Proceedings in Manufacturing Systems
Proceedings in Manufacturing Systems, Volume 11, Issue 1, 2016, 47–52 ISSN 2067-9238

INNOVATIVE EQUIPMENT FOR IMPROVED COAL EXTRACTION TECHNOLOGY IN THICK SEAMS

Nicolae ILIAȘ[1], Iosif ANDRAȘ[2,*], Sorin Mihai RADU[3], Iosif GRUNEANȚU[4], Aurelian SERAFINCEANU[5]

[1, 3, 4, 5)] Prof., PhD, University of Petroșani, Dept. Mechanical, Industrial and Transportation Engineering, Petroșani, Romania
[2)] PhD., Eng, GEROM INTERNATIONAL S.A., Petroșani, Romania

Abstract: *The paper deals with a series of innovative solutions of equipment devised in order to improve the efficiency of mechanized coal faces in thick seams which avoids the inconveniences related to the effect of the increased face height on the on shearer, armored face conveyor(AFC) and shield supports, by a new concept of mechanized extraction complex. The presented system encompasses some innovative constructive changes on the shearer, on the face conveyor and shields, such as a new positioning of the shearer's body and the drums symmetrically related to its longitudinal axis, a new concept of AFC, allowing the reduction of height and offering accessibility to chains and flight bars and a new construction of shield allowing the increase of operating height with a shortest canopy, and offering a better kinematics in a wider range of working heights. The proposed system is only a concept, the refining of it being suitable for the construction of a new generation of mechanized longwall faces with increased working height, with relevant advantages in terms of productivity.*

Key words: *mining equipment, coal extraction, mechanized longwall face, shearer, AFC, support shield.*

1. INTRODUCTION

The fully mechanized longwall (Fig. 1) is the most used method in underground coal mines worldwide.

The longwall complex equipment consists of a set of three specialized equipment, devoted to fulfill specific unit operations: the shearer-loader, which realize the breaking of coal in massif and the loading of extracted coal on the armored face conveyor (AFC); this second equipment has as main function to haul the produced coal out from the face towards the main transportation chain of the mine, and a first secondary function to act as a sliding way for the shearer loader, and finally, a second auxiliary function to be a rigid connection element for the support shields; the support shields, arranged along the face, realize the support of the face roof, and to control the gob laying down behind the face.

The main parameters of a longwall face, as a basic production system in underground coal mining, are the panel width, face height and panel length.

As the literature and the acquired experience shows, the longwall face output increase is driven by all these three design factors [1].

All these factors are limited both by inherent geometry of coal seam and technological design decision variables. As the face width is actually limited by technological factors (installed power of AFC drives) to 300–400 meters and the panel length, in favorable conditions can reach values from a few hundred meters to kilometers, the height of face is determined by the thickness of the seam.

* Corresponding author: Universității str. 20, 332006, Petroșani, Hunedoara county, Romania
Tel.: 0040 254 549011
E-mail addresses: *iosif.andras@gmail.com* (I. Andras)

In seams with thickness until 4–5 meters they are mature technological solutions, using the so-called one slice mining [2]. If the thickness is greater than 5 m, the multi-slice (Fig. 2) or top coal caving (Fig. 3) method can be utilized.

Both methods are rationale if the thickness of the seam is greater than 10 meters, in case of top coal caving method, and no less than 6 meters in case of multi-slice method because the height of an individual slice less than 3 m lead to other inconveniences, such as limited productivity and difficult roof control, the upper slice having natural roof and the lower one artificial roof [3].

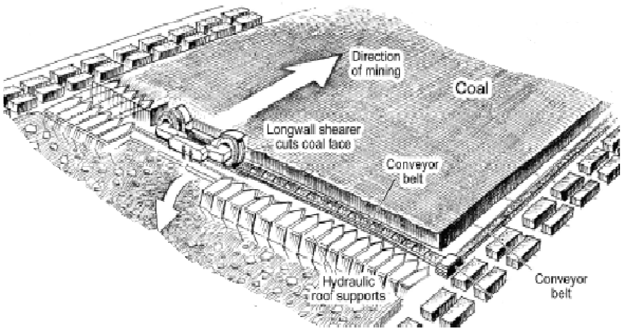


Fig. 1. General view of a classical fully mechanized longwall mining system.

