DESCRIPTION AND IMPORTANCE OF MECHANISED SYSTEMS WITHIN THE EXTRACTIVE ENERGY INDUSTRY

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Abstract: The extractive industry and production of mining machinery and equipment has travelled in the European Union and Romania over the past decades a route called deindustrialisation, which slowed down and/or halted mining, which actually supported coal-based energy security. The development of a mining industry and implicitly strong energy is conditioned by the existence of coal resources, which are characterized by diversity, accessibility, safety, stable prices, etc, ensuring the desired quantities for as long as possible. In this strategic context, mechanised systems represent critical mining infrastructures, without which coal production can be stopped, generating massive financial losses and implicitly energy insecurity. As is known, energy security is a vital component of national security in the current global geopolitical, geoeconomic and technological context, which ensures the stability, prosperity and sustainable development of modern society, being a central pillar of a resilient and competitive economy. In order to have extensive energy security, we need to continue and increase coal-based power generation in the context of preventing energy crises.

Keywords: mechanised system, mining machinery, extractive energy industry.

1. INTRODUCTION

Coal is the primary energy resource of the energy mix, being a strategic fuel in support of national and regional energy security. In extreme weather, coal is the basis of the resilience of the power supply and the proper functioning of the National Energy System, covering one-third of the electricity demand. Lignite resources in Romania are estimated at 690 million tons [124 million tep], of which are exploitable in concessioned perimeters 290 million tons [52 mil. tep]. At an average resource

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consumption of 4.5 mil. tep/year, the degree of insurance with lignite resources is 28 years, given that in the next 25 years the consumption will remain constant and no other deposits will be valued lignite. The average calorific value of the exploited lignite in Romania is 1800 kcal/kg. Because the lignite deposit in Oltenia consists of 1-8 layers of exploitable coal, their superior use requires the urgent adoption of regulations that guarantee rational exploitation in a safe and efficient manner, with minimal losses. The known hard coal resources in Romania are of 232 million tons [85 mil. tep] from which exploitable in concessioned perimeters 83 million tons [30 mil. tep]. At an average consumption of reserves of 0.3 mil. tep/the insurance degree with hard coal resources is 104 years, but the exploitation of this primary energy resource is conditioned by the economic feasibility of the exploitations. The average calorific value of the hard coal mined in Romania is 3 650 kcal/kg. [1]

The share of coal mining within the global extractive energy industry on current energy security, as well as the nature and physical-mechanical properties of coal, they favored and determined the continuous development of mechanization systems specific to their extraction process. A striking moment in the evolution of coal mining mechanization was the appearance of mining combines equipped with mobile arm and snail drum cutting organ in the 50s in England. These marked the beginning of a new generation of mining technology machines, which can ensure complete mechanization of the extraction process and its continuous flow. Currently, worldwide, more than 80% of the abattage combines are of the type with movable arms equipped with drum type – snail. [2]

2. GENERALITIES REGARDING MINING COMBINES

Mining combines are high-productivity machines that allow simultaneous execution of cutting, crushing and loading of dislocated material from the working front. The main advantages that characterize them over other means of exploitation are: [2, 3]

- *the rhythmic unfolding of the work process in the abattage;*
- *improvement of the conditions for directing the mining pressure;*
- *increasing the speed of advancing the front, increasing production and labor productivity;*
- *improvement of working conditions and safety during work.*

In mining practice, a wide variety of mining combines are used, determined by the specific conditions of the deposit, classified according to several criteria, as follows:

a) by the length of the front in which they work:

- *combines for short fronts (preparation work and camera abattage);*
- *combines for longs fronts (front abattage).*

b) by type of executing organ:

- *with havator organs;*

- *drilled;*
- *cutting.*

c) by type of travel organ:

- *on the sled or guide skates (with cable or traction chain);*
- *on wheel trains;*
- *on the tracks;*
- *grazer.*

d) after the energy used for the actuation:

