Analysis of Studies of the Rock Pressure Manifestations During the Development of the New Kuzbass Seams

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***Abstract*—Based on the analysis of studies in domestic and abroad practice it is defined that the accumulated experience is a subject to significant adjustment in conditions of new Kuzbass coal deposits (Erunakovskoe, Kazankovskoe and others.). There is a comparison between the obtained measurements of the manifestation of rock pressure, obtained by the following methods: measuring the displacements of contour and depth benchmarks, pressure in the hydrostatic supports of the mechanized complex, relative deformations of the coal massif on the conveyor drift are shown at the approach of the coalface during the development of the seam. The relation of different cases is presented. Also the distinctive feature of rock pressure formation in comparison with the same picture observed at other deposits remains in the process of rapid blanking of the waste area disintegrated into the pieces of small size mudstones, which are being used as the cushion. In the final part, the solutions for investigating the manifestations of rock pressure in neighboring mines of new deposits are proposed. (*Abstract*)**

***Keywords*— seam thickness, seam inclination and depth, coal mining, displacements of contour and depth benchmarks, the pressure in supports, relative deformations, field researches.**

I. Introduction

The experience of testing the suite of shallow coal seams in Kuzbass mines shows, that mining in the increased rock pressure zones is complicated becomes by the substantially increased loads on the supports [1, 2]. But this is not confirmed at the new coal deposits development in Kuzbass (Erunakovskoe, Kazankovskoe and others), that are characterized by low strength and deformation properties of the surrounding rocks, increased water content and others.

This makes necessary to clarify of the geomechanical parameters of the changing mining and geological conditions during the development of suits of seams in new developed areas of Kuzbass, shown by [3]. Unfortunately previously performed studies do not allow the unconditional usage of the state of the rock massif assessment experience similar to analogical experience with the developed deposits in Kuzbass [4], as this document does not reflect the new specific conditions.

Based on the described facts the goal was to set to make further researches in relation to the new Kuzbass deposits mentioned above.

II. Theory Question

Separate researches in mine conditions (complicated, lengthy in time and expensive) are not sufficient to justify the regularities of rock pressure with a large variety of geological and mining factors.

Simulation of mining processes is reflected in the foreign authors works, for example, in [5, 6] the modeling of the extraction area with simulated strength characteristics similar to real conditions is described , and the process of zones formation of the reference pressure ahead of the coalface complex is studied. When searching for a possible research base was also considered in [7] mathematical modeling of a system with linking the movement of drift over of the coalface was studied. In addition, foreign authors [8 - 10] with respect to local field studies, noted that the length of the zones of the reference pressure did not exceed 15-20% of the depth of development, but the value numbers of the reference pressure can exceed hydrostatic 2 - 4 times.

The manifestation of rock pressure in longwalls was investigated in [11] in the conditions of the mines, currently being the part of PJSC “Southern Kuzbass” and “Raspadskaya”, and in [12], the results of instrumental observations in the "Signal" mine, it is noted that the magnitude of the roof lowering in the conveyor and ventilation drifts away from the longwall at of 160 meters distance was 140 - 160 millimeters.

In the works [13, 14], the parameters of the roof exposure were studied considering the location of the workings and the structures of the massif with the help of simulation.

Based on the described analysis, there was a goal to research to set the manifestations of the rock pressure (on "Tagaryshskaya" mine for example) with a task of obtaining new data in order to update the normative document [4].

III. MATERIALS AND METHODS

During the mining of seam 34-3, measurements of the displacements of contour and depth benchmarks on the conveyor and ventilation drifts were made, the displacement of the direct roof over the worked out space was recorded, the influence of changes in the rock pressure on the supports of the MKD complex was evaluated. The relative deformations of the coal massif on the conveyor drift were measured at the approach of the coalface (longwall 34-3).

The places for measuring points (MP) and messdoses (MD) are shown in Fig. 1.

During the period of mining of seam 34-3 (thickness 2.8 meters, inclination 5-8 degrees, depth 320 - 340 meters) in the longwall (length of the uprising 250 meters, length of the stretch 2500 meters) the MKD complex was applied. Coal mining was carried by KSV-460 miner in the presence of the undermined layer 35 (interlayer thickness 90 meters). The immediate layer roof is the fine-grained siltstone (thickness 9.0 meters, rock strength 3 - 4), the main layer roof is also the fine-grained siltstone (thickness 20.0 meters, rock strength 3 - 4). The average speed of the longwall movement was 2.5 - 3.5 meters per day with the coal mining productivity from 2500 to 3500 tons per day. On the another mines of region with the longwall movement 2.5 - 3.5 meters per day the coal mining productivity fluctuated from 5000 to 6000 tons per day. In these conditions the rock pressure formation and redistribution will be determined during the mine and laboratory studies on models from equivalent materials.

