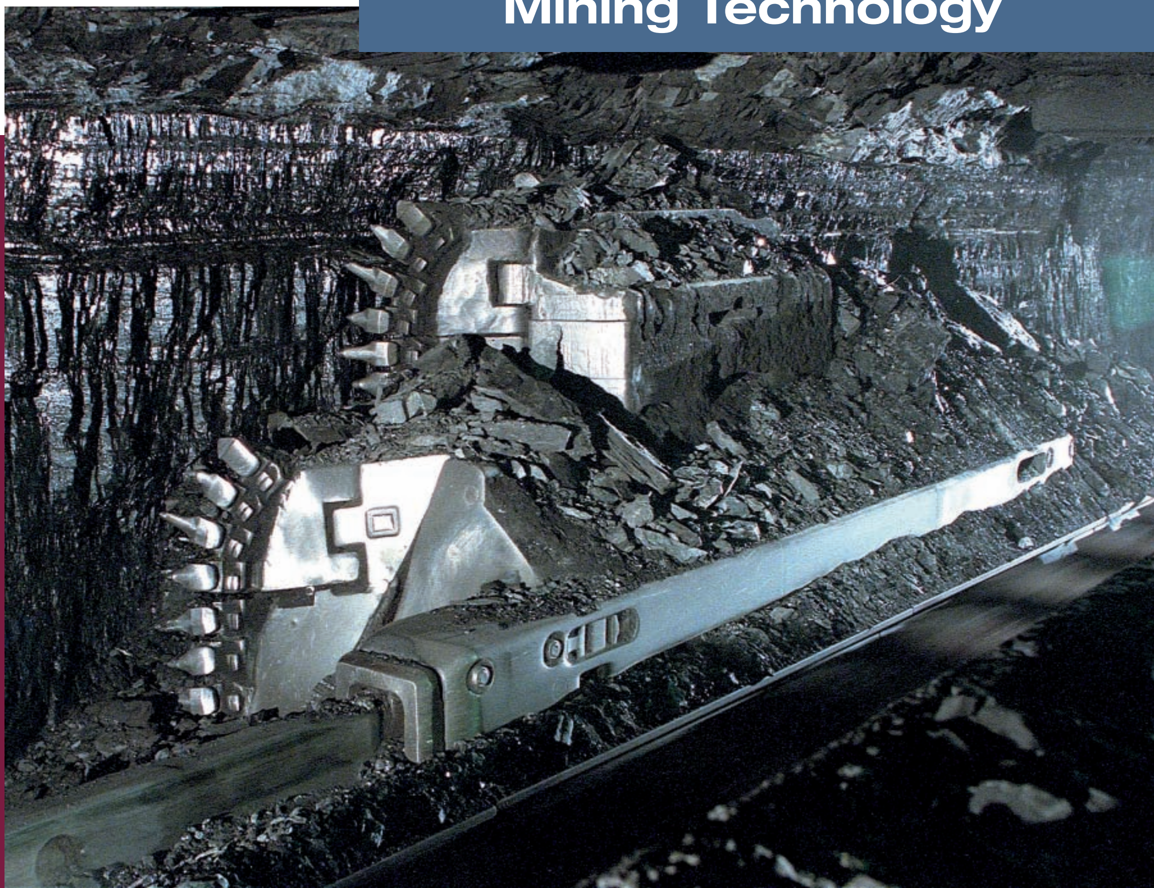
Reliability at work

Mining Technology



Longwall Mining in Seams of Medium Thickness

Comparison of Plow and Shearer Performance under Comparable Conditions

By Dr Michael Myszkowski and Dr Uli Paschedag

Longwall Mining in Seams of Medium Thickness

Comparison of Plow and Shearer Performance under Comparable Conditions

By Dr. Michael Myszkowski and Dr. Uli Paschedag

Contents

1 Importance of coal

At the present time, coal plays a most important role in power generation. And this role is set to continue in decades to come, whether we like it or not. Coal currently fuels 40% of the world's electricity and this proportion will last for many years.

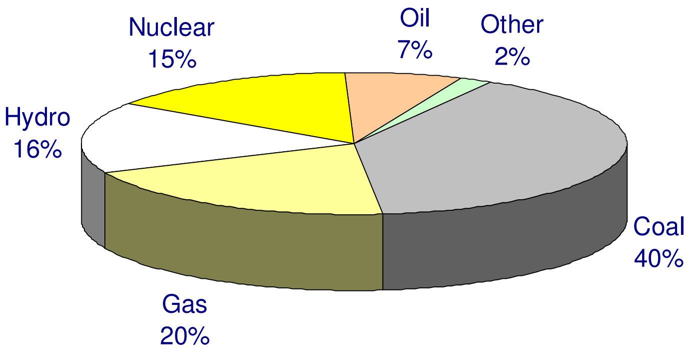


Fig. 1: Total World Electricity Generation by fuel in 2005 [46]

Coal reserves are available in nearly every country worldwide, with recoverable reserves in around 70 countries. At current production levels, proven coal reserves are estimated to last 147 years [46], while other sources speak of 200 years or more [14]. In contrast, proven oil and gas reserves are equivalent to around 41 and 63 years respectively at current production levels. According to numerous sources "proven reserves" of uranium will only last some 50 years at current consumption levels. Additionally, the nuclear energy is limited by its economics and serious concerns about the treatment of nuclear waste. Hydro energy appears to be reaching its upper limit [5]. Implementing a renewable energy generation (today approx. 2%), is vital, may take a long time and cannot seriously change the statistic from Fig. 1 within the next decades. Thus, according to International Energy Agency (IEA) demand for coal in 2050 should be greater than that today.

In the face of environmental issues like global warming and air pollution, the energy generation from coal needs to be significantly upgraded. Under the fair assumption that coal will remain a primary fuel in power generation and a vital player in a balanced energy mix for the future, the following steps seem to be necessary:

1. The net efficiency of coal fired power plants has to further improve, the introduction or improvement of ultra-supercritical steam conditions need advancement.
2. The more environment-friendly gasification of coal should gradually replace combustion.
3. Flue gas treatment, which can already today achieve virtually any level of emissions clean up, needs to be widely established.
4. CO_2 capture and storage need to be largely implemented.

The previously mentioned measures will compulsory increase operational costs of power production. Nevertheless, since they are indispensable, in the long term they will allow generation of clean energy from coal.

2 Underground mining in low seams

Mining of low seams will gain an importance since thick seams have been intensely mined in the past. Therefore, there are numerous reserves with good quality coal in thin seams. Fig. 2 presents the distribution of reserves as the function of seam thickness in the German Ruhr District [7]. According to that statistic approximately 80% of deposits are placed in seams lower than 1.5 m. Mineable reserves located less than 1,500 m below surface in seams between 0.6 m and 1.5 m make up 60% of all black coal deposits.

The situation is also similar in other countries. In the USA, the trend toward increased underground output from thinner coal seams (less than 1,675 mm or 66 in.) is anticipated to accelerate during the next five years [44]. Coal reserves located in seams with a thickness lower than 1.3 m in China, are estimated to be 25%.

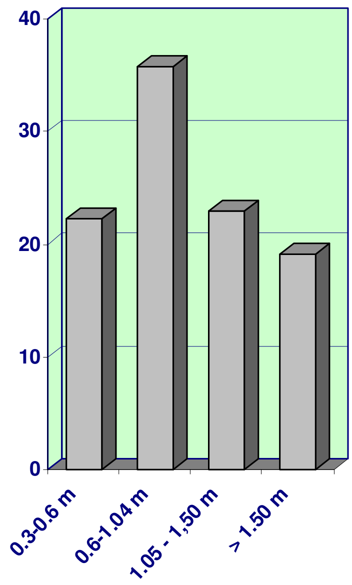


Fig. 2: Distribution of black coal reserves in the Ruhr-District

In order to mine those reserves with economic reliability, efficient extraction technologies are necessary. Thin seams can be mined in different ways. Today there are two underground extraction methods widely used:

- Room-and-Pillar
- Longwall

Room-and-pillar technology is commonly used in the USA. In the room-and-pillar method rooms are cut into the coal seam leaving a series of pillars, or columns of coal to help support the mine roof and control the flow of air. Generally, rooms are 6 m to 10 m wide and the pillars up to 30 m wide. As mining advances, a grid-like pattern of rooms and pillars are formed. There are two types of room-and-pillar mining:

- Conventional mining
- Continuous mining

Conventional mining is the oldest method used today. In conventional mining, the coal seam is cut, drilled, blasted and then loaded into cars. In continuous mining, a machine known as a continuous miner cuts the coal from the mining face, an advantageous technique that obviates the need for drilling and blasting.

Room-and-pillar mining in low seams is detrimental in comparison to longwall mining (where some 50% of coal is irrecoverably lost).

Besides room-and-pillaring, the longwall method is used. There are two main longwall extraction systems: shearer and plow. In the German underground hard coal mining industry, both systems have been used for a long period of time. In the past decades there were periods of dominance of both extraction technologies. Between the 1950s and 1980s, plows clearly dominated the German coal mining industry. In the first half of the 1990s, shearers became more capable and thus more important. Since then, shearers have outbalanced plows. This situation lasted over a decade, but now the tendency is turning back for the benefit of plow technology. In the near future, plow systems will again constitute the majority in German longwall statistics [11].

Today, there exists many prejudices regarding the capability of plow technology. In many countries, based upon experiences from the distant past, a wide spread opinion about lower performance of plow systems in comparison to shearers can be heard. This approach to an objective analysis, based upon all available data and a comprehensive comparison, should bring light to a science-based answer for medium thickness coal seams: shearer or plow?

3 Comparison Plow versus Shearer

In the past, there were different approaches to reduce both techniques to a common denominator and a partial consideration was carried out in most cases. Most frequently, some technical facets of shearers and plows were compared, sometimes the technology was considered, but a holistic analysis is difficult to find in the literature. Nevertheless, a comprehensive comparison between two different technologies makes sense only in the case of an integral analysis under consideration of all important technical, procedural, and economic aspects.