- *electrical;*
- *hydraulic;*
- *electrohydraulic;*
- *pneumatic (very rare).*

Considering that these mining machines overlap in time the execution of three operations (cutting, crushing, loading) with significant weight in the extraction process, they have gained a wide spread, both on long front and short front abbeys. [2, 4] Apart from the classification criteria for mining combines in general, the abattage ones can also be:

a) after the angle of inclination of the layer:

- *for strateges with small inclination;*
- *for medium-tilt strata;*
- *for high-tilt strata.*

b) by the thickness of the layers:

- *for thin layers (0.7 – 1.2 m);*
- *for medium thickness layers (1.2 - 3.5 m);*
- *for thick layers (over 3.5 m).*

c) after the width of the cut strip:

- *wide strip (1 - 2 m);*
- *narrow strip (0.5; 0.63 and 0.8 m).*

d) by the sense of forwardness:

- *with one-way cutting, with one stroke in the void;*
- *in the spool (with bidirectional cutting).*

e) after the scheme of work in the abattage:

- *flank combines:*
    - with parallel displacement to the front on the abattage;
    - with travel on the conveyor in the abattage;
    - with movement on a ramp or special gutter attached to the conveyor.
- *frontal combines.*

f) by type of the advance mechanism:

- *with discontinuous mechnical advance (with ratchet or pulsator);*
- *with hydraulic advance, continuous.*

g) by type of loading organ:

- *with the help of the cutting organ (snail drums);*
- *with special devices attached to the cutting organ.*

The main component parts of a abattage combine are (fig. 1):

- *actuation system and movement transmission mechanism (2);*
- *the advance mechanism (3);*
- *working organs (1).*

These abattage machines have technical characteristics that give them definite advantages in terms of adaptability to mining technology with long front extraction, of which we can mention:

- adaptability to the variation of the thickness of the layers, both as *typodimension and as dynamic adaptation, by modifying the working height;*
- *loading the dislodged coal, by the cutting organ;*
- *the possibility of two-way cutting without additional tools when attacking the strip;*
- *the possibility of modularization of construction;*
- *adaptability to the realization of high-productivity mechanized complexes;*
- *the availability of improvement of the arm-organ working system, in order to increase the adaptability to the technological requirements imposed by the variation of the geo-mining conditions.*

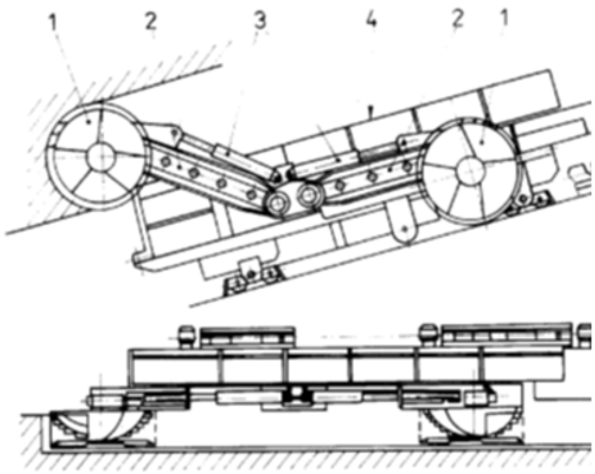

Fig. 1. Abattage combine with snail drums

In this context, solutions, both regarding construction and command, should reconcile two relatively contradictory trends: [2, 5]

- *ensuring a great applicability in a wide range of technical-mining conditions and technologies appropriate to them;*
- *the construction specialization for certain specific working conditions.*

The **executing organ** of the abattage combine is called the sub-assembly with the help of which are performed the operations of detachment of the massif mining mass, its fragmentation and loading on the means of transport. There are two types of executing organs:

- *with integral cutting:*
  - after stratification (drum with vertical axis of rotation);
  - perpendicular to the stratification (cylindrical and snail drums with horizontal axis of rotation).
- *with grooves (forator crowns, discs, bars).*

The executing organs in the form of a drum with the horizontal axis of rotation are in themselves a cylinder on whose outer surface are fixed in a determined sequence knife jaws. During contact with the front, each knife cuts a strip in the form of a sickle. The drum is easy to adjust to the thickness of the layer, it is simple as construction, it has safe operation, but it sharpens the mining mass and requires special loading devices.