Conveyor and ventilation drifts in the roof are fixed by anchors with length 2.2 meters and amount 6 anchors on the roof bar (lengh 4.4 meters), including 2 key anchors (with the presence of compliant washers) at the side of the ventilation drift and 1 key anchor at the side of the conveyor drift. The drift boards are fixed by SK anchors with length 1.8 meters, one anchor on the sides with a distance along strike 1.0 meters in alignment with the roof bars.

The displacement on the contours of the conveyor and ventilation drifts in the direction of "roof - flour" was carried out on the measuring point (MP1, MP2), 2 on each drift, and in the direction of the "side-by-side" it was carried out at 2 measuring points (MP3) [15].

To check the roof displacement over the worked out space (measuring point of the depth benchmarks MPDB, fig. 1) the mining chamber was expanded by 0.7 meters at a distance of 5.0 meters from the conveyor drift, a hole was drilled with a diameter of 44 millimeters at an angle of 75 to the intersection with the main roof from the production face. The length of the hole was 14 meters. This borehole was equipped with three depth benchmarks of R1, R2, R3 at a distance of 400, 600, 800 millimeters from the immediate roof of the seam. The measuring of the displacement of deep and contoured frames carried out by the VNIMI method [16].

To fix the pressure of the collapsed rocks on the flour layer messdoses (MD1, MD2, fig. 1) were applied [17]. Pressure control in messdoses was performed with help of manometer (up to 65 kilonewtons per square meter).

To record the pressure in hydraulic cylinder powered support in the front row working in sockets for indicators manometers were turned on (in the back row stands the pressure was less). At a distance of 12 meters from the conveyor roadway installed the pressure manometer No. 1 (M1), a distance of 12 meters from ventilation drift, set the pressure manometer No. 2 (M2), and in the middle of the lava set the pressure manometer No. 3 (M3); the possibility of registration of all pressure manometer up to 30 megapascals. Thus, the pressure in supports as it was moving in the production face was recorded at three points of the lava.

Instrumental measurements of the rocks deformation, surrounding the development, were carried out by means of the MIS-11 display rack with attachment dial (measurement accuracy ± 0.01 millimeters) or with a VNIMI micrometer stand.

The deformation measurements were carried out on a special measuring point (SMP, fig. 1) at a distance of about 500 meters from the mining chamber, about 1.1 - 1.2 meters from the MP3.

To equip SMP the pressed coal production in the wall was robed on depth 0.8 - 1.1 meters. In the formed recess two boreholes were drilled up to 1.1 mmeters. The distance between the holes was determined by base of micrometer rack or IMS-II rack and was 870 millimeters. The boreholes were concreted with metal benchmarks (diameter16 - 18 millimeters, length 1.0 - 1.2 meters) by means of BRC cement (fast setting, expanding).

The benchmarks had a recess with a diameter of 3 - 4 millimeters to fix the rack position and placed into the niche so that during the observations deformations normal to bedding were measured.

IV. DISCUSSION OF RESULTS

The displacement of the contour benchmarks on the conveyor drift began to appear at the approach of a longwall face to MP1 at a distance of 27 meters, reached 33 millimeters and 29 millimeters respectively for ventilation and conveyor drifts and at the approach of the longwall face 29 meters on MP2 displacement reached 47 and 50 millimeters respectively on the conveyor and ventilation drifts. On MP3 displacement was 11 and 15 millimeters respectively on the conveyor and ventilation drifts [16].