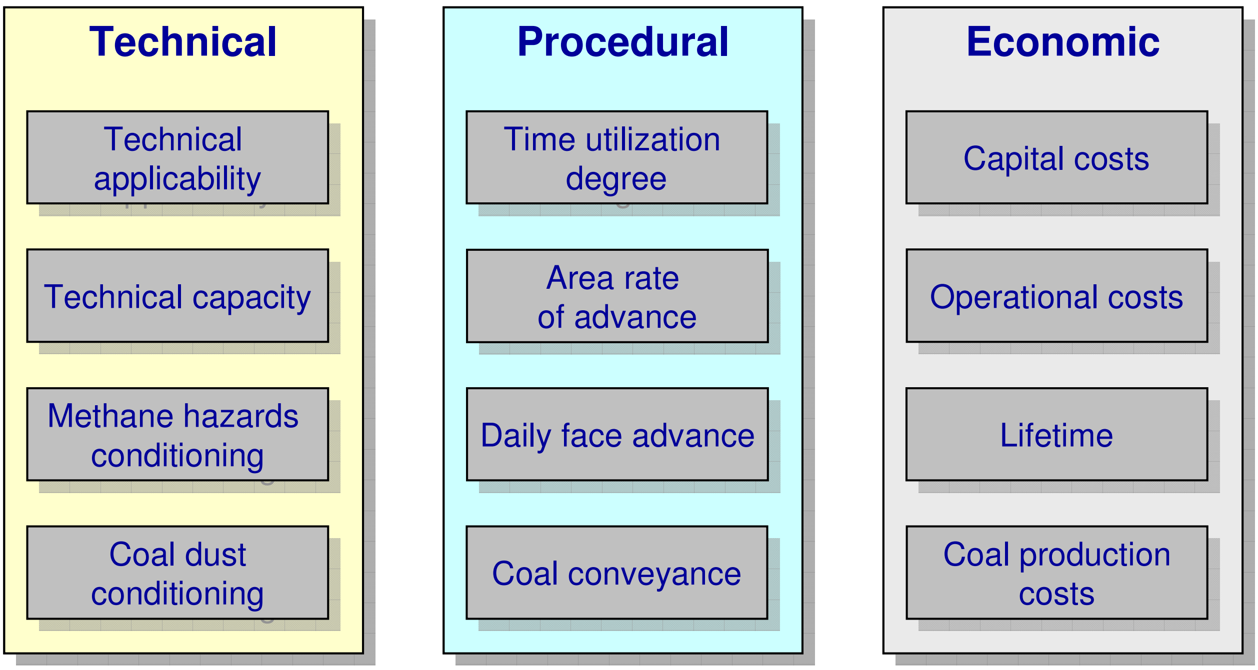


Fig. 3: Levels of comparison for the shearer and plow technologies

The following text presents a compendium of a wide study comparing plows and shearers on multiple levels.

4 Procedural aspects

From technological (procedural) aspects there are two factors of major importance for a performance of a longwall: firstly the "Time utilization degree" (TUD) and secondly the "Procedural utilization degree" (PUD). Further important parameters connected to TUD and PUD, describing the organizational and technological efficiency are the "Area rate of advance" and "Daily face advance". Lastly, a constant stream of coal plays an important role in some applications.

4.1 Types of procedures in longwall faces

A variety of different procedures for cutting sequences, both for shearer and plow faces, exist. These depend upon:

- Speeds of the shearer or plow in pass to the tail and to the main gate
- Cutting depths of the shearer or plow in pass to the tail and to the main gate
- Speeds of the AFC during shearer's or plow's pass to the tail or to the main gate

Commonly, those procedures can be divided into:

<u>For a shearer</u>

- Bi-directional cutting – The shearer cuts coal in both directions with two sumping operations at the face ends in a complete cycle.
- Uni-directional cutting – The shearer cuts the coal only in one direction. On the return trip the floor is cleaned and there is only one sumping operation.
- Half web cutting – The shearer cuts full web only at the face ends and in the face it cuts a half web in order to avoid sumping operation.
- Half/partial opening cutting – The shearer cuts a full web in one direction taking the top coal with one drum and the bottom coal with the other drum, it sumps at mid face.

Shearers usually cut either full or half web. The volume stream of extracted material (coal) is in most cases regulated by setting a required shearer haulage speed.

<u>For a plow</u>

- Conventional procedure – The plow travels in both directions, slower than the AFC with relatively high cutting depths.
- Combination procedure – The plow travels to the tail gate as fast as the AFC and to the main gate slower than the AFC.
- Overtaking procedure – The plow travels in both directions faster than the AFC with relatively low cutting depths.

Plows always cut the full height of the face in both directions, although in weak coal, the height of plow body is usually lower than the face height. The volume stream of extracted material can be regulated by setting the required plow speed and/or cutting depth. The cutting depth in both directions is frequently set different thanks to the modern control systems in order to set the optimal procedure. When a situation allows, the operation can be carried out without sumping. This can be carried out by making the so-called "double cut" procedure on both face ends.

4.2 Utilization degrees

There are two utilization degrees related to the organizational and technological aspects:

- Time utilization degree
- Procedural utilization degree

The whole circle as shown in Fig. 4, represents the total working time of the crew on the face. This time can refer to a single shift or like in most cases, to a working day. Theoretically, this is the time when the face could be in operation.

1. Time utilization degree (TUD)

$$\eta_T = \frac{t_{EE} + t_{PL}}{t_{DT} + t_{EE} + t_{PL}}$$

2. Procedural utilization degree (PUD)

$$\eta_P = \frac{t_{EE}}{t_{EE} + t_{PL}}$$

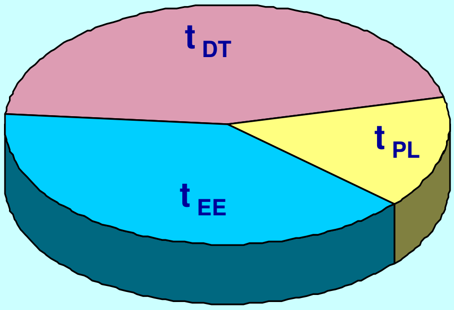


Fig. 4: Utilization degrees in longwalls

Where:

t_{EE} - effective extraction time [min/d]
t_{DT} - breaks, downtime [min/d]
t_{PL} - procedural losses [min/d]
η_T - time utilization degree [-]
η_P - procedural utilization degree [-]

4.2.1 Time utilization degree

The time utilization degree, also called “availability”, shows the proportion of cumulative running time of a shearer/plow to the working time in a shift or day. For practical purposes, TUD expressed in a percentage is determined by the following formula:

$$\eta_P = \frac{t_{RT}}{t_{OT}} * 100 \qquad (1)$$

where:

t_{RT} - total daily running time of a shearer or plow [min/d],
t_{OT} - daily working time [min/d],
η_T - time utilization degree [%].

Apart from the scheduled maintenance time or some special non-productive activities, the rest of the time where the crew is present in the face, could potentially be used for effective mining. These situations rarely occur. In practical terms, there are some breaks in the production. Those breaks can be caused by:

- Internal reasons like operations requiring standstills, oversize load stoppages, methane shutdowns, equipment damages, accidents, etc.
- External reasons including, but not limited to; haulage stoppages, breaks in electric or hydraulic energy supply, communication disturbances, etc.

TUD can vary drastically. On average, TUD in longwalls ranges between 40% and 70% [18], [36], [39]. The lowest average TUD reported in different sources amounts to 30% [39], the highest one reaches over 90% [26], [29].

In German coal mines, the TUD in an average shearer face was slightly higher than an average plow face. This effect was connected to mining activities at the junction, between the longwall face and gate road. Since a plow needs less time than a shearer for a full cycle, various time consuming works had been causing production breaks. This tendency cannot be confirmed while analyzing the best high performance shearer and plow faces, where a significant difference between shearers and plows could not be found.

4.2.2 Procedural utilization degree

Procedural utilization degree also called “machine utilization”, describes the extent of production equipment exploitation in the face. PUD specifies an equivalent fragment of the machinery running time, while a shearer or plow is working with a nominal cutting depth at a nominal speed.

The selection of a correct procedure plays an essential role in the performance optimization of underground longwalls. This allegation is vital both for shearer and plow faces.

Both shearers and plows only work a part of their total running time with nominal cutting depth and speed. In the residual time they are working either with lower speed and/or lower cutting depth or idling in situations like:

- Cutting 50% of the cutting depth in the “Half web cutting procedure”
- Loading coal during a return trip in the “Uni-directional procedure”
- Acceleration at the beginning of a pass towards another gate end
- Slowing down while arriving to the gate
- Running without cutting (standing) after a direction change
- Sumping
- Lowering/raising of ranging arms, rotating of cowls

The procedural loses can be divided into:

- Losses resulting from deceleration
- Losses connected to lower cutting depth

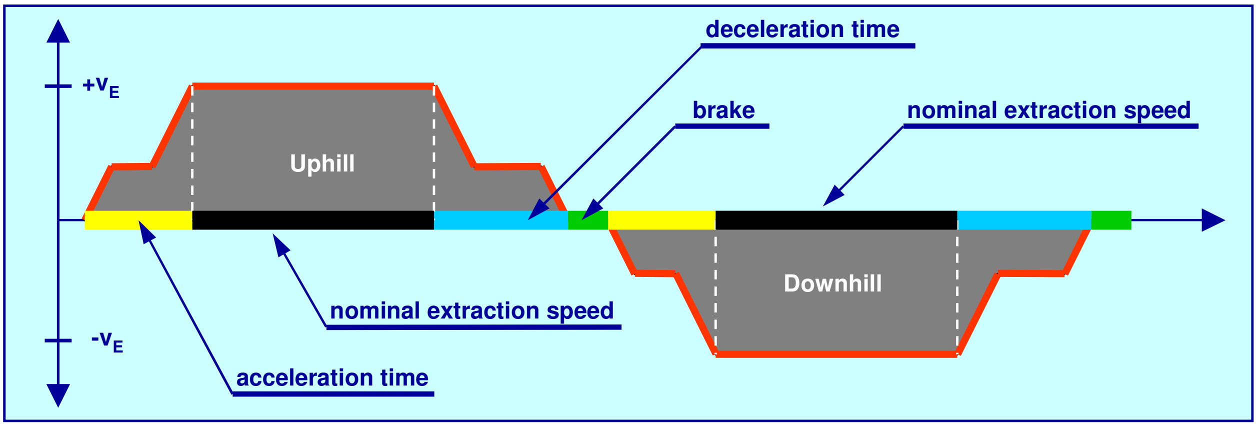


Fig. 5: Losses resulting from a speed reduction

Fig. 5 shows the mechanism of time losses in situations when extraction is running with a speed lower than the nominal one or during procedural breaks. Thus, a shearer or plow after turning on, needs some time to accelerate before reaching its nominal speed. Plows using pole-changeable motors, switch first to primary speed and after a couple of seconds change to their nominal (secondary) speed. First after a certain period of time the shearer or plow is running at its nominal speed. While approaching the face ends, the speed is first reduced to the primary stage and then after some time, prior to the arrival of the face end it is further decreased until stopped. After a short break in the case of plows or a longer period of time in the case for shearers (while the operator swings the drums and cowls), the cut in the opposite direction begins.

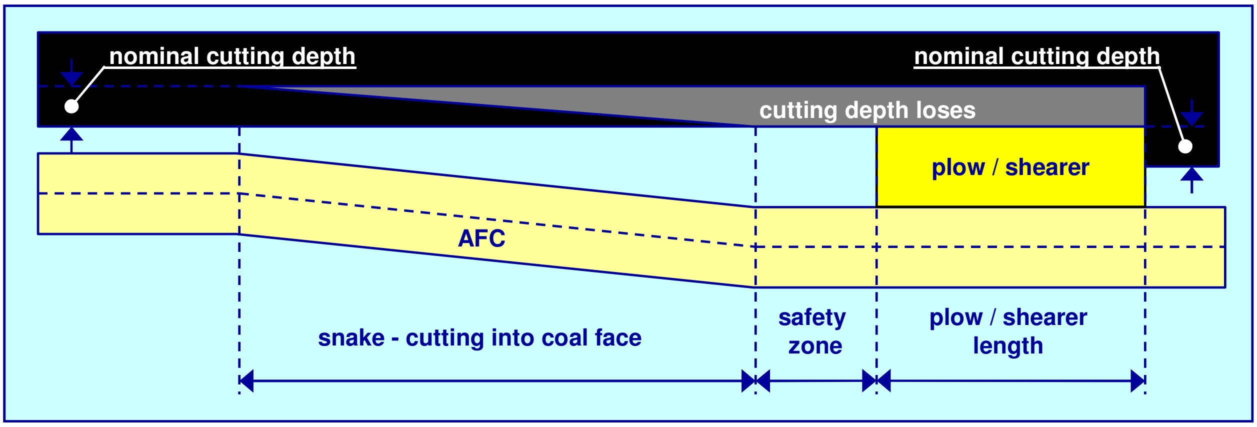


Fig. 6: Losses resulting from a reduction of cutting depth

Fig. 6 presents the origin of cutting depth losses. The AFC push is carried out first after a certain distance behind a shearer or plow. In case of a direction change in the face, the shearer or plow does not cut the face within this distance. Afterwards, the cut along the length of the snake is theoretically only half a web on average. Only behind the end of the snake zone, it is working again with its nominal cutting depth. This situation repeats after every directional change.

The reductions in reversing losses, of a nominally achievable cutting depth count to this category. The cutback of 50% of the cutting depth during “Half web procedure” or a return run at zero cutting depth during the “Uni-directional procedure” rank among web loses.

Both types of time losses related to the hypothetical extraction time at nominal speed and web, constitute the procedural utilization degree. Thus, PUD can never reach 100%, even in the best possible situation for both shearers and plows. The reason for this is that both machines need to reverse running directions at the face ends.

In practical terms, PUD can be easily determined if the total daily running time of the shearer or plow and daily advance are known. Under consideration of the nominal cutting speed and depth the following formula can be used:

$$\eta_P = \frac{l_F * l_A}{\Delta_W * v_E * t_D * 60} * 100 \qquad (2)$$

where:

l_F - face length [m],
l_A - daily face advance [m/d],
Δ_W - nominal cutting depth (web) [m]
v_E - nominal cutting velocity [m/s]
t_D - total daily running time of plow or shearer [min/d]
η_P - procedural utilization degree (PUD) [%]

PUD varies strongly both for the shearer and plow faces. The following PUDs are known from past experience:

- For shearers: between 20% and 75% [16], [17], [26], [38],
- For plows: between 40% and 95% [23], [24], [30].

According to the above stated statistic, the PUDs for plow faces are higher than those of shearers. In the case of shearers, the lowest PUDs occur for "Bi-directional cutting" and the highest PUD for "Half-Web" procedures [4], [26], [35]. In the event of plows, the lowest PUD arises in the case of sectional plowing. The highest PUD can be achieved while plowing from face-end to face-end while double-cutting the face ends. Similarly, to the shearer "Half web" procedure, the plow avoids double reversing in the face, maximizing PUD.

4.3 Area rate of advance

The area rate of advance is an important factor describing the performance of longwalls. This indicator describes a floor or a roof area exposed over a time unit. The area rate of advance can be based upon running or operational time and is usually presented in m²/min. The area rate of advance is based upon running time is determined by following formula:

$$\dot{A} = \Delta_W * v_E * \eta_P * 60 = \frac{l_E * l_A}{t_D} \qquad (3)$$

where:

$\dot{A}$ - area rate of advance [m²/min].

Adapted from German experiences and statistics, the area rate of advance based on running time is essentially higher in plow than in shearer faces. In a comprehensive study carried out in Germany in 75 faces over four years, the area rate of advance in plow faces were 58% higher than in shearer faces [37].

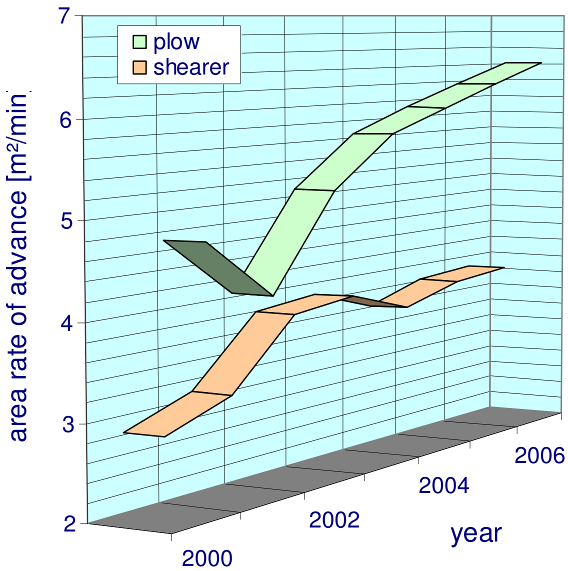


Fig. 7: Average area rate of advance in German shearer and plow longwalls[1]

This tendency can be observed in recent years [42]. Fig. 7 shows the development of area rate of advance for shearer and plow faces in the last decade in German longwalls in the Ruhr Region.

[1] Source: DSK AG

4.4 Daily face advance

The comparison of the daily face advance in German shearer and plow longwalls, generally favors plow faces. Plow faces on average have a 20% to 40% higher daily advance.

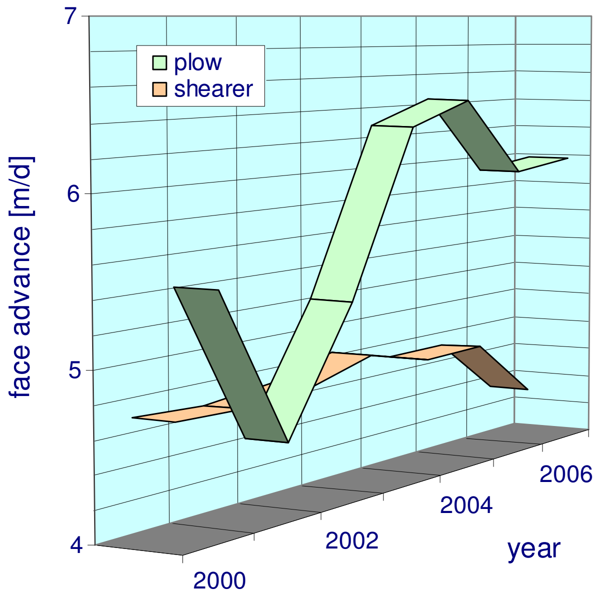


Fig. 8: Average daily advance of shearer and plow longwalls in Germany[2]

The diagram in the Fig. 8 shows the development of the average daily advance in German coal mining industry in the years between 2000 and 2006.

4.5 Coal conveyance

The volume stream coming out from a face, plays a vital role in circumstances where the operational capacity of connected haulage infrastructure is limited. Such a situation can occur if a number of coal streams (e.g. from different faces) are flowing together on one conveyor belt. Any load peaks can cause an overloading of that conveyor. This type of restriction occurred frequently in the past in the German coal mining industry.

A volume stream coming from a face depends strongly on the procedure chosen for that face. Shearer faces usually generate irregular volume streams. The shearer traveling from main to tail is loading a relatively thin layer of load on the AFC. The reasons for that behavior are the high difference speed between shearer and AFC and a restriction caused by limited space under the shearer. On the contrary, the trip from tail to main gate, the load layer is analogically higher. In the case of unidirectional procedures, periods with high load are interlaced with periods where the AFC is almost empty.