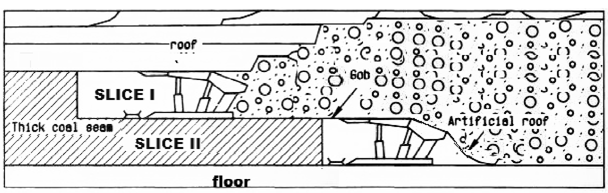


Fig. 2. Schematics of a multi-slice mining system.

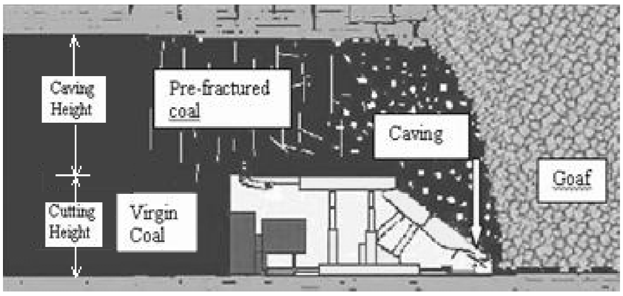


Fig. 3. Schematics of a mechanized top coal caving mining system.

The one slice mining (full thickness mining) at seams with 5, 6 or 7 meters do not have yet a mature solution, because in this height range the technical solutions cannot be extrapolated from those used in thinner seams, because this implies major technical problems related to the equipment behavior and functionality [4].

One of the problems is that not satisfactory constructive solution for support shields with working height were devised and manufactured, mainly because height increase lead to dramatic increase of other dimensions , i.e. canopy length, shield length and weight.

The second problem, is the corresponding increase of cutting height of the shearer-loader, which lead to drum diameters greater than 3 m, excessive length of drum ranging arms, great installed power of electric drives, dimensions of embedded gearboxes, and last but not least the stability in transversal direction due to asymmetric location of drums and need to ensure enough clearance underneath the shearer main body to allow the haulage of extracted coal flow.

The third problem is coming from the influence and interdependence between the parameters of the three production system's elements, and is related to the armored face conveyer (AFC).

It increases in dimensions, weight, installed power because of the increased flow of extracted coal and supplementary mechanical loads due to the need to support a heavier shearer loader and increased maneuver forces from the support.

Taking into account the above mentioned issues, our research team proposed an integrated solution – for now only at concept level – which tries to solve this problem.

Some parts of the technical solutions presented in the paper are subjects to patent proposals under evaluation.

2. ACTUAL SITUATION

A fully mechanized longwall coal face consist mainly in three interoperating correlated equipment. i.e. the shearer loader, (Fig. 4) the face support shields (Fig. 5) and the armored face conveyor (Fig. 6).

In case of great height, the drums of the shearer, roughly with diameter equal to the half of the face height, can reach on actual designs 2–3 meters, allowing an extraction height of maximum 4–6 meters.

The width of drums, equal with the advance step of the face, is limited to max 0.6–0.7 m, and this is a standard dimension for AFC width and shield support advance step.

The rationale of this value is dictated by roof stability reasons, related to maximal value of unsupported roof in front of the tip of the shield's canopy. This constraint influences the role of the face height as a secondary parameter in increasing the transversal cross section area of the face, with the inherent negative effects related to height increase.

