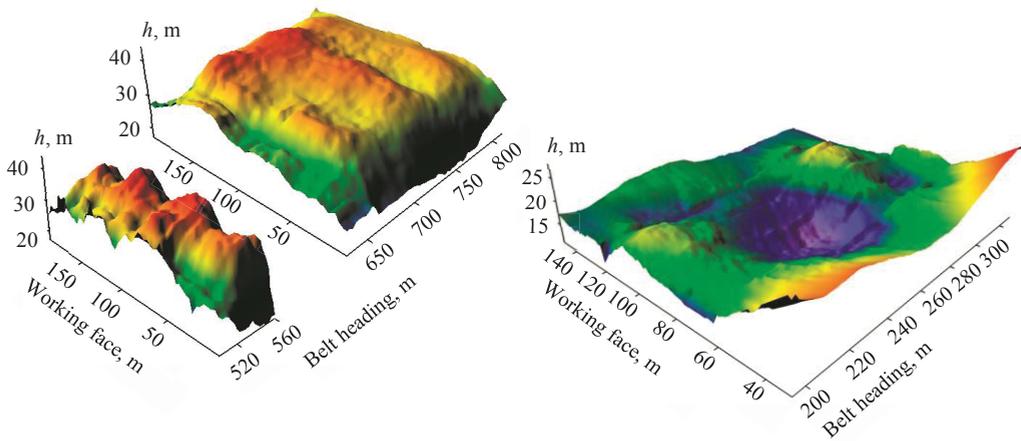


Fig. 2. Height of the rock layer exerting pressure on the longwall support
Рис. 2. Высота слоя пород, оказывающего давление на крепь лавы

The undermined disintegrated rock mass is presented at the vertical diagram in the form of displacement arches hierarchy, the height of which determines the thicknesses of the geomechanical layers. The parameters of the displacement arches are determined from the mined bed towards the daylight surface.

Rock mass disintegration process originates at the mined bed with the formation of arches with a minimum sizes of h_0 and l_0 (not shown at fig. 3), then, in the vertical direction, arches 1 are developed; after that, arches 2 are formed, indicated by the dashed line; the process is finished with arches 3, which reach the daylight surface (fig. 3).

Minimum dimensions l_0 and h_0 of arches-paraboloids are calculated by the formulae, m:

$$l_0 = \frac{l_{wf}}{2^n} \approx \frac{L_1}{4} \approx L_2; \quad h_0 = l_0/2,$$

where l_0 is the foundation diameter of the minimum arch, which is accepted as close to secondary caving step and multiple of the length of the working face, m; l_{wf} – the length

of the working face, m; n – the level of the structural hierarchy (an integer), it is determined based on the condition $L_1/L_2 \approx 4$; L_1 and L_2 – steps of the primary and secondary caving of roof rock correspondingly, m (either determined by the known dependences in the *Interim Guidance on the Primary and Subsequent Steps of Roof Rock Caving when Mining Coal Beds with a Room and Pillar Method along the Strike in the Conditions of Kuzbass. 973. 27 p.* or specified according to the mining and technological data); h_0 – the height of the minimum arch, m.

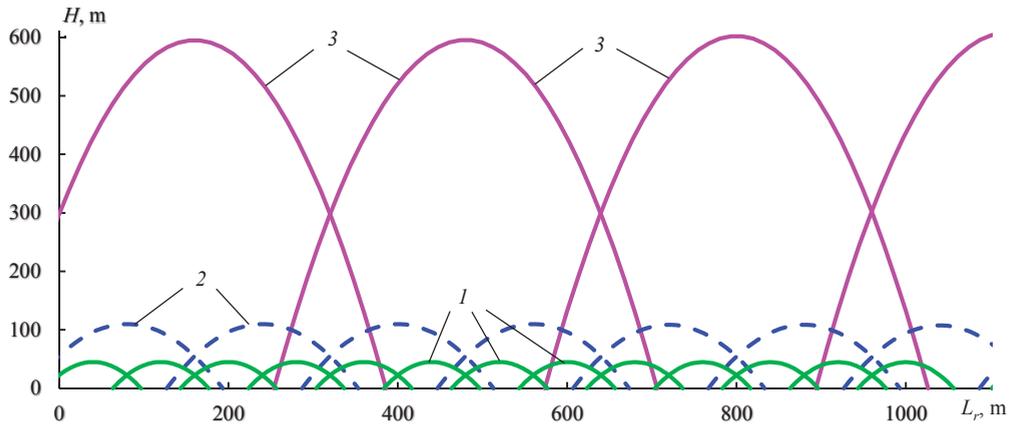


Fig. 3. Vertical structure diagram of the disintegrated rock mass:

1 – arches n_3 ; 2 – arches n_4 ; 3 – arches n_5

Рис. 3. Вертикальная схема структуризации дезинтегрированного массива:

1 – своды n_3 ; 2 – своды n_4 ; 3 – своды n_5

The diameter of the n -level arch according to the structural hierarchy, m:

$$l_n = l_0 2^n.$$

The height of the n -level arch according to the structural hierarchy (with the account of the elastic energy of the mass), m:

$$h_n = h_0 2^n E n,$$

where $E n$ – is rock elastic energy spent to form the volumetric surfaces of arches-paraboloids and dismember the corresponding masses, MJ.