In case of plow faces, the volume stream is also dependent on the procedure. In the event of the combination procedure, a constant volume stream can be easily achieved through a selection of cutting depths for both cutting directions. For the overtaking procedure, a constant volume stream from the face can be obtained if the plow is running from drive to drive with the same cutting depth and a plow speed of three times that of the AFC velocity. In the case of sectional plowing, an irregular load stream will occur.

[2] Source: DSK AG

5 Technical aspects

Technical aspects of both longwall extraction techniques concentrate on topics around their applicability and main features for the use in underground longwall mining.

5.1 Technical applicability

The technical applicability is an important issue in the course of a selection for an extraction method. Under this category, a number of relevant geological (inclusive tectonic and stratigraphical) and operational conditions are considered.

Topic		Shearer	Plow
1. Seam thickness		1.5 m up to 6.0 m	0.6 m up to 2.3 m
2. Coal hardness		both types of coal extraction systems are comparable[3]	
3. Inclination	face	up to 20°	up to 45°
	panel	uphill up to 20°, downhill up to 20°	uphill up to 45°, downhill up to 20°
4. Mining through faults		both types of coal extraction systems are comparable[3]	
5. Undulations		plow can negotiate seam undulations much easier than a shearer	
6. Immediate roof		friable roof can easily lead to roof falls	smaller cutting depth allows safe operation even under friable roof
7. Immediate floor		the applicability of both systems is comparable (shearer shields use a base lift, plow shields use a special feature called elephant-step to work in soft floor)	
8. Raw coal size		shearer produces more fine particles	plow produces more large lumps
9. Entry dimensions		tail drive located inside the face	plow normally requires a wider tail entry[4]
10. Automation		shearers are not fully automated yet	Bucyrus plow systems are full automation capable and used world-wide

Fig. 9: Important factors regarding the technical applicability of shearers and plows

The topics stated in Fig. 9 are detailed and discussed in the sections below.

5.1.1 Seam thickness

Shearers are commonly used in seam thickness between 1.5 m and more than 6.0 m. In the past there were many trials to use shearers cost-effectively in seams lower than 1.5 m. Most of those attempts were unsuccessful regarding the efficiency and cost-effectiveness. The relatively low installed power, difficulties with operation in strongly narrowed space and bad loading properties, were the main reasons. In many cases, shearers operated at cutting heights higher than the seam thickness as they were cutting additional floor and/or roof, increasing rock content and production costs. In seams with changeable thickness, shearers can easily adapt their cutting height.

Plows work in seams from 0.6 up to 2.3 m, although plows were used in Germany in seams up to 3 m. Generally, in seams below 1.0 m base plate plows are used, while in seams thicker than 1.0 m gliding plows are in operation. Through their low height, plows are able to mine in-seam to extract coal without the necessity of cutting adjoining rock. Seams with variable thickness are not a problem for plows, as long as the seams have a good parting on the roof or the layer of top coal can be brought down by the canopies. The plow body height can also easily be adjusted if required.

[3] Application of the GH42 plow system with 1.6 MW installed power
[4] Doesn't apply for a plow system with only one drive placed on the main gate

5.1.2 Coal hardness

Shearers can operate in weak and hard coal seams. With increasing hardness of coal, the specific extraction energy (i.e. an amount of energy necessary to extract and load of 1 m^3 of coal) also increases reducing the performance of shearers.

Plows were used more frequently in soft coal in the past. The main reasons for that issue were low installed power and difficulties to utilize that power. The situation was vastly improved over the last ten years because of following issues:

- An implementation of reliable working microprocessors brought a breakthrough for plows. An incremental plowing now allows a setting of cutting depth with high precision and thus an elimination of previously frequent blockades.
- Chain breakages have been greatly reduced through an implementation of effectively working overload protection systems.
- Available power on plow system was steadily increasing. Today's plow systems have up to 1.6 MW installed cutting power.
- Variable frequency drive (VFD) motors allow infinite speed adjustment; together with AFC motors of the same kind, allow the optimization of plow longwalls.

Due to the previous facts, the up-to-date plow systems are able to extract the same hardness coal that shearers do.

5.1.3 Face inclination

Shearers can operate in faces with longitudinal and transversal inclinations up to 20°. Only specially designed shearers are able to work in longitudinally higher inclined faces.

Plows are able to work in faces with longitudinal inclination up to 45° and transversal inclination by 45°at up-dip and 20° at dip face. Faces up to 60° longitudinal inclination have been operated before.

5.1.4 Mining through faults

Shearers are able to cut hard rock when reducing the haulage speed. Although in such a situation, the specific extraction energy becomes inevitably higher, and a large amount of fine coal and dust is created.

Plows, in the past, had difficulties crossing geological faults. This was due to a non-adjustable cutting depth and limited plow speed adjustment. The plow speed could only be reduced to either 50% or 33%. The setting of a defined smaller web was in practical terms, almost impossible.

A modern plow system equipped with incremental plowing and variable frequency drives, having a significantly higher installed power is able to set (reduce) precisely both web and speed to a required level. Thereby modern plows can cross faults as effective as shearers do. For example, at Ibbenbüren Mine in Germany, a plow system was cutting rock at 60 MPa UCS on full height over a long distance while crossing a fault with a significant vertical step [1].

5.1.5 Undulations

Shearers are much longer than plow bodies and the AFC pans can bend vertically up to ±3°. For that reason, shearers have difficulties negotiating undulations.

Plow bodies are shorter and plow guides attached to the AFC pans are able to bend vertically up to ±6°. Thus, plows can handle face undulations much easier than shearers [32].

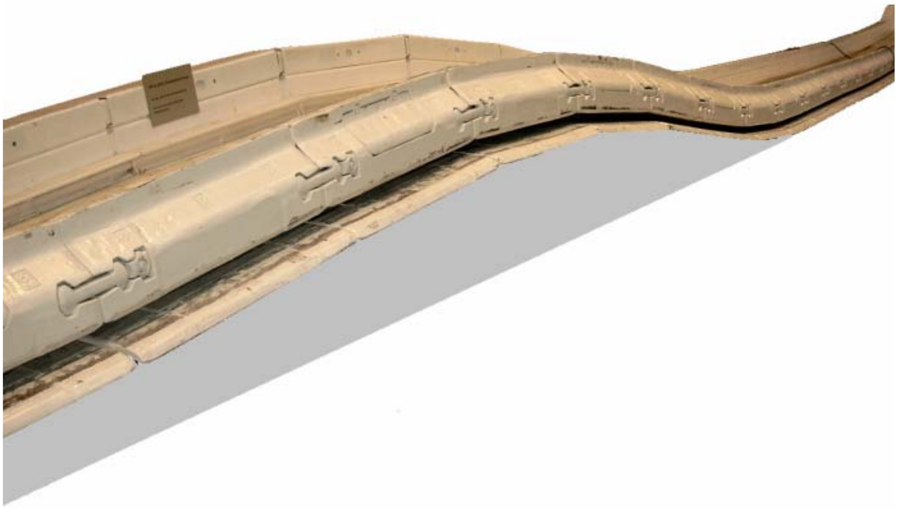


Fig. 10: Saddle on a plow system

5.1.6 Intermediate roof

<u>Shearers</u> can easily operate, if the roof is sufficiently strong to span one open web cut.
<u>Plows</u> are better suited to control the roof by reducing the shield advancing web, if the roof is friable in front of the shield canopy tip [32].

5.1.7 Intermediate floor

<u>Shearer</u> faces operate better under hard floor conditions. If the floor is weak, more attention needs to be paid for the height control while extracting the face. Regarding the support, problems associated with soft floor can be handled by a base-lift device on the shield.

<u>Plows</u> run smoothly in conditions of hard floor and are sensitive regarding the height control if the floor is weak. This problem is technically not an issue through the usage of the adjustable height control system, provided the face crew is trained and has the necessary experience. Modern shield support in plow faces use the "elephant step" (i.e. lifting one of the bases) during advancing in the case of weak floor.

5.1.8 Raw coal size

<u>Shearers</u> crush and mill the coal and adjoining rock during extraction, which is inevitably connected to the principle of shearing extraction. Thus, the mined coal is pulverized in comparison to plows [20].

<u>Plows</u> cutting with a relatively high web and small velocity achieve bigger size yield [32], leading to less processing costs later.

5.1.9 Entry dimensions

<u>Shearers</u> and plows with comparable performance require similar sized entries. Normally, the minimum entry width equals 4-5 m and the minimum entry height amounts to 2 m.

<u>Plow</u> faces normally are equipped with a tail drive for both the AFC and plow, which is located in the tail entry. The gate dimensions are thus determined by the size of the drives. However, developments are underway to operate the plow with only one large drive at the main gate.

5.1.10 Automation

Shearers in recent years, use a technique called "Memory cut" in order to adopt the position of the ranging arms to local situations in the face. Nevertheless, even very modern shearers need constant assistance. Thereby, haulage speed is limited, as the operators need to walk with the shearer. It is expected that shearers will also require assistance in the future, even if the technical developments move forward.

Plows today, are capable of working fully automatically. In some mines, crews are not permitted to stay at the face during production; therefore the plow is running unmanned using a remote control from the surface without any assistance in the face. In many coal mines around the world, plow faces have been running automatically for some time.