The snail drums do not differ from the cylindrical drums as a way of dislocation of coal from the massif, but they have better conditions for the material to be evacuated and loaded onto the conveyor; instead, they have better conditions for the material to be removed, they have limited transport capacities at small diameters. The cylindrical execution bodies with the vertical rotation axis perform the extraction on the entire front surface and are reversible.

As disadvantages it is mentioned that they have totally unfavorable load conditions, additionally break down the useful table, have a small tuning fork on the thickness of the layer, which is, being difficult to drive after bed and roof hypsometry. [2, 6]

The cutting organs of the combines are equipped with knives (radial or tangential) which, working under heavy conditions (uniform cutting forces frequently exceeding 5 to 8 times the average forces, are, the uneven advance speed of the combine, the transportation of the small material, the presence of hard intercalations in the layer) must meet a number of requirements: to be resistant to wear and shock, and, be of suitable shape and size, have a simple fastening system in the jaws allowing quick change and wear protection of the jaws, allow the possibility of reconditioning.

The working organ of these systems most commonly used in combination abattage is a drum-type cutting organ with the axis of rotation perpendicular to the plane of pivoting of the movable arm. In the construction of long-front abattage combnes, in particular, these drum-type organs have prevailed in competition with the other construction types (forators, haversors) due to important advantages such as:

- *specific lower energy consumption;*
- *registration possibilities in layer hypsometry;*
- *the possibility of efficient dislocation with narrow strips;*
- *the possibility of advantageous location over the combine body;*

- *the possibility of full extraction from the variable height front;*
- *it corres*
- *ponds best to the movement on the conveyor, of the combine in the front;*
- *could ensure round-trip cutting in continuous flow.*

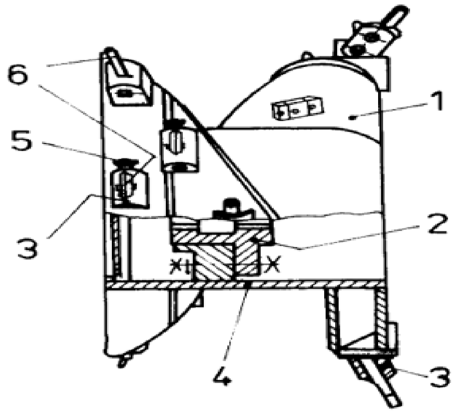

Fig. 2. Executor organ of snail drum type:
1 helical body; 2-buttock; 3-pocketknife; 4-cylindrical drum; 5-lock device; 6-knives

It is noted that the advantages of the work arm-organ system in general, already mentioned, are very related, in the case of combines, to the use of this type of cutting organ. The simplest, as a construction, organs of this type are cylindrical drums (drums) with horizontal axis, the shape of a cylindrical drums, on whose outer surface are fixed in a determined sequence the knives, which cut the sickle-shaped splinters from the front. These drums are simple, safe and robust but in addition to a pronounced shattering of coal, they have the main disadvantage of requiring special load devices. The most commonly used constructive variant as a drum type cutting organ is the snail drum (fig. 2) which currently equips over 80% of the long front combines encountered in world practice, in domain. It ensures, in addition to cutting and discharging the displaced coal from the front and loading it onto the conveyor, keeping a relatively good grain of extracted coal. Also, equipped with front knives on the font side, can cut and advance transversely in the front, self-introducing itself into the massive. So it does not require cut niches with other means for insertion into the massif. These advantages explain the preponderance of using these drums and the fact that they best ensure the continuity of the extraction process, favoring the good framing in the mechanized complexes. Still, there remain to be found improved constructive solutions regarding: optimal placement of knives, increasing the efficiency of the double load cutting actions, ensuring the best possible granulation of extracted coal. As functional limits can be mentioned: the impossibility of reversal, and at small diameters, limited transport capacity. [2, 7]