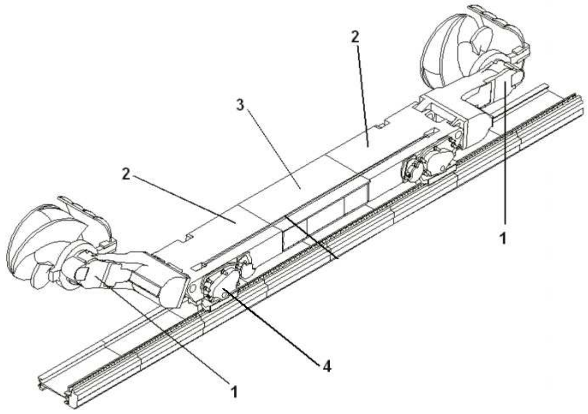
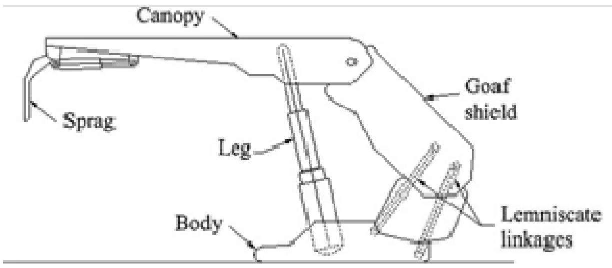
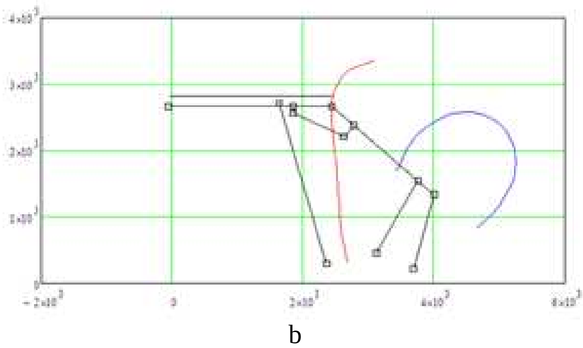


Fig. 4. Schematics of a shearer-loader: 1 – cutting-loading unit; 2 – haulage unit; 3 – energy distribution; 4 – haulage mechanism.



a



b

Fig. 5. *a* – Schematics of a longwall support shield; *b* – kinematics of four bar (lemniscate) mechanism.

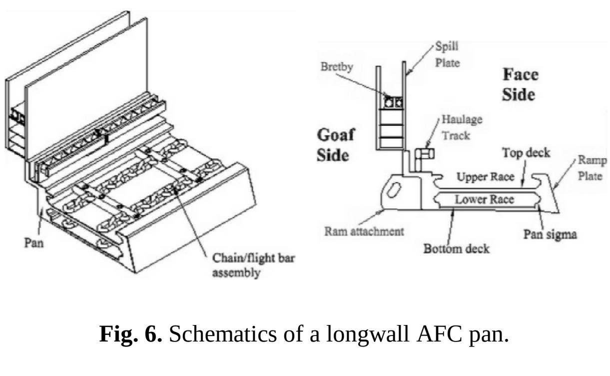


Fig. 6. Schematics of a longwall AFC pan.

The technological forces and torques with three directional components acting on the drums, can disturb the mechanical stability of the shearer (mainly those acting on the upper drum) and induces high reaction forces on the other structural parts of the support shield and on the AFC.

This is mainly because the body of the shearer is sliding on the AFC pans and the two drums are non-symmetrically disposed on the vertical plan (Figs. 7 and 8).

The powered roof supports (shields) with great height imposes a length of the goaf shield (rear side of the face) somewhat proportional with the height, because of the construction of the four bar (lemniscate) mechanism which connect the canopy to the base and insures the vertical straight movement of the pin of the canopy (Figs. 5,*a*,*b* and 9).

The AFC capacity is dependent on the width of the pan, which cannot be greater than 0.5–0.6 meters, the height of the pan, also limited because of the loading possibility of the shearer's drum, and the clearing beneath the shearer (Fig. 8).

The optimal correlation of these dependencies is very difficult to be realized, for the classical arrangements (up to 3–4 meters face height this is a result of a 50 years experience of miners, equipment manufacturers and designers [5] and, in the past years CAD and evaluated software involvement.

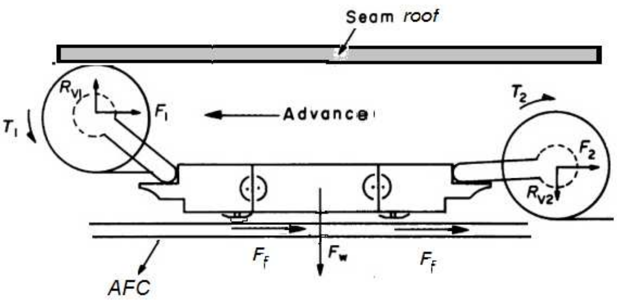


Fig. 7. Disturbing forces due to non-symmetric arrangement of drums in longitudinal plane F_w – weight; *F*, *R*, *T* – horizontal, vertical forces and torque on drums; F_f –frictional force of haul advance.