5.2 Technical capacity

Technical capacity of shearers and plows working under specific conditions in underground seams depends basically on following factors:

- Hardness of coal
- Installed power
- Haulage speed
- Face height
- Cutting depth (web)

The hardness of coal is described differently in the situation of shearers than with regard to plows. In the case of shearers worldwide, the most used parameter is the uniaxial compressive strength (UCS). The following scale can be found in the literature [32]:

- Soft coal – UCS < 10 MPa
- Medium coal – 10 MPa < UCS < 20 MPa
- Hard coal – UCS > 20 MPa

For the description of the coal hardness with regard to plowing technology, the most recognized scale was developed by the German Research Institute DMT GmbH. The so-called "plowability" of coal is described by an average cutting force F_s of a single plow bit put in kN. This cutting force is determined during "in-situ" measurement with a special device [24], [28]. According to that criteria there are following plowability categories of coal seams:

- Good plowable – $F_s < 1.5$ kN
- Normal plowable – 1.5 kN < F_s < 2.0 kN
- Hard plowable – 2.0 kN < F_s < 2.5 kN
- Very hard plowable – 2.5 kN < F_s

A correlation between UCS and F_s is weak because during linear cutting, mechanical properties of coal are only partially responsible for the dimension of cutting forces. A medium plowability force reckons bedding and joint faces that are present in every humic coal and takes into consideration the influence of strata pressure.

The installed power both on shearers and plow systems were increasing steadily over decades, although in the 1990s more rapid development for shearers was observed. In 2002, with the design of the powerful (1.6 MW) GH42 plow system, plow technology caught up with shearers. Today, shearers with height between 1.5 to 2.0 m as a general rule, have a total installed power of up to 1.2 MW.

Modern shearers can cut coal with velocities up to 40 m/min (0.7 m/s). Today, plows move with speeds between 2 and 3.6 m/s.

The disputable area, where both systems are applicable, is placed between 1.5 and 2.3 m face height. Below that range, plow systems are definitely the only cost-effective option for a longwall. Today, only shearers are used in seam heights above 2.3 m.

Shearers cut with a web between 0.8 and 1.2 m. A cutting depth of plows, depending on coal hardness, installed power, speed and face height varies, between 5 and 25 cm.

All five above named parameters are connected to the performance of a shearer or plow, which is adequate to the amount of energy necessary to extract and load one unit of volume or mass. This energy is called *specific energy* and is expressed in MJ/m^3 (Fig. 11).

The specific energy of shearers varies between 0.7 and almost 10 MJ/m^3, although in a variety of cases it does not exceed 5 MJ/m^3 [10], [26], [32], [45]. Plow systems are characterized by a specific energy ranging from 1.0 to nearly 10 MJ/m^3, while in most plow faces the specific energy does not go beyond 5 MJ/m^3 as well.

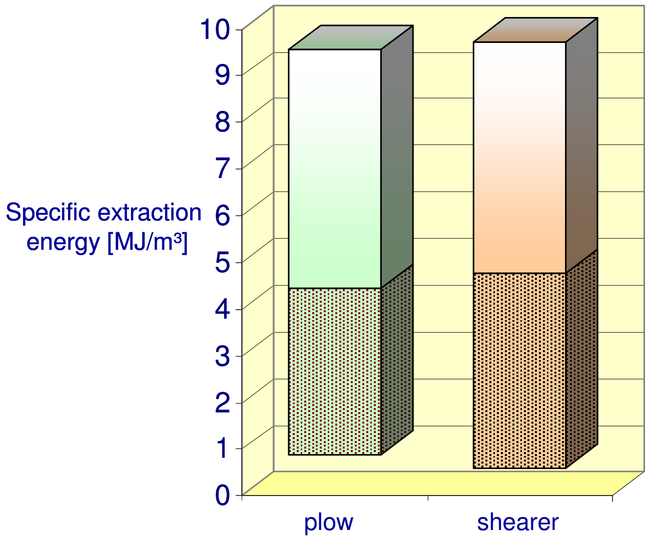


Fig. 11: Specific energy of shearers and plows

In case of soft coal, the specific energy is in both cases placed in the lower parts of ranges described above. Thus, based upon numbers shown above it can be stated, that the specific energy for both extraction systems is comparable. An explanation for that fact can be found in:

- Process of coal extraction – Plows cut coal with bigger web and lower cutting velocity. Thus, plows extract coal more effectively achieving bigger coal sizing. On the contrary, shearers mill the coal through lower web and higher speed on bits, which is more energy consuming.
- Energy transfer efficiency – The proportion of energy for cutting and loading to the absorbed electric energy is higher in case of shearers, as in the event of plows a part of the energy is consumed for converting the rotational into the longitudinal motion and for moving the masses of chain and plow body.

Summarizing: In the case of shearers, their lower cutting efficiency is compensated by a better energy transmission in comparison to the plow. This makes the plow and shearer have a similar specific energy needed to extract a volume unit of coal under comparable conditions.

The diagram in the Fig. 12 presents the theoretical performance of a shearer in a medium thickness coal seam. The saleable daily production is presented as the function of specific energy and shearer daily running time. The calculation is based upon an algorithm presented by RWTH [26], under consideration of the following assumptions:

- Face length 300 m
- Seam thickness (equal face height) 1.8 m
- Seam density 1.5 t/m³
- Shearer cutting power 2 x 500 kW
- Technical efficiency 85%
- Drum diameter 1.4 m
- Half web procedure with 0.4 m cutting depth
- Shearer haulage according to the specific energy [26]
- PUD 60%

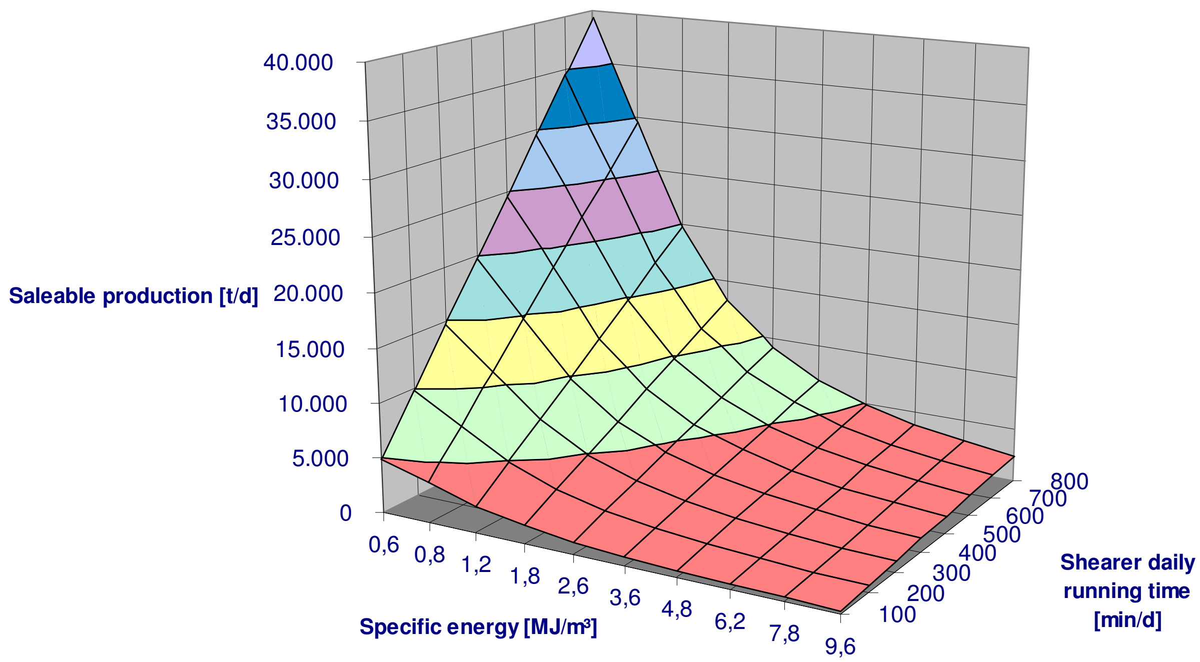


Fig. 12: Shearer face production referred to specific energy and daily running time

The parameters of the shearer were chosen to compliment the face height of 1.8 m. At that height, a suitable drum of 1.4 m diameter and a reasonable installed power for cutter motors of 500 kW were assumed.

The diagram in Fig. 13 presents the theoretical output from a plow system in a medium thickness coal seam. The saleable daily production is presented as the function of seam cutability and plow daily running time. The calculation is based upon an algorithm of DMT [25], [28], under consideration of following assumptions:

- Face length 300 m
- Seam thickness (equal face height) 1.8 m
- Seam density 1.5 t/m³
- Plow installed power 2 x 800 kW
- Technical drive efficiency 80%

- Plow speed 3 m/s
- Double cut overtaking procedure
- Cutting depth according to the coal hardness [25]
- PUD 75%

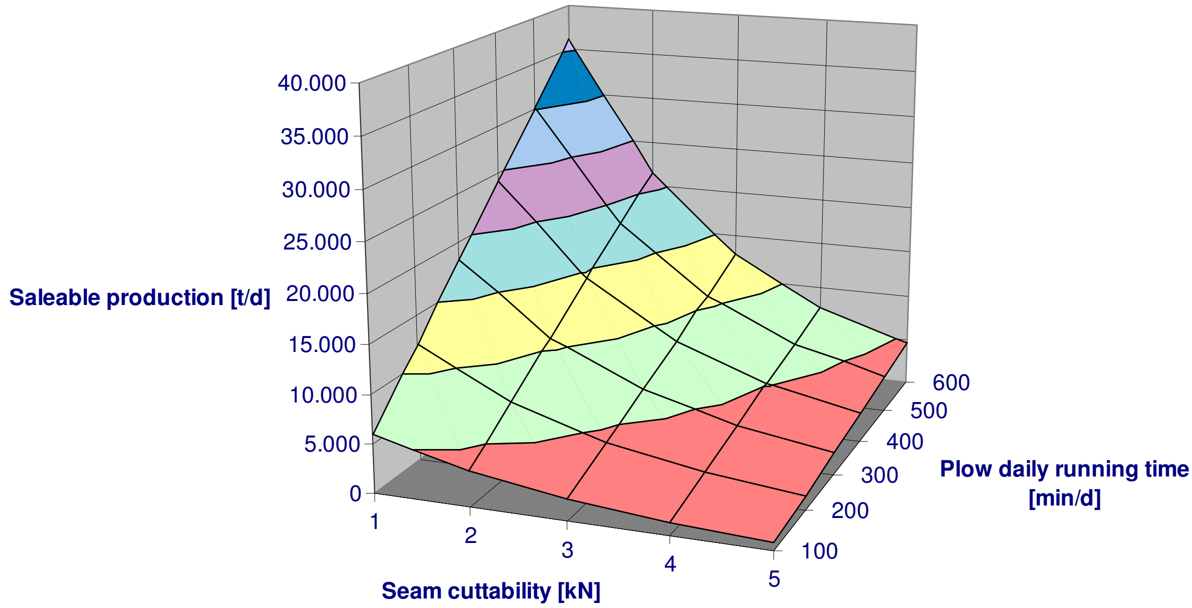


Fig. 13: Plow face production referred to specific energy and daily running time

Both calculations are based upon praxis related algorithms, considering realistic field-tested parameters. The asserted PUD input numbers are higher-than-average values, distinguishing excellent faces for both the shearer and plow. In both cases, cutting of coal at full height has been assumed.