Rock elastic energy is determined as a nonlinear function, MJ:

$$E n = \varphi(k, H, E),$$

where k is the coefficient of the lithological pressure, MPa; H – the depth of the mined bed occurrence, m; E – rock elasticity modulus, MPa.

Results. As it is shown at fig. 2, the magnitude of active rock layer thickness is limited to 45 m. It should be stated that this layer exerts direct pressure on the powered support, i.e. it is the thickness of the disintegrated rock layer, the power of which is carried by the powered support. The presented data meet the diagram of rock disintegration. It is known that the main superstrata pressure upon the near-face rock mass is carried by the coal bed. Geomechanical structure diagram shows the sequence of disintegrated rock displacement arches formation. The magnitudes of arch foundations are multiple of the length of the working face [15]. Within the limits of the arches, the load will be equal to the weight of the disturbed rock within, and the load

falls upon the support of the longwall, while between the forming arches, rock pressure acts on the coal bed, and it will be equal to the value of overburden rock pressure plus the bearing pressure which is often 3–4 times as large as the overburden pressure. The amount of the overburden and bearing pressure depends on the depth of coal bed occurrence, working face advance rate, m/day, and roof rock strength. It is the sum of the overburden and bearing pressure that is reflected on the state of the coal bed ahead of the face of the longwall; their impact is wave-like. Coal sloughing develops, and coal bed cutting resistance alternates along the length of the working face.

Summary. Rock pressure alternation values determination along the length of the longwall will make it possible to eliminate its negative effect and plan the capacity of the cutter-loader and the load of the working face in various mining and geological conditions more reasonably. The method of controlling rock pressure is proposed at the longwall face when mining gently-sloping coal beds by the room and pillar method with roof cave-in; the method includes the construction of geomechanical structure diagram of coal-bearing disintegrated rock mass in the form of the hierarchy of geomechanical layers, the thickness of which corresponds to the height of the forming displacement arches, and it is distinguished by the fact that the constructed diagram will make it possible to forecast the sites of the increased rock pressure upon the coal bed and the support of the longwall face.

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Изменчивость горного давления по длине очистного забоя**Шинкевич М. В.¹**

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Реферат

Введение. Повсеместное углубление горных работ вызывает сложности с сохранением достигнутого уровня добычи. Возникают вопросы о способности механизированных крепей выдерживать горное давление в таких условиях. Оснащение современных крепей датчиками давления позволит контролировать и предотвращать негативное влияние повышенного горного давления и визуализировать результаты.

Цель работы. Определение величин изменений горного давления по длине лавы, чтобы избежать его негативного влияния и более обоснованно планировать производительность комбайна и нагрузку на очистной забой в разных горно-геологических условиях.

Методология. Использование программного продукта Surfer для визуализации процессов смещений и построение схемы геомеханической структуризации углевлещающего дезинтегрированного массива горных пород в виде иерархии геомеханических слоев позволяет прогнозировать участки повышенного горного давления на угольный пласт и крепь длинного очистного забоя.

Результаты. Техническим результатом является заблаговременное и обоснованное определение участков повышенного горного давления на угольный пласт и механизированную крепь при движении длинного очистного забоя.

Анализ и обсуждение. Схема геомеханической структуризации показывает последовательность формирования сводов смещений дезинтегрированных пород. На пласт угля между сводами смещений действует геостатическое и опорное давление, которое зависит от глубины залегания угольного пласта, скорости движения очистного забоя, крепости пород кровли. Именно суммарно геостатическое и опорное давление отражаются на состоянии угольного пласта впереди забоя лавы, и их влияние волнообразно.

Выводы. Построение схемы позволит прогнозировать участки негативного влияния горного давления по длине лавы, повысить эффективность отработки пласта угля за счет более точного расчета нагрузки на очистной забой и производительность комбайна, уточнять усилие рабочих органов горно-выемочных машин при разрушении пласта угля, выбирать крепь лавы по несущей способности, планировать на определенных участках мероприятия по устранению негативного влияния горного давления, укреплять краевую часть пласта для снижения видимого отжима угля.

Ключевые слова: горное давление; угольный пласт; вмещающий массив; горные породы; длинный очистной забой.

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