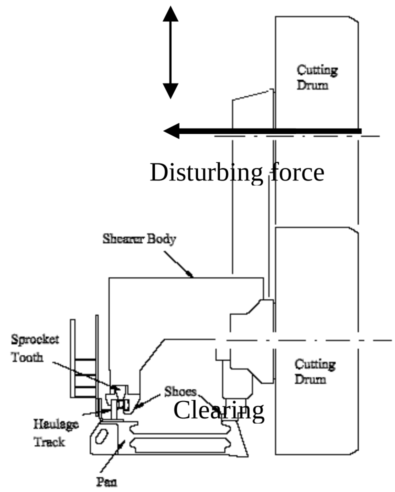


Fig. 8. Disturbing forces on transversal plane.

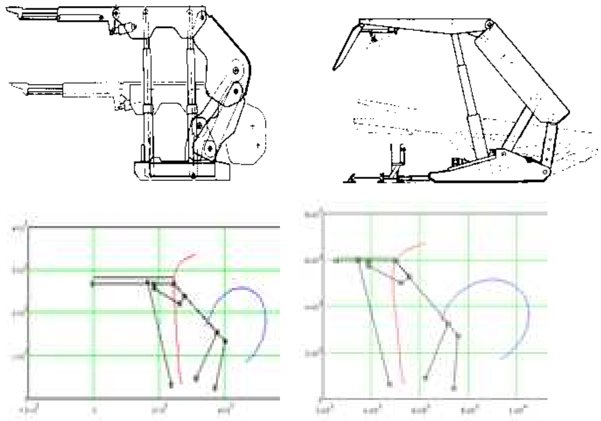


Fig. 9. Height limitation of classical shield supports with corresponding lemniscate linkage kinematics.

3. THE IMPROVED SOLUTION

In order to overcome these inconveniences, in the paper a proposal of an innovative longwall system is presented, as can be seen in the Figs. 10–13.

The main improvement of the proposed solution is the construction of the shearer loader and its haulage support (Fig. 10).

Firstly, the two drums are disposed symmetrically relative to the longitudinal axis of the shearer's body, in order to avoid the transmission of loads towards conveyor pans in longitudinal and transversal plane, and to insure the stability (balance) of the entire machine during operation.

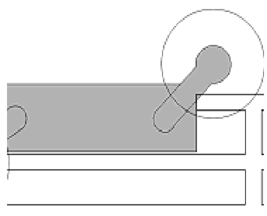
Secondly, the sliding of the shearer is performed on a structure containing three guidance points on which the shearer's body is sliding on roll bearings.

The guiding structure has its own reaction transmitting to ground system, consisting in floor bars disposed between shield support's base, aiming to reduce the amount of supplementary load on the conveyer.

The armored face conveyor is also an innovative one (Fig. 11)

In classical solution (Fig. 6), the chains and flight bars are moving inside the pans, the laden branch beneath the empty one, the upper branch conveying the coal. As the flow rate increases, the dimension of chains increases accordingly, and the height of pan make difficult the load of coal by the drums.

On the other hand, in view to ensure a sufficient clearing the body of the legs supporting the shearer body must be longer.



:onveyer and the shearer
proposed system.

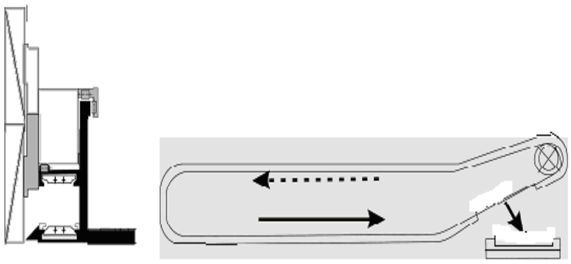


Fig. 11. The lateral (left) and longitudinal view of the conveyer pans and the chain-flight bar contour (right).