The comparison of both diagrams displays a higher performance of a plow for that face height at the same running time. This fact should be explained by the higher specific power on the plow system, which is able to fully utilize its installed power.

The diagram in Fig. 14 presents specific installed power for modern plows and shearers working in low and medium thickness coal seams. The term “specific” denotes that the installed power of a shearer or plow is expressed per unit of the face height.

$$\overline{P}_S = \frac{\sum P_{Inst}}{h_L} \qquad (4)$$

where:

$\sum P_{Inst}$ - total installed power on shearer or plow [kW],

h_L - longwall height [m].

The diagram in Fig. 14 shows the specific power installed on a shearer or plow versus face thickness. Presented curves are calculated according to the formula (4) for following machinery:

- Shearers with 600 kW, 1000 kW, 1200 kW, 1500 kW and 1800 kW
- Plow systems with 800 kW and 1600 kW

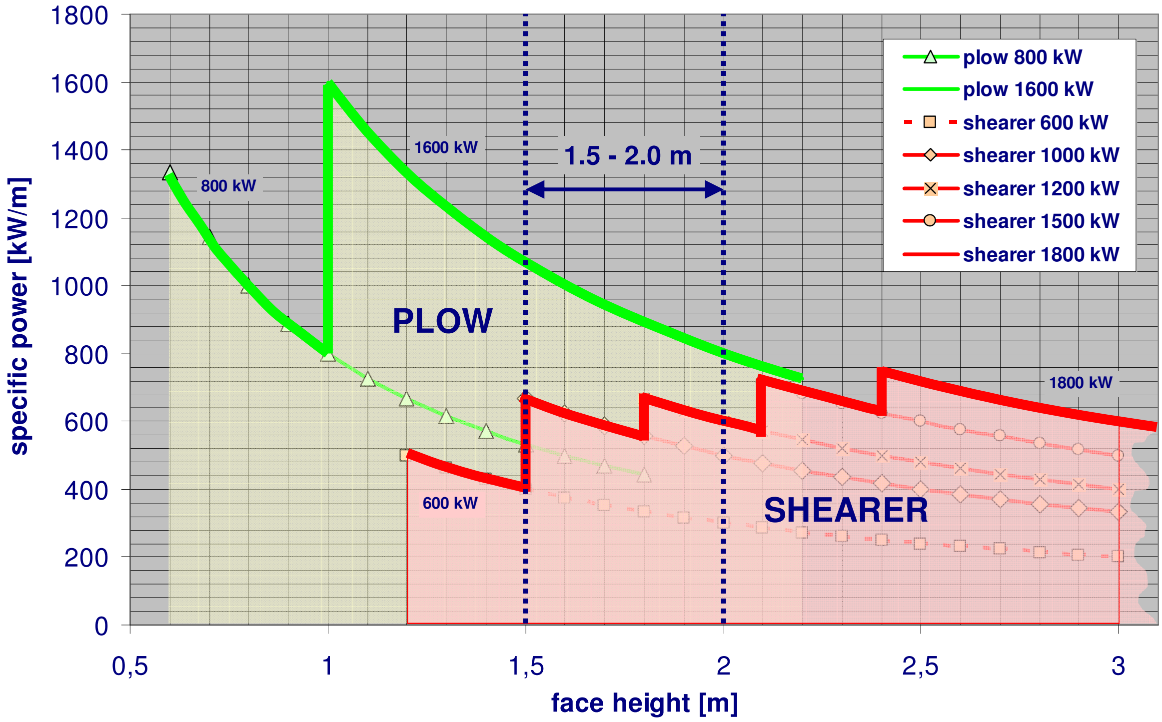


Fig. 14: Specific shearer or plow power rating vs. face height

The diagram clearly presents that in the range between 1.5 and 2.2 m the 1600 kW plow have a higher specific power than shearers. Beyond 2.2-2.3 m, shearers take the lead.

Summarizing: Power and in-seam mining are both positive attributes today for plow technology in low and medium seams. In contrast, some people have unfair opinions of plow technology bases upon improper interpretations or non up-to-date information [6].

5.3 Methane hazards

Shearers work with lower speeds and larger cutting depths, so the volume stream of crushed coal from the face is much more concentrated on one place in the face than in the case of plows. Additionally, as previously stated, shearers crush and mill the coal vigorously, releasing in a short time, more methane from a unit of extracted coal. Therefore, a higher level of local CH_4 concentration is more probable in a shearer than in a plow longwall face. Unfortunately, there are no known (at least to the authors) publications about direct comparison tests, thus a quantitative consideration and comparison of CH_4 emission in shearer and plow faces can be only of theoretical nature.

5.4 Coal dust hazards

Shearers create a lot of fine coal dust concentrated in a relatively small area [20]. The reasons for that behavior are principally the same as described in the section 5.3. Coal is crushed and milled by the rotating drum and the coal dust is blown into the surrounding atmosphere. The quantity and quality of dust depends on the type of extracted coal and on a number of shearer parameters like drum diameters, type, number and distribution of bits, rotational speed of the drum, and shearer haulage speed [45]. In order to suppress the distribution of dust into the atmosphere, sophisticated spray systems are used. In most cases, the nozzles are placed directly on drums. Water spray booms attached to the shearer are also frequently used to assist in dust suppression.

In comparison with the shearer, a plow produces more large coal lumps and less airborne dust. The percentage of large lumps increases and the airborne dust reduces as the plowing depth increases. The airborne dust produced by the plow is more uniformly distributed in the air along the face [34], [45].

While cutting the face, the plow body always pushes a heap of crushed coal in front of it. With this type of system, the plow bits on the body are always cutting under a covering of coal, which suppresses dust propagation [24]. In plow faces, spraying systems are usually located under the shield canopies and sometimes in the spill plates of the AFC. The plow control system activates the nozzles just seconds before the arrival of the plow body and deactivates seconds after the plow passes.

6 Economic aspects

Economic facets are of equal importance as technical and procedural aspects discussed in previous chapters. Every comparison of different techniques, technologies, or procedures has to comprehend a financial analysis. In the past, many countries subsidized their coal mining industries; hence economic aspects had a lower priority than today. Today, such a situation is unimaginable and thus, the production costs play the most important role. A comparison between longwall mining with shearers and plows can be comprehensive and complete only if all costs are widely considered and precisely analyzed.

6.1 Capital costs

The longwall mining is decisively more effective, but also more capital consuming than the room-and-pillar systems. Face equipment consists of extraction machinery, i.e. a shearer or plow, an armored face conveyor (AFC), and a roof support.

6.1.1 Roof support

The most expensive part of every longwall is the roof support, which is composed of an array of shields. One shield presents a cost factor of many tens of thousands of Euros. Roof support costs are linearly proportional to the face length. The longer the face is, the higher the number of shields needed to be used. In general, there are minor design distinctions between shields for plow and shearer faces. The most important differences can be described as follows:

- Shearer shields have rigid bases, plow shields have split bases.
- Shearer shields are equipped with base lift cylinders, plow shields not.
- Shearer shields have much longer canopies (nearly 20 – 30% longer).
- Shearer shield canopies are equipped with front cantilevers, plow shields not.
- Plow shields (even when fully automated) may operate with a control device on every third shield. The adjacent shields are controlled by the control unit placed on the mid-shield.

It can be stated that shields for a shearer face are slightly more expensive than plow shields for comparable geological conditions.

6.1.2 Extraction machine

The costs of a longwall cutting machine such as a shearer or plow system, are essentially lower than expenses for a roof support. The expenses for the extraction machine are some 10% to 20% of those for a roof support.

A modern shearer is a highly comprehensive machine. Next to an excessive amount of steel parts, a shearer comprises of many mechanical, hydraulic, electric, and highly sophisticated electronic parts. The price for a shearer is almost irrespective to the face length.

The costs for a plow system, depend in certain degree, on the length of the face. A plow system consists of:

- Plow body
- Plow guidance attached (welded) to the AFC pans
- Plow chain of 38 or 42 mm thickness and double face length
- Two drives comprising of plow box, gear box and motor

For plow systems in the past, a pole-changeable asynchronous motors were used. This type of motor has only two different speeds i.e. low speed and high speed, these speeds are proportional by 2 or 3 times. Since the beginning of this decade, VFD motors are frequently used on plow systems. This type of motor allows a continuously variable setting of speed and is more expensive than the asynchronous motor.

As a general rule, the costs for a shearer are roughly similar to those of a plow system under consideration of comparable face conditions, although the price for the most capable plows can be slightly higher.

6.1.3 Face conveyor

AFC costs depend strongly on the face length and height. Longer faces need accordingly more pans, longer chain assemblies, and thus more power. More power means larger drives and accordingly larger supply units. Higher faces require wider pans in order to accommodate extracted coal.