The snail - the helical palette wrapped on the hub - can be wrapped on the left or right, can have 1-2 to 3-4 beginnings, proportional to the diameter of the drum. The load capacity is dependent on the shape of the surface of the helical blade and the pitch of the propeller. The step can be constant in the usual way, or variable to improved construction. It is estimated that a progressive - combined - increase in the axial pitch of the propeller, can increase productivity by 15-20% compared to the constant step drums, but, does not allow an optimal placement of knives for a balanced cutting regime. Variation of the step in the radius is considered more advantageous, allowing the constant step to be kept at the periphery and therefore a more rational placement of the knives. There are also original solutions with axial-radial variable pitch, of the snail propeller; for example, the one developed for CA-1, a combine, helical pallet having concave loading surface on the half from the combine and straight to the front. Also, there are constructions with pallets inclined towards the active loading face, at drums of large diameters (1600-2000 mm), this prevents the material from being thrown away and centrifugal shredded and favours good loading. The fastening of the knives can be tangential or radial. It is made simple and fast in clamping jaws, welded on the drum. Fixing is done with locking devices (with screws, bolts or clips, etc.). Currently, tangential knives predominate, but on the front and corner, radial knives are usually mounted. An optimal distribution of knives on the drum is the one that generates a balanced system stress, with maximum 5% variations of the moment at the drum shaft. This is a problem of these drums, the difficulty of which is emphasized by the fact that its solution depends also on the concrete cutting conditions, which implies differentiated solutions. These drum-type cutting organs are also used in the construction of short front abattage combines with the same general constructive concept as for the long front.

Any cutting organ in the form of a drum-melc is characterized by the following parameters: the diameter of the cutter, the outer diameter of the cutting organ, the base diameter of the snail, the width of the cut strip, and, the length of the working organ, the number of snail beginnings, the number of knives on the cutting line, the distance between the cutting lines, the number of cutting lines, the number of knives on the cutting organ, and, snail pitch, propeller winding angle, propeller tilt angle, distance between front knife cutting lines, number of front knife cutting lines, number of front knives. Some of the listed parameters determine the cutting regime (number of knives on the cutting line, distance between the cutting lines, etc.), another part the loading regime (snail pitch, the winding angle of the snail, the angle of inclination of the snail, etc.), and another part influences both the cutting regime and the loading process (the number of snail beginnings, the number of snail's, cutting diameter, cut strip width, etc.).

The **cutting diameter Dt** is the diameter measured at the level of cutting knives mounted on the periphery. In the construction of modern combines most of the cutters with a diameter of 1.2 ..1.8 m. To date, the largest known diameter is 2.2 m (combine AM-1000 STAR). This parameter is determined according to the conditions and technology of working in the abattage. For example, a working height of over 4 m requires cutting organs with a diameter of 2 ..2 m. For lignite mines it is enough to use diameters of 1.6; 1.8 or possibly 2 m.

The ***outer diameter D of the working organ*** results depending on the cutting diameter and the active height of the knife-wrapper assembly (which exceeds the periphery of the snail itself), as follows:

$$D = D_t - 2h_c, \tag{1}$$

where:

- *hc - represents the active height of the cutting knife, mounted on the periphery of the working organ.*

The ***base diameter of the d_b snail*** (button diameter) is a basic constructive parameter of the cutting organ. It is determined in such a way as to ensure the installation of the cutting organ on the tree, and on the other hand to allow the achievement of a height of the snail to ensure the maximum flow rate at loading.

$$d_b = D - 2I_e, \tag{2}$$

The ***width of the cut strip B_1*** defines the advance step of the front and influences the length of the cutting organ. When establishing it, it will be taken into account the correlation of the machinery in the complex to the lignite mines, the frequency of the section steps and its influence through “pistoning” ceiling, on the pressure in the abattage, etc. In relation to these and in correlation with the chosen diameter of the cutting organ and the power of action, it is recommended that the width of the cut strip be between 0.4 .. 0.8 m, more frequently between 0.5 .. 0.7 m.