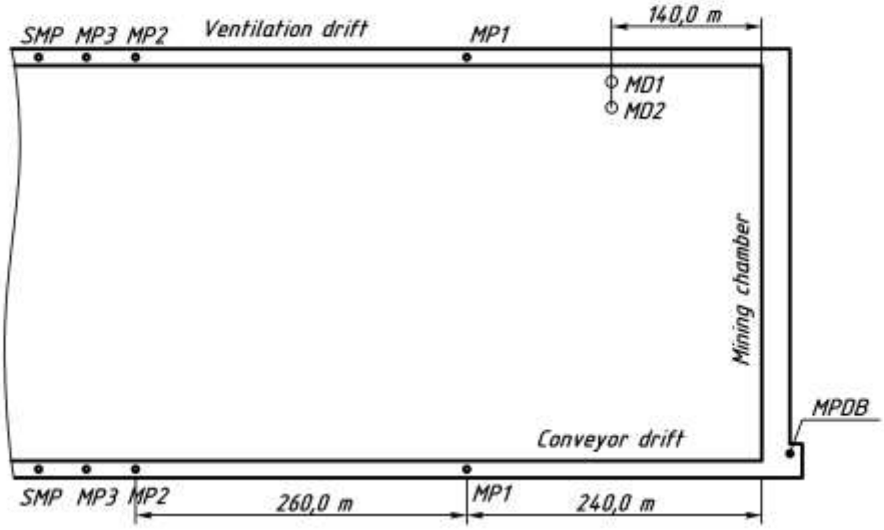

Fig. 1. The places for measuring points (MP) and messdoses (MD).

Thus, the offset on the conveyor and ventilation drifts, in the research of the authors recorded a significantly (2-3 times) lower than the results obtained in [11, 12]. These differences can be explained by the fact that in these cases the motion of the bottom of the roof collapse happened in large blocks, hanging on a length of over 60 m, with formed high confining pressure.

The displacement values of the depth benchmarks above developed space are presented in table 1.

TABLE 1 The displacement values of the depth benchmarks at movement of a coalface

Distance from depth benchmarks to coalface, m		**10**	**15**	**20**	**25**	**30**
Replacement of depth benchmark from roof, mm	***No. of benchmark***	***Displacement of roof, mm***				
400	R1	23	50	158		
600	R2	3	23	50	162	
800	R3	0	13	33	98	180

Data analysis (table 1) shows that the offset of the seam roof began: the benchmark No. 1 at 5.0 meter from the bottom of the longwall, the benchmark No. 2 at 10.0 meters from the bottom, and the benchmark No. 3 - 15 meters from the bottom.

The benchmark R1 has lost the spacers (the part of the hole stratified) at a distance of 20 meters from the bottom, when the total was offset roof 158 millimeters, the benchmark R2 lost spacers at a distance of 25 meters from the bottom with a total displacement of roof 163 millimeters, and the benchmark R3 lost thrust at 30 meters from the bottom with a total registered displacement of the roof of 180 millimeters. The total displacement of the three benchmarks on the removal of 4.0 meters from the roof was 5.0 millimeters. Thus was recorded the time of complete separation of the immediate roof along the entire height of 9.0 meters, therefore, the primary step of the collapse of the roof was approximately 27 - 28 meters, because from this point on the curve of the displacements of benchmark R3 has increased dramatically.

The distinguishing feature of phased separation (collapse) of the immediate roof due to the fact that at the first output of laminated hole of the first frame, the developed space was filled with collapsed mudstones, so the stratification of the main roof was for a long time (not observed) a reliance on a “cushion” of the immediate roof, fulfilled the role of the backfill array.

The pressure of the collapsed rocks in the developed space, recorded by messdoses (MD1, MD2) began to appear from 10 - 12 meters from the bottom with consequent increase it up to 4000 - 4700 kilonewtons per square meter. The pressure increases when the location messdose closer to the middle of the longwall. The pressure is almost stabilability at a distance of 45 - 50 meters behind the stope at the level of 4000 kilonewtons per square meter for MD1, MD2 - 4500 kilonewtons per square meter [17].

Thus, recorded in [11] the length of the zones of increase and pressure stabilization of collapsed rocks is 1.7-1.8 times more than in the research of the authors.

When monitoring the pressure change in the supports was not recorded landings “dry”, but when you stop culling (preventive maintenance) the pressure in the supports was increased by 0.1 - 0.3 megapascals. In all cases, the stable operation of the lining was ensured. Safety valve (25 - 30 megapascals) was occurred. In the span of an excavation cycle racks worked without additional load.

The character of change of pressure in the hydraulic pillars of supports on the sides of drifts (M1, M2) and in the middle of the lava (M3) are presented in table 2.

According to the indications of table 2 we can highlight areas of extraction pillar with different intensity of manifestations of rock pressure until complete phase separation of the immediate roof (primary and subsequent steps of caving).

In the beginning, at the distance of 3 - 4 meters from the mounting chamber, a predetermined thrust has changed to 11 - 12 megapascals. When the complex was at a distance of 10 - 15 meters from mounting the camera the pressure reached 12 - 13.5 megapascals, and at a distance of 20 - 25 meters, the pressure was 15.5 megapascals, at a distance of 30 meters the pressure increased to 17.5 megapascals. This increase of pressure can be explained by the completion of the separation of the immediate roof on the entire power 9 meters (the primary step of the collapse).