The differences between shearer and plow AFC are fairly distinct. Drive frames for a plow system are more complicated because the plow drives are attached to the frame on the opposite side than those for the AFC. The pans for both systems are comparable, but spill plates have some differences. Additional elements for a shearer are the components of the haulage system i.e. racks. Additional parts for a plow are cylinders for the height control (so-called outrigger steering). Those cylinders are commonly placed every second pan in the face, sometimes on every pan.

AFC costs for a shearer face are slightly higher than in the case of a plow face.

6.1.4 Face auxiliary equipment

Face equipment needs a number of auxiliary apparatus like transformers, switches, control and communication devices, pumps, etc. In the case of both a shearer and a plow face, most auxiliary devices on both faces are the same. The differences occur only with regard to the extraction machine. A plow system needs an additional switch for the energy supply of its drives and a shearer commonly has its own switch on board.

6.1.5 Total face equipment costs

The table in Fig. 15 shows a general relative comparison of capital costs for a comparable shearer and plow face. The face equipment was subdivided into:

- Extraction machine i.e. shearer or plow system. A shearer is an integral device, but a plow system has a fragmented structure with plow guidance attached to the

AFC containing chains and two (or one) drives placed at face ends and attached to frames

- AFC being relatively similar in both cases
- Electric and hydraulic equipment is slightly different in both cases
- Shields of the roof support. Differences of shields for shearer and plow faces are described in section 6.1.1.

Component	Shearer	Plow
1. Extraction machine	less expensive	more expensive[5]
2. AFC	more expensive	less expensive
3. Electric & hydraulic equipment	less expensive	more expensive
4. Shield support	more expensive	less expensive
Total	comparable	

Fig. 15: Comparison of main capital costs for a shearer and a plow face

The composition of main longwall components presented in the table in Fig. 15 shows a comparability of capital expenses for a shearer and a plow face.

6.2 Equipment lifetime

Modern shearers are very sophisticated. A shearer consists of a frame and in most cases two ranging arms with drums. Shearers have on-board a number of motors, gear boxes, and pumps as well as electric, hydraulic and control equipment. All together a contemporary shearer is a hybrid of different technologies. This highly sophisticated machine is continuously exposed to damaging factors during production like: vibrations, mechanical loading, varying temperature, moisture, aggressive water, dust, etc. In spite of the robust design, such circumstances inevitably cause frequent damage and corresponding repairs and overhauls. Shearers have many wearing parts like bits, cutting drums, trapping shoes, etc. Generally, due to the high wear and frequent replacement of pars, the life of a shearer mining coal is approximately 10 million to 20 million tons.

In the case of a plow, the situation is different. A plow body moves along the face cutting and loading coal. The plow body consists “only” of steel parts. There are no rotating parts like motors, gear boxes, pumps, which can be easily damaged. Although the plow is complex in design, it is indeed just a hunk of steel that is resistant to mechanical forces and other destructive factors. Even though the plow body moves a couple of times faster than a shearer and is a subject to higher forces, its robustness makes it much less vulnerable than a shearer. The wear parts of a plow system are the bits, gliding parts of the plow body, chain and sprockets. The wear parts will need to be periodically replaced and the plow guidance and plow body will need to be overhauled through welding. The life-span of plow can amount to 35 million ton, depending on working conditions.

Longwall equipment has to be maintained. Periodical overhauls are to be planned and repairs need to be considered and budgeted. These periods of repair and

[5] Including plow drives, plow guidance, chain and plow body

overhaul, along with the costs associated with them, are based on previous experiences. Nevertheless, while planning new longwall, funds for those operations have to be allocated. Based upon the authors' experiences, the average costs and overhaul periods are described below.

Shearer – Repair costs for a shearer, within the course of a longwall panel, lie between 10% and 30% of the original purchase price. Similar expenses need to be also planned for an overhaul of the shearer. As a rule, an overhaul of a shearer is carried out after the conclusion of a longwall panel. On average, some 4 to 8 overhauls are performed, within a lifetime of a shearer.

Plow system – A plow system working under comparable conditions requires similar overhaul periods as what a shearer does, although the average overhaul expenses are slightly lower. Thus, the total number of overhauls during the life of a plow is similar to that of the shearer.

6.3 Operating costs

All expenses connected to mining activities are combined together and referred to as "operating costs". The following list accounts for most of the operating costs:

- Salaries, wages
- Materials and consumables
- Spare parts
- Energy
- Depreciation, depletion, amortization
- Insurances
- Rents

In order to compare shearers with plows, operating costs also have to be matched. For the purpose of making that comparison as objective as possible, both longwall systems need to operate under comparable conditions. In the case of different conditions, an adequate sample must be taken to produce accurate results.

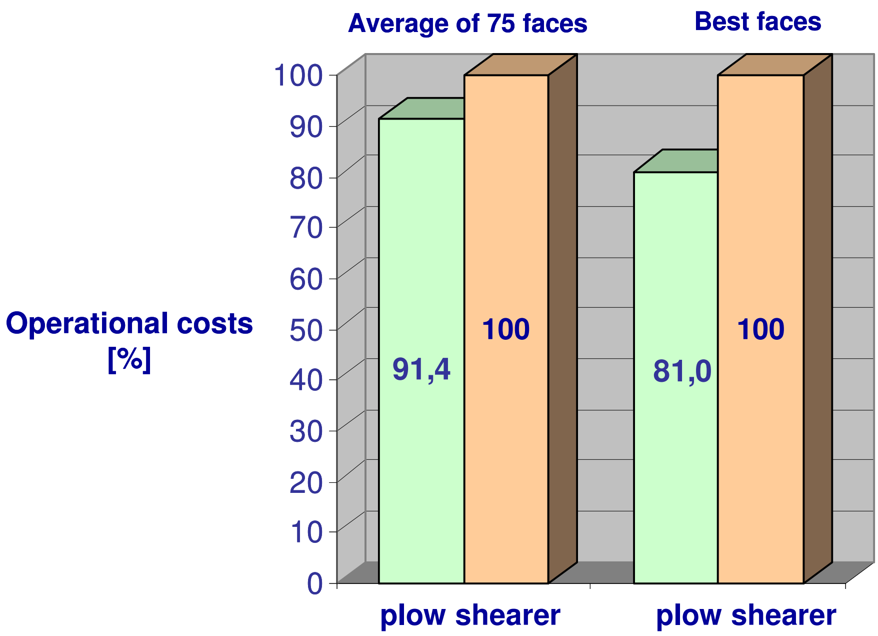


Fig. 16: Comparison of operating costs for shearer and plow faces in Germany

In Germany, where numerous shearer and plows were in use, a comprehensive study of operating costs among other factors was carried out. Over a period of four years, there were 75 longwalls analyzed. They consisted of 18 shearer and 57 plow faces [9], [37]. The analysis spanned all faces and specifically focused on the most efficient longwalls. Fig. 16. shows the results of the analysis.

In both cases operating costs of plow faces were lower than those of shearer faces. In the case of all faces, the difference amounted to 8.6%. The comparison of the best longwalls of both groups was even more specific. In this group, the discrepancy between operating costs of plow longwalls compared to shearer longwalls scored almost 20%.

6.4 Coal production costs

The final mine costs associated with producing a unit of saleable coal is a very important factor that can show how well a mine or coal company has performed during a certain period of time. The total production costs per ton imply all previously said parameters, which in a certain degree are linked to each other. The higher the technical capacities and procedural degrees are, the lower the cost of production will be. On the other hand, the lower the capital and operating costs are, the cheaper one ton of coal can be mined.

This elaboration was focused directly at the cost of longwall mining only. In most cases, the expenses of the mines are actually higher than just the longwall costs. Those costs are only in an insignificant figure (or even not at all) depending on the type of longwall, so they were not considered here. Those costs do need to be considered in the final calculation, as they do influence the final price of coal production.

Real mining industry production costs of a shearer and a plow face working under comparable conditions are not easily obtained, but having comparable capital costs and lower operating costs, the plow face shows to be the more favorable longwall system.

7 Summary and conclusions

Today, coal fuels 40% of the world's electricity. This percentage is said to last for the next several decades. Coal reserves are decisively larger than oil or gas reserves, so coal will maintain an important role throughout the future. A large part of the remaining coal reserves are located in thin and medium thickness seams, i.e. below 2 m mark. Underground longwall extraction of coal between the height of 1.5 and 2.3 meters is possible by usage of shearers or plows. In this approach, authors tried to conduct a comprehensive comparison of both longwall extraction methods, by having a closer look at relevant aspects.

In order to compare the performance of shearer and plow faces in medium thickness coal seams, a comprehensive consideration of technical, procedural and financial aspects needs to be carried out.

A. Shearers are characterized by a better energy transmission, but a lower extraction efficiency than plows. With that said, the specific energy needed for the extraction of a coal unit under similar face conditions is comparable for both types.

B. Within the range of up to 2.1-2.3 m, modern plow systems are equipped with higher specific power, i.e. installed power related to the face height than shearers.

C. The average shearer face has a higher time utilization degree (TUD) than an average plow face, but referring to high performance faces, the TUD for both extraction methods are reaching the same level. TUD ranges in normal situations from 40% to 70%, with the best faces having achieved a value of 90%.

D. Plows are earmarked by a higher procedural utilization degree (PUD) than shearers. The best plow faces can reach a PUD of up to 95%, while the most effective shearer faces top out at 75%.

E. Production costs depend on face performance along with capital and operating costs. In general terms, it can be stated that for a seam thickness ranging between 1.5 and 2.3 m, modern shearer and plow faces show comparable capital expenditures, but operating costs for plows are lower. Thus, the production costs of plow faces are lower than those of shearer faces.

Recap: Longwall face performance is a function of all five factors presented above.

Performance = f (A, B, C, D, E)

Having lower capital and operating costs, and efficient production numbers, will yield lower total production costs.