The ***length L_1 of the cutting organ*** results from the width B1 of the cut strip and taking into account the possibility of mounting the marginal knife holders on the propellers, respectively the necessary safety space up to the working front to avoid friction of the cutting organ against the coal massif. As regards the choice of an appropriate knife placement scheme on the cutting organ in the form of a snail drum, the number of i snail beginnings and the number of c knives on the cutting line. Taking into account the advantages of the knife placement schemes for the whole number i/c ratio and par, there are two rational possibilities for designing the knife placement scheme, namely:

- with two snail beginnings and a single knife on the cutting line (fig. 3.a);
- with four snail beginnings and two knives on the cutting line (fig. 3.b).

Two-primary placement schemes are recommended for cutting organs up to 1600 mm in diameter and four-primary ones for diameters over 1400 mm. Thus, for the diameter of 1600 mm you can choose both variants, while for the diameters 1800 and 2000 mm you can choose only the scheme with i = 4 and c = 2. These recommendations are followed by most of the construction companies of abattage combine, such as: Anderson Mavor, Eickhof, Famur, etc.

In practice, there are also combines that have an integer and odd i/c ratio, such as the Russian combines KS-1KG, KS-3M, 2KS-3 and others. There are also Russian manufacturing combines that follow the i/c integer ratio rule and appear, such as the K-52 and GS-68 family combines.

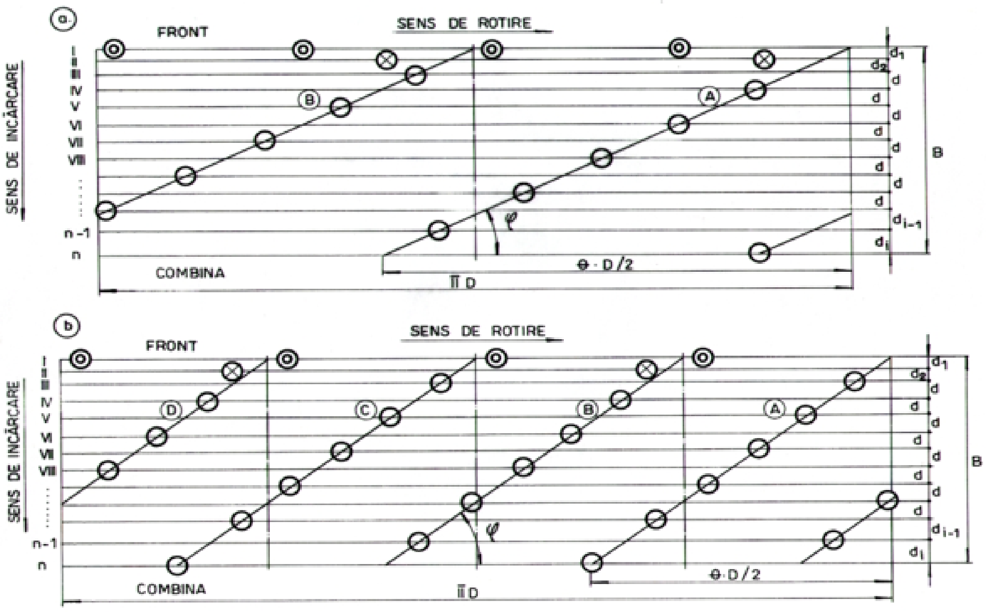

Fig. 3. Principle schemes for placing knives with i/c integer number and par

Another basic parameter of the knife placement scheme on the cutting organ is the *distance d between the cutting lines*. This is determined from the correlations established following the analysis of the specific energy consumption at cutting with the combination in the working front, depending on the characteristics of coal cutting, the geometric parameters of the knives and the functional parameters of the combine. [2, 7]

Thus, in the case of using parallelepiped knives, we will have the correlation:

$$\frac{b}{2}+\frac{50v_a \cdot tg\psi}{c \cdot n} \leq d \leq b+\frac{50v_a \cdot tg\psi}{c \cdot n}, \tag{3}$$

and for cilindro-conical knives:

$$\frac{40v_a \cdot tg\psi}{c \cdot n} \leq d \leq \frac{45v_a \cdot tg\psi}{c \cdot n}, \tag{4}$$

As regards the distance between the marginal cutting lines to the front and to the exploited space, they shall be determined according to the following considerations:

- the knives on the first cutting line to the front work semi-blocked (the chips are only detached on one side, on the opposite side being the massif) and are more in demand than the others;
- the marginal knives should be tilted to the working front to achieve a cut-off width greater than the drum length (including the front knives) to avoid friction

during cutting of the front between the front knives and the coal massif, the front knives coming into contact with coal only at the ends of the abattage, namely the digging of the niches;

- the number of cI knives to be mounted on the first cutting line, cII to be mounted on the second cutting line and possibly cIII on the third cutting line will be:

$$c_I \geq c_{II} \geq c_{III} \geq c \tag{5}$$

- the number of knives on the first lines is higher than for the others, it follows that they will cut shavings of smaller thickness according to the correlations (1.3) or (1.4) and the distance between these cutting lines must be smaller, that is, according to figure 1.3, have:

$$d_1 \leq d_2 \leq d_3 \leq d \tag{6}$$

- the knifes from the exploited space units work in lighter conditions than the others and that is why for the last cutting lines the distances between them will be greater, that is:

$$d_i \geq d_{i-1} \geq d \tag{7}$$

where:

- *d_i represents the distance between the cutting lines n and n-1, d_i-1 represents the distance between the lines n – 1 and n – 2, and*
- *d distance between non-marginal cutting lines (see fig. 3).*

The ***number of cutting lines*** is determined according to the width B of the cut strip and according to the distance d between the cutting lines with the relation:

$$n_l = \frac{B - \sum_{j=1}^{m} d_j}{d} + m \tag{8}$$

where:

- *m represents the number of cutting lines that are exempted from the rule, that is, have dj≠d;*
- *d_j – distances between marginal cutting lines.*

The ***total number of knives on the cutting organ*** is determined according to the number of nl cutting lines and the number of knives on the cutting line, as follows:

$$z = n_l \cdot c + n_s \tag{9}$$

where:

- *n_s represents the additional number of knives that are mounted on the marginal lines from the front, that is:*

$$n_s = (c_I - c) + (c_{II} - c) + (c_{III} - c) + ... \tag{10}$$

The *p-step of the* snail is determined both from the cutting condition and from the loading condition. For the placement scheme with i = 2 it is recommended that the step on the periphery of the propellers be:

$$B_1 < p < 1{,}5B_1 \tag{11}$$

For the placement scheme with i = 4 it is recommended that the step on the periphery of the propellers be:

$$2{,}5B_1 < p < 3{,}5B_1 \tag{12}$$

In any case, taking into account the process of loading coal into the abattage, there must be a ratio between the step and the cutting diameter, according to the relationship:

$$0{,}7 \le \frac{p}{D_t} \le 1{,}0 \tag{13}$$

Taking into account previous propeller step recommendations, the angle of winding them is recommended to be:

- for i = 2

$$\pi < \theta < \frac{3\pi}{2}, \tag{14}$$

- for i = 4

$$\frac{3\pi}{4} < \theta < \frac{5\pi}{4}, \tag{15}$$

The ***angle of inclination φ*** of the propeller (see fig. 3) is recommended to be 12° .. 25°, smaller for placement schemes with c = 2 and higher for placement schemes with c = 4. As regards the parameters of the location of the front knives, they are established analogously with those of the peripheral knives, bearing in mind that these knives work on the forator principle in cutting niches at the ends of the abattage. Most jumper combines have cutting organs equipped with front knives, but there are also cutting organs without front knives**.** The front knives are mounted after concentric circles on the front surface of the cutting organ. These circles actually represent the cutting lines. The distance between them shall be determined according to the knife parameters and the coal cutting characteristics, so that during the cutting of the niches the chip “rhombus” is obtained. In this case the *number of front knives on the cutting line* $c_f = 1$, and the number of cutting lines and implicitly the number of front knives depends on the diameter of the cutting organ. For cutting coal in the central area, either properly located front knives or a cutting tool in the form of a rotating spindle head is used.