TABLE 2 Pressures in the pillars of the supports of the complex MKD as far as the movement of the coalface

No. M	**Distance from the mounting chamber to the coalface, m**														
	5	***10***	***15***	***20***	***25***	***30***	***35***	***40***	***45***	***50***	***55***	***60***	***65***	***70***	***75***
	Pressure in the pillars, MPa														
M1	10	12	13.5	13.7	152.	17	13.5	11	10	11.5	11	11	10	10	10
M2	10.5	11.5	13	14	14.7	16.8	13.7	11.5	10.5	11.6	10.6	10.6	10.7	10	10.5
M3	11	12	13.5	15	15.5	17.5	14	12	11	12	11	11	11	10	11

Based on the described above, it is possible to estimate the beginning of stratification of the roof of the seam in the worked out space, to predict the primary and subsequent steps of collapse of the immediate and main roof, and on this basis to take measures to prevent the landing of the pillars of the "dry" and other protective measures. This conclusion is especially relevant for the extraction of coal in longwalls with the presence of difficult-to-break roofs on the alrady developed Kuzbass deposits.

Table 3 shows the relative deformation $\varepsilon{\cdot}10^{-4}$ of the coal massif, depending on the distance from the SMP to coalface.

TABLE 3 The value of the relative deformation $\varepsilon{\cdot}10^{-4}$ of the coal mass, depending on the distance from the special measuring point (SMP) to coalface *L*, m.

The distance from the SMP to coal face *L*, m	**-5**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**
$\varepsilon{\cdot}10^{-4}$	25	25	24	21	17	12	8	4	2

It shows that the relative deformation is not exceeded the 25 value, that in comparison with extremely high performance for coal samples lower than in [15], since there is such an order of magnitude lower, therefore the relative deformations of the coal mass on the conveyor drift were in the range of elastic deformation, so there was not be destruction. The transition of long face over the SMP marked the relative deformations decline that indicates the presence of tensile strain (unloading). Figure 2 shows it graphically.

The considered character of the deformations of the coal array is given as the ability to search control options and valid deformations of undermined and overmined rock mass in mining of suites of layers.

It should be noted that the relative deformation compared with the displacement on the contour of the conveyor and ventilation drifts began to emerge not at 27 - 29 m from long wall face, and at 36 m. It can be explained by the fact that the displacements on the MP1 were fixed at a distance of 240 m from the mining chamber and on the MP2 at a distance of 500 m from the mining chamber, so this fact can be explained that the movement came to the main roof of the layer.

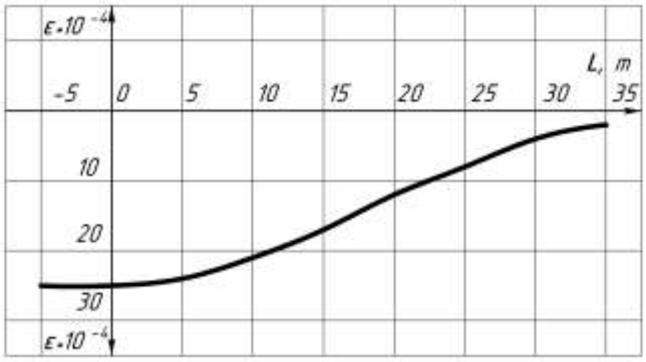

Fig. 2. The formation of the relative deformation $\varepsilon{\cdot}10^{-4}$ of the coal massif, depending on the distance from the SMP to coalface L, m: $\varepsilon=\Delta l/l$, where Δl is the rock deformation, mm; l is the distance between benchmarks, mm.

V. CONCLUSION

Accomplished rock pressure manifestations researches conducted on the "Tagarishskaya" mine, that is the part of new Kuzbass coal deposits compositions (Erunakovskoe, Kazankovskoe and others), also characterized by siltstone and mudstone presence in the seam's roof and their collapses by small blocks with step 22 - 28 meters (first step) and 8 - 13 meters (next step), allowed to compare it to rock pressure manifestations on the seams with sandstone in the roof and with 9 - 30 m thickness and able to hang up during the process of the roof exposure on length to 60 - 120 meters with forming of the elevated rock pressure zones and with the stress concentration factor K=3 and more. Thus, it makes the necessity to force roof descent in order to prevent rock strikes.