Taking a high performance shearer system and plow system into consideration, the following conclusions have been drawn:

- Below a 1.8 m face height, the plow system is the better choice
- Between 1.8 m and 2.3 m height, the choice of plow or shearer depends on the geological and mining conditions
- In longwalls above 2.3 m height, shearers present the most suitable extraction technique

8 References

[1] Beimdieck, J.; Stöttner, M.T. – „*Schnellentwicklung eines Strebes am Beispiel der Bauhöhe 6/7 Westen, Flöz 65/68*“ – Bergbau 1/2008

[2] Bittner, M.; Weiß, H-J. – “*Einsatz schwerer Hobelanlagen – von der Innovation zum Standard*“ – RWTH Aachen 2007

[3] Brandt, J.; Sdunowski, R. – “*Optimierung der Gasabsaugung zur Leistungssteigerung in Abbaubetrieben*” – RWTH Aachen 2007

[4] Bussmann, H. – “*Wirtschaftliche Gewinnung dünner Flöze – Vergleich verschiedener Produktionsmethoden und Ansätze zur Steigerung der Produktionskapazität für den Strebbau mit schneidender Gewinnung*“ – RWTH Aachen 2001

[5] Catelin, M. – ”Coal - *Essential fuel for the 21st century*“ – Optima 2007

[6] Cooper, R. – “*Let’s talk longwall*” – Mining Perspectives for Both Worlds, Vol. 12, No. 1

[7] Daul, J.; Juch D. – „*Die Verteilung der Vorräte der Steinkohlelagerstätten an der Ruhr vor dem Abbau und am 1. Januar 1995*“ – Glückauf 135-1999

[8] Deutsche Steinkohle AG – *Different documents*

[9] DMT GmbH - “*Empfehlung für die Wahl des schälenden oder des schneidenden Gewinnungsverfahrens in Flözen mittlerer Mächtigkeit*“ - Betriebsempfehlung für den Steinkohlenbergbau Nr. 34 – Verlag Glückauf

[10] Dolipski, M.; Jaszczuk, M.; Sobota, P. – “*Specific energy in aspect of the correctness of a shearer application*” – Mine Planning and Equipment Selection - Calgary 1998

[11] Eikhoff, J. – “*Entwicklung eines Produktionssystems im deutschen Steinkohlenbergbau*“ – RWTH Aachen 2007

[12] Filipiak, A; Paschedag, U. – ”*High-Performance Longwall Mining in Thin Seams*“ – RWTH Aachen 2000

[13] Geisler, J. – “*Betriebserfahrungen mit einer Hobelanlage für schwer gewinnbare Flöze auf dem Bergwerk Walsum*” – Glückauf 125

[14] Gesamtverband des deutschen Steinkohlenbergbaus – “*Steinkohlenbergbau in Deutschland*“ – Essen 2006

[15] Irresberger, H.; Gräwe, F.; Migenda, P. – “*Schreitausbau für den Steinkohlenbergbau*“ – Verlag Glückauf 1994

[16] Jaszczuk, M. – “*Operational productivity of shearer loaders*” - Mechanizacja i Automatyzacja Górnictwa, – KOMAG, Gliwice 2007

[17] Jaszczuk, M. – ”*Czynniki techniczno-organizacyjne determinujace wykorzystanie przodka scianowego*” – Maszyny Górnicze, KOMAG, Gliwice, 2004

[18] Jaszczuk, M.; Kozieł, A.; Sikora, W. – ”*Etapy rozwoju ścianowych systemów mechanizacyjnych w polskim górnictwie węgla kamiennego*” **.** – Mechanizacja i Automatyzacja Górnictwa 6/49 2008

[19] Junker, M. – “*Gebirgsbeherrschung von Flözstrecken*“ – Verlag Glückauf GmbH·Essen·2006

[20] Kundel, H. – „*Kohlengewinnung*" – Verlag Glückauf 1983

[21] Lisowski, A. – "*Podstawy ekonomicznej efektywności podziemnej eksploatacji złóż*" – PWN Warszawa 2001

[22] Martin, H.; Paschedag, U. – "*Shearers versus plows*" – American Longwall Magazine, August 2006

[23] Myszkowski, M.; Plum, D. – "*Verfahrenstechnische und maschinentechnische Auslegung von Hochleistungs-Streben*" – RWTH Aachen 2000

[24] Myszkowski, M. – "*Erstellung eines Berechnungsmodells zur Auslegung und Optimierung von Hobelanlagen auf der Grundlage von Betriebsdaten und experimentellen Untersuchungen*" – Berlin 2004

[25] Myszkowski, M. – "*Auslegung des optimalen Hobelverfahrens für Hochleistungsbetriebe mit Maximierung der Gewinnungs- und Förderleistung*" – DMT 1996

[26] Nienhaus, K.; Bayer, A. K.; Haut, H. – "*High productivity – A Question of Shearer Loader Cutting Sequences?*" – RWTH Aachen 2000

[27] Paschedag, U. – "*Low Mining*"– World Coal, 2006 Volume 15 Number 12

[28] Paschedag, U.; Schwolow, G. – "*Die DMT-Zerspanbarkeitsmessung als Grundlage zum Bestimmen der Hobelbarkeit von Kohlenflözen*" – Glückauf-Forschungshefte 1992

[29] Paschedag, U. – "*Rekordfördermengen mit Hobelanlagen in den USA*" – Glückauf 1999

[30] Paschedag, U.; Schwaak, A. – "*Steigerung des effektiven Flächenverhiebs durch Langfronthobeln*" – Glückauf 124 (1988)

[31] Peng, S.; Chiang, H.S., "*Longwall Mining*", – First Edition – 1984

[32] Peng, S. - "*Longwall Mining*" – Second Edition – 2006

[33] Plum, D. – "*Die Strebtechnik im deutschen Steinkohlenbergbau*" – Glückauf 1994

[34] Reuther, E. U. – "*Lehrbuch der Bergbaukunde*" – 11 Auflage 1989

[35] Rutherford, A. – "*Half-web benefits remain untapped*" – Australia's Longwall, 2001

[36] Rutherford, A. – "*Automation and Increasing Output on Australian Longwall Faces*" – RWTH Aachen 2000

[37] Scheidat, L.; Schwolow, G. – "*Schälende oder schneidende Gewinnung in Flözen mittlerer Mächtigkeit*" – Glückauf 128 No. 1

[38] SPG Media - http://www.mining-technology.com/projects/twentymile

[39] Traud, W.; Tafel, T.; Rump, K. – "*Betriebserfahrungen beim Einsatz von Walzenladern in Flözen mit geringer Mächtigkeit auf dem Bergwerk Walsum der DSK AG*" – RWTH Aachen 2000

[40] Turek, M. – "*Scenariusze rozwoju technologicznego przemysłu wydobywczego węgla kamiennego*" – Główny Instytut Górnictwa 2008 – praca zbiorowa

[41] US Department of Energy – "*Longwall Mining*" – Washington DC 1995

[42] Voß, H-W. – "*Experimentelle und theoretische Untersuchungen zur Steigerung der Gewinnungsleistung von Gleithobelanlagen unter Berücksichtigung der Massengutinfrastruktur*" – Clausthal-Zellerfeld, 2005

[43] Voß, H-W.; Junker, M.; Bittner, M. – "*Erste Betriebserfahrungen einer neuen Hochleistungs-Hobelanlage in harter Kohle*" – Glückauf 140-2004

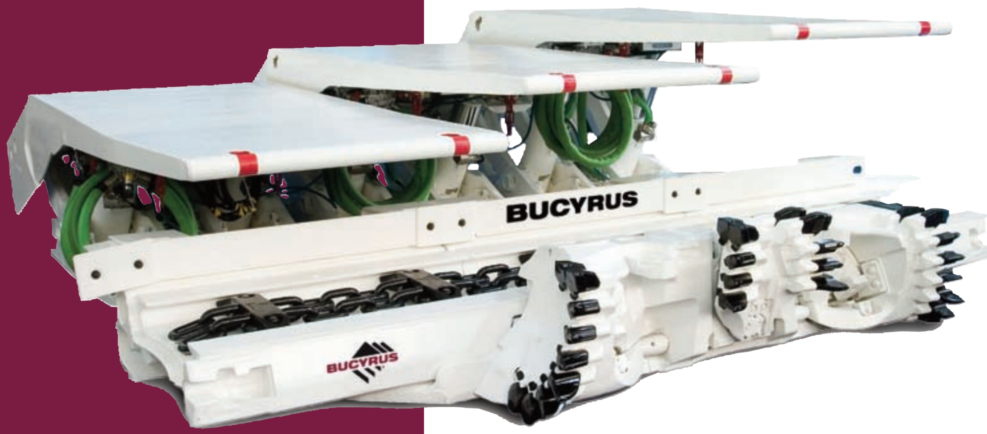
[44] Weisdack, G.V.; Kvitkovich, J.F. – "*U.S. Longwall Development Projected to Increase"* – Mining Engineering 2005-2006

[45] Wolter, N. – "*Theoretische und Experimentelle Untersuchungen zur Staubentwicklung am Walzenlader unter Anwendung von Hochdruckwasser*" – Berlin 1992

[46] World Coal Institute - *Different publications* – www.worldcoal.org – UK

[47] Zorychta, A.; Burtan, Z.; Tajduś, A. – "*Technologie eksploatacji węgla kamiennego w aspekcie ich innowacyjnego i efektywnego stosowania*" – Mechanizacja i Automatyzacja Górnictwa 6/49 2008

9 Table of figures



Longwall mining allows the most effective underground coal extraction method today. A large part of global coal reserves is located in seams between 1.5 m and 2.3 m thick; these are often high-quality reserves. The question is whether the use of a shearer or of a plow longwall system is economically better. Only a comprehensive comparison of both longwall mining methods, looking at the latest system technology available results in an in-depth analysis of all relevant geological, technical, procedural and economical aspects allows operators to find the best solution to mine their individual deposit.

BUCYRUS®