The movement of the abattage combines is made by means of the advance mechanisms, of the built-in type (mounted directly on the combine) or separately (on the frames of the drive blocks of the conveyor in the abattage). Hydraulic imprest mechanisms have the possibility of smooth adjustment of the advance speed and immobility of the traction element, thus ensuring its relatively comfortable and safe location on the actuation elements of the combines. The operation of the mining combine includes the power equipment, the transmission mechanisms and the means of manual, remote and automatic driving. The force equipment comprises only motors (usually electric, three-phase asynchronous with short-circuit rotor, with the stator winding connected to voltages of 380 **V** or 660 V, with the speed up to 1500 rot/min, but lately there have been introduced electric motors of direct current), switchgear and cables (hoses). [2, 8] Abattage combines are chosen by correlating their technical parameters with: the physico-mechanical characteristics of the useful mineral substance and the surrounding rocks, the layer geometry, the dimensions of the abattage field, but also technical-functional parameters of the machines with which they will work in the complex. The right choice is aimed at obtaining, as low as possible, the cost of production of the useful mineral substance extracted, the highest possible productivity of labor, the highest degree of labor security, and, assortment of useful extract corresponding to the beneficiary's requirements and the highest coefficient of extraction.

The main factors that determine the performance of the abattage combines are:

- *the possibility of using a type of combine in the widest possible range of thicknesses and tilt of layers;*
- *the possibility of working organ handling after layer hypsometry; adjustable advance and cutting speeds;*
- *safety and stability during work;*
- *selective extraction; loading to be executed at the same time as cutting, even by the cutting organ;*
- *high enough installed power;*
- *the thing in a mechanized complex considering the proper realization of the support after the combine;*
- *constructive concept that lends itself to automated handling (possible robotization);*
- *the possibility of rapid interventions in the current maintenance;*
- *correlating the gauges with the dimensions of the mining works.*

From the world practice, at the current stage, we can highlight several directions followed in the construction of long front combine, of which regarding the mechanical structure, we can notice: [2, 9]

- *the generalization of combines with drums for narrow strip (up to 0,7m) with displacement on the conveyor;*
- *the orientation predominantly towards types with two working organs mounted on symmetrically located adjustable arms, more frequently at the ends of the combine;*
- *guiding the combine on the conveyor by captive supports (especially round profile) on the suppor side, and skates or rollers towards the front.*
- *extension of chainless advance systems, chain-guided or advance devices with intermediate gear elements, formed by chain with pins and specially profiled gears (the latter still having a lower presence).*

3. CONCLUSIONS

Regarding the current stage of development and application of combination abattage, the following observations can be made:

a) the current development and improvement of the abattage combines is marked by the preponderance of the extension of the use of those with mobile arm system - snail drum type working organ, in particular, in the case of long front abattage, those having two drum-port arms located at the ends of the combines, the reels being arranged side-horizontal, with the axis of rotation perpendicular to the plane of pivoting of the arm (vertical plane, longitudinal to the front);
b) a basic direction of development which determined this applicative preponderance was the necessity of achieving relatively simple constructive combines of abattage, enabling the continuous flow extraction process, achieved through an efficient correlation of the functions of the combine with the other machines in the dam, within the working technologies with mechanized complexes;
c) ensuring the continuity of the extraction process is mainly related to the possibility of the combine cutting in both directions, with the guided movement on the conveyor (in horizontal or slightly inclined layers); the possibility of the combination to independently perform the full extraction on the height of the layer, including at the ends of the abattage; performing the cutting, evacuation and loading of the dislocated material with the same working organ, during cutting. It is found that the use of the mobile-drum snail arm system can ensure in good conditions these functional requirements, which explains the preponderance of its current use;
d) the advantages of the system are maintained also in the case of short front combines, allowing for constructive-functional adaptations specific to the overall constructive guidelines, to these combines (shorter, more compact,

etc.); for example, the location of the system so that the pivoting of the arms is made in a vertical plane transverse to the front, the system being able to perform its own movement of transverse advance.

e) the location of the boom-to-drum system as the combine effector sub-assembly may be adapted to the conditions of the deposit. In good conditions regarding the strength of the roof, especially when working in a mechanized complex, it is preferable to place the two arms at the ends; if the roof is weak, unstable, the system allows the grouped median placement of the drum arms to avoid elongation of the combine for such conditions.

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