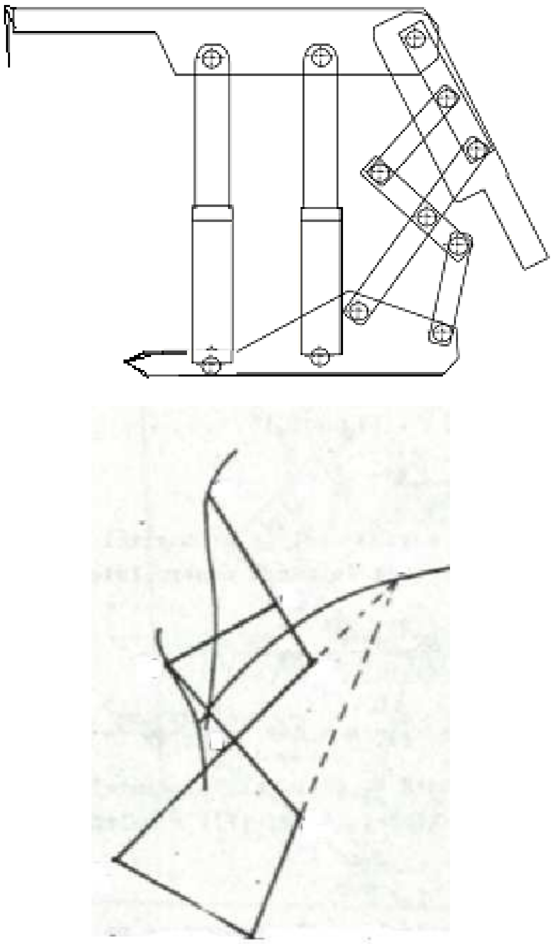


Fig. 12. The proposed construction of the shield support

This produces an increase of the moment of disturbing forces with negative impact on the shearer's lateral stability.

In the presented solution, the two sliding ways are separated and inverted, the active (laden) branch being the lower one, and the return (empty) branch the superior one.

By this constructive measure, the thickness of the pan are reduced to about half, and the available space for the coal flow is independent from the shearer clearance, being dependent only on the distance between the upper and lower branches (sliding ways of the chain-flight bars).

The discharge of the coal at the head-gate is possible through a window in the lower plate of the pan. (fig.11)

An important improvement is proposed also regarding the shield support.

In this respect, the lemniscate mechanism being replaced with a so called pantograph mechanism, fulfilling the same function and reducing the shield's length towards the goaf side of the face (Fig. 12).

As we see a shield support in a simplified plane lateral view, it cannot handle horizontal forces on the canopy, unless a guiding mechanism is mounted between the base and the canopy.

The classical guiding mechanism consists on a four bar linkage (Figs. 5 and 9). This linkage ensures the longitudinal mobile rigidity of the entire frame, and allows a quasi straight line movement of the front tip of the canopy.

The proposed solution, which the structural and kinematic synthesis and analysis has been performed using CAD software, based on the mentioned requirements and the minimal weight – maximal resistance criteria is a pantograph mechanism (Fig. 13).

A view of the entire face equipment setup arrangement can be seen in the Fig. 14.

Another possible improvement is to detach the rear shield from the lemniscate linkage, in view to allow its free movement to better control of falling rock from the roof.

Complementarily, the symmetric construction allows advancing the face in both directions, only by transferring the shearer and AFC during the transition of the face from a slice to the further one in descending.

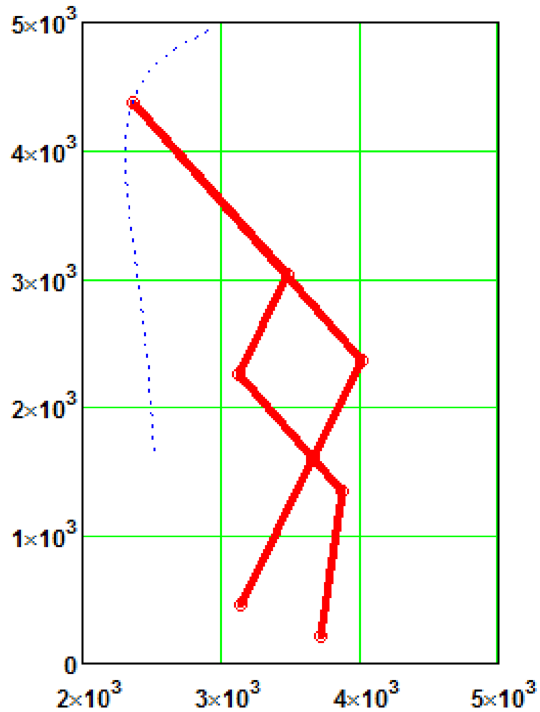


Fig. 13. CAD based analysis of the pantograph mechanism.