The results received from the studies of the rock pressure manifestations were compared with the same results on the JSC "Southern Kuzbass" mines (the old deposits) to justify the need of holding additional researches on the physical models to develop the normative documents for unfolding the closed suites of layers in the new Kuzbass deposits.

Because when seam 34 developed the preparatory workings were not performed on the contiguous seams, the necessity to imitate the working off the suit of seams on models made from equivalent materials with observance of the similarity conditions appeared and to to receive correction factors for calculations and modeling of other mines with change of longwall movement speeds and thicknesses of seams.

Based on the materials mentioned above and on the accumulated experience of model development in Prokopyevsk branch of the KuzSTU there is being prepared a method to simulate the development of suit of seams on the models made of the equivalent materials applicable to geological and mining conditions of new coal deposits.

REFERENCES

[1] G. Korshunov, A. Paltsev, N. Krotov, F. Ivchenko and R. Istomin, “Selection of sequence of mining the contiguous seams at coal mines of JSC SUEK-KUZBASS”. Mining informational and analytical bulletin, 2011, 5, pp. 24-28.

[2] V. Zubkov, A. Vyunnikov and I. Zubkova, “Geomechanical substantiation of the project for working out the closely related seams "Fifth" - "Powerful" at the mine "Severnaya" JSC "Vorkutaugol"”. Mine Surveying News, 2012, 3, pp. 41-44.

[3] D. Yakovlev, “The tasks facing VNIMI and its Siberian branch in Kuzbass”. Problems of mining geomechanics and mine surveying of Kuzbass (to the 60th anniversary of Kuzbass), 1990,: pp. 3-7.

[4] “Guidance on the rational development of the suites of adjacent steep and steeply inclined reservoirs of Kuzbass”. VNIMI, 1985.

[5] V. Sotskov and I. Saleev, “Investigation at the rock massif stress strain state in conditions of the drainaged rift overworking”. Mining of mineral deposits, 2013, pp. 197-201.

[6] V. Sotskov and O. Gusev, “Features of using numerical experiment to analyze the stability of development workings”. Progressive technologies of coal, coal bed methane, and ores mining, 2014, pp. 197-201.

[7] K. Stefan, “Arched and soil-locked fastening systems, means of protecting drifts from the side of the worked out space and strengthening the rocks”. Glückauf, 2004, 1, pp. 50-57.

[8] K. Erer and A. Heidareh – Zadeh, “A Review of in situ stress measurements techniques with reference to coal measures rocs”. Mining Science and Technology, 1985, 3, pp. 191-206.

[9] P. Lane, “Ground control study of mechanizedLongwall coal operations in West Virginia”. Rept. Invest Bur Mines us Dep. Intez., 1985, 89, pp. 29-34.

[10] “Prediction of shears zones associated with outbursts in coal mines”. 20 th Conf. Satety mines Res. Inst., 1987

[11] L. Gapanovich and V. Kruglikov, “Exploration of the manifestations of rock pressure in the development of a thick, shallow layer”. Problems of mining, 1974, pp. 141-149.

[12] M. Vagapov, A. Karasyov and V. Karasyov, “The manifestation of the mountain pressure in the drift formed in the worked out area of the face”. Innovation is the basis for the comprehensive development of the coal industry in the regions of Russia and CIS countries: Proceedings of the II International Scientific and Practical Conference, 2009, pp. 45-49.

[13] A. Shaikhislamov, “Results of displacement measurements on the contour of preparatory excavations during formation testing 34-3”. International scientific-practical conference "Prospects of innovative development of the coal regions of Russia", 2016: pp. 111-112.

[14] “Methodical instructions for the study of the manifestations of rock pressure in coal mines”. VNIMI, 1976.

[15] N. Bedarev, O. Lyubimov, I. Borodin and A. Shaikhislamov, “Formation of pressure of collapsed rocks in the worked-out space”. V International scientific and practical conference "Perspectives of innovative development of the coal regions of Russia", 2016, pp. 86-87.

[16] N. Kovalev, “Justification of the rational location of working developments in development of approximate seams and significant storages of Prokopyevsk-Kiselevsk deposit”. Thesis of dissertation, 2015.

[17] S. Kostyuk, N. Bedarev, O. Lyubimov and A. Shaikhislamov, “The Relationship Between the Manifestations of Rock Pressure and the Relative Deformation of Surrounding Rocks”. The 1st International Innovative Mining Symposium, 2017.