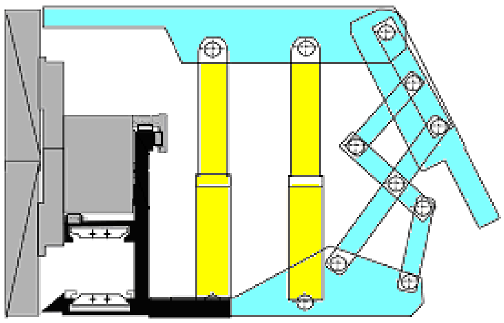
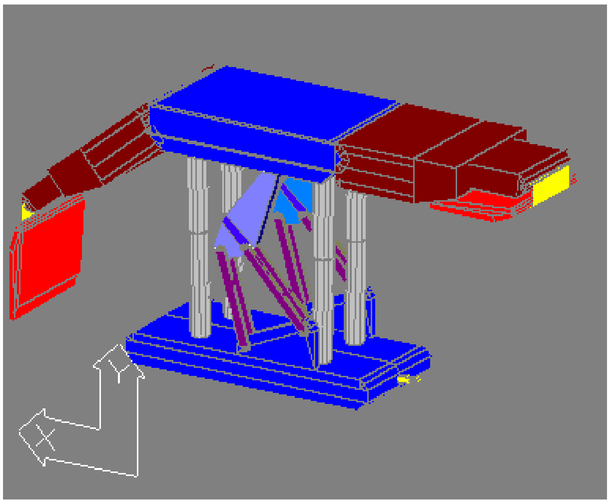
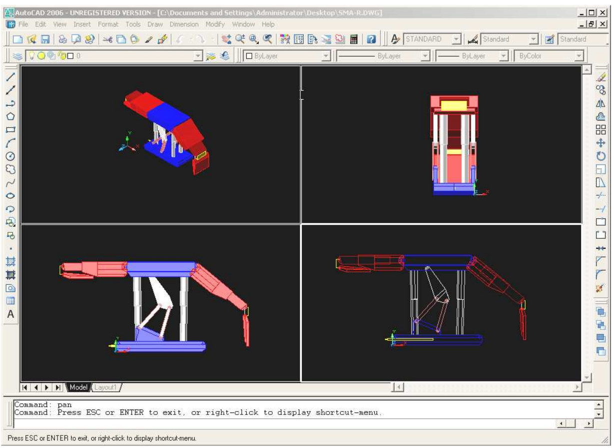


Fig. 14. Overall aspect of the mechanized coal face (lateral view).



a



b

Fig. 15. Screen captures of the design phase of the reversible shield support.

This new concept (Fig. 15) allows using the support both for multi-slice method and the top coal caving method if necessary.

The detachment of the lemniscate linkage from the rear shield, allows a better stability of the canopy because of the median location of the guiding mechanism connecting pin to the canopy, and more freedom to dimensional synthesis of the linkage.

As a result, a better kinematics of straight line guidance can be obtained on a larger range of working heights of the support , as it can be seen in Fig. 16.

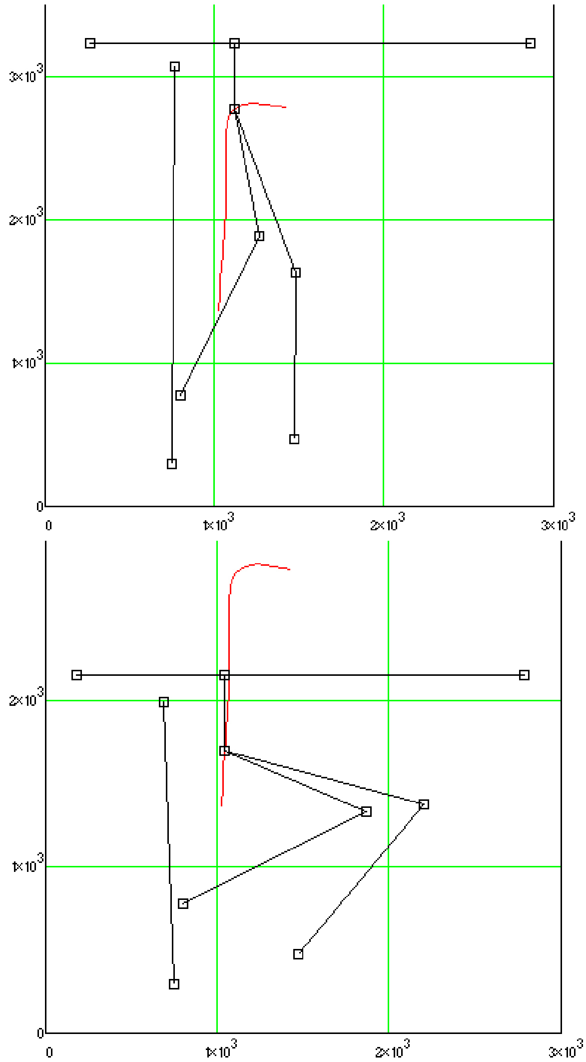


Fig. 16. Results of kinematic analysis of the reversible support unit for two extreme values of working height.

On the other hand, the possibility to modifying the slope angle of the shield with an appropriate hydraulic cylinder, allows the setting it in an adequate position to obtain best roof sliding control, not dependent on the working height of the support.

The structural design of the floor plate (base) of the presented shield support units has been optimized using FEM in order to ensure the better pressure distribution on the floor, which is suitable for a good longitudinal stability of the support.

The model used considered a variable cross section beam on elastic continuous support (Winkler) beam model.

The pressure distribution along the base is presented in Fig. 17.

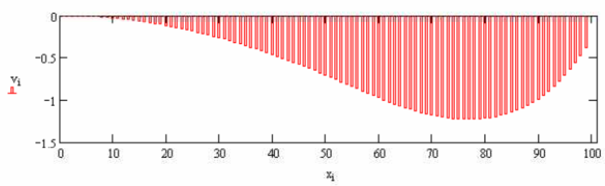


Fig. 17. Pressure distribution on contact between base and floor.

4. CONCLUSIONS

In order to improve the efficiency of mechanized coal faces in mining out the seams of height around and over 6 m. and to avoid some inconveniences related to the effect of the increase of the face height on the shearer, armored face conveyer and shield supports, a new mechanized ensemble is presented.

The presented system, make some constructive changes on the shearer, on the face conveyor and shields, as:

- a new positioning of the shearer body and the drums symmetrically related to the longitudinal axis which eliminates the effect of disturbing lateral forces;
- a new concept of AFC, allowing the reduction of height and offering accessibility to chains and flight bars;
- a new construction of shield allowing the increase of operating height with a shortest shield part , and a better kinematics in a wide range of working heights.

The proposed system is only a concept, the refining of it being suitable for the construction of a new generation of mechanized longwall faces with increased working height, with the cited before advantages in terms of productivity.

REFERENCES

[1] N. Ilias, I. Andras, L. Ilias, I. Gruneantu, S.M. Radu, *Longwall Face Mechanized Complex Equipment*, Bulletin Petroleum Gas University Ploiesti, Vol LX, No. 3, 2008.

[2] J. Wang, *Development and prospect on fully mechanized mining in Chinese coal mines*, International Journal of Coal Science & Technology, September 2014, Vol. 1, No. 3, pp. 253–260.

[3] G. Wang, H. Ren, *New development of sets equipment technologies for coal mine long-wall face*, China Journal of Coal Science and Engineering (China), March 2012, Vol. 18, No. 1, pp. 1–9.

[4] N, Ilias, I. Andras, S. Radu et al., *Mechanized underground coal mining to increase safety and productivity*, Risk Management, Assessment And Mitigation (RIMA '10), Bucharest, Romania, April 20–22, 2010.

[5] J. Wang, B. Yu, H. Kang, G. Wang, D. Mao, Y. Liang, & P. Jiang, *Key technologies and equipment for a fully mechanized top-coal caving operation with a large mining height at ultra-thick coal seams*, International Journal of Coal Science & Technology, June 2015, Vol. 2, No. 2, pp. 97–161.