LONGWALL COAL CUTTING MACHINES
THE FUTURE

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ABSTRACT

For more than 30 years shearer loaders have been the most important winning machines for longwall mining. While the machines of the first generation had a driving power of only 100 or so kW, the present day shearer loaders may be powered by more than 1000 kW. Daily outputs of 24000 tonnes have now been reached, but this still does not set a limit. If the deposit conditions allow, further increases are possible. This requires the optimum coordination of all system components.

For this paper the use of coal plows has been of little import as plows have found no favour, and nor are they likely to do so in today’s economics in Australian coal mining.

In order to consider the future we consider the current status of longwall shearer loaders with the view of predicting future trends.

The main system components of high-performance shearer loaders are discussed in the paper. The cutting drum which is the tool of the shearer loader must use the available machine power for cutting and loading the coal. The drive concept of the shearer loader is a base on which success can be built, a high-performance haulage system is a pre-requisite for this.

The rapid development of micro-computers enables us to meet the requirements of the future of automation, monitoring and diagnosis.

At this time the potential production rates of shearer loaders in underground high production longwalls are higher than can be realised with current coal clearance systems. As a result it seems likely that the not too distant future will see evolutionary change of this type of

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equipment rather than revolutionary change in coal mining systems.

**INTRODUCTION**

The underground coal industry has demonstrated continuing increases in productivity largely due to improvements in production rates from longwalls which for the year 1987 for the first time exceeded an average of 1 million tonnes per face (fig. 1) and demonstrated daily production records culminating in the production of 24000 tonnes in a day from Glen Colliery in November. At this level underground productivity is such that direct competition with open-cuts is possible. Can this trend be continued? We believe that it will by the continued application of available technology and perseverance in improving availability and working times.

**FIG. 1 LONGWALL DAILY PRODUCTION RATES**

We have seen longwalls equipped with cutting machines of over 1000 kW installed power being able to cut at rates of 3000 tonnes per hour. If one half that rate can be averaged - which is feasible - outputs of 36000 tonnes per day are achievable and with even the 50% system availability common today then 18000 tonnes per day average or more than 4 million tonnes per year seems in prospect.

At such levels it is unlikely that the constraint in reaching higher production rates will be the shearing machine. Such issues as coal clearance capacity, support move rates, dust and gas are far more likely constraints. In this circumstance we see future prospects lying in continuing improvement in existing types of cutting machines, particularly improvement in availability and to a lesser extent in computer control, remote operation and automation.

This is so because in the thick coal (2 to 3.5 metres thick) generally being mined in this country automation of the cutting machine does not produce significant gain in total production or productivity. In thinner coal however, more sophisticated systems can lead to significant improvements in production and productivity as such systems as remote shearer operation and shearer initiation of roof supports can obviate the need for people to traverse the face on every web that is cut.

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This paper does not examine plows as these units have not found favour in Australia and have been losing ground in Europe even in coal seams as low as 1.2 metres as shearer loaders have been shown to be more positive and more easily controlled where the seam height is sufficient to allow their installation (i.e. at thicknesses over 1 metre).

In order to consider future prospects it is necessary to examine the current status of cutting machines.

**SHEAVER LOADERS FOR HIGH-PERFORMANCE LONGWALL FACES**

1. **A SHEAVER LOADER IS ONLY AS EFFICIENT AS ITS CUTTING DRUM.**

   This fact is often forgotten due to the comparatively low price of only a few percent of the machine value. The cutting drum serves for extracting the bed mineral out of the solid face and for loading it on to the conveyor. While at the beginning the drums had only the task of loosening the mineral, they were later fitted with loading vanes in order to direct the loose mineral on to the conveyor. The integration of both functions is fully realized in modern cutting drum designs. In the following the design parameters of the present day cutting drum designs will be summarized:

   - Machine technique.
     - Dimensions and shape of the cutting drum, rotational speed, travelling speed, type of picks, pick lacing on the end ring and on the drum etc.
   - Process technique.
     - Direction of rotation, cowl, operation of the machine, unidirectional/bi-directional.
   - Rock parameter.
     - Breaking angle, rib breaking factor, compressive and tensile strength, brittleness, intercalations, cleat planes.
   - Technical environment.
     - Gradient in the direction of advance and in the direction of working, form of the travelling track and of the face conveyor, design of the drive frames of the face conveyor.

   In a simplified way one could say that the loading properties of cutting drums depend on the pick lacing and the loading properties on the drum shape. The difficulty in the design of cutting drums is due to the fact that from a geometrical point of view the pick lacing and the drum shape are often opposed, so that a compromise must be found between "loading" and "cutting".

   We have developed a computer program for the design of cutting drums and are
FIG. 2 CUTTING DRUM: CAD PRINT

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now in a position to optimize the shape, the dimensions and the pick lacing of cutting drums of all specific requirements (fig. 2). This naturally also includes the minimization of vibrations induced by the cutting drum (fig. 3).

A look into the future shows that after many successes we will have reached a certain state of the art with regard to the design of cutting drums and the future development activities will have to be directed to the following areas:

- new cutting tools
- dust avoidance
- and for certain areas the prevention of methane gas ignitions due to the hot pick trace.

In the last few years we have seen an increasing application of round shank picks. Although they require a higher thrust force than flat picks this disadvantage is compensated by their longer service life.

It can also be noted that new ultrahard materials will replace or supplement the carbide metal tips. Picks coated with polycrystalline diamond (PCD) have been successfully tested in some countries. The ceramic materials used for machining metals, for instance on turning and milling machines - such as aluminium oxide, silicon nitride, boron nitride and similar materials - can also be used for the cutting tools of coal getting machines if they are modified accordingly.

This will probably lead to the realization of picks which are adapted to the breaking mechanics of coal, have a long service life and require less energy.

The problem of the dust produced by shearer loaders is as old as the machine itself. However, the total...
The dust load in the working area is only partially due to the cutting operation of the shearer loader. The mining method itself, the geological conditions, and the machines and equipment used all contribute to the raising of dust.

With regard to the dust make of shearer loaders there have been surprising achievements in the course of the last few years. The main dust producers of the shearer loader are the cutting picks and the loading operation (Fig. 4).

**Dust Control for Drum Shearers**

**Dust Source:**
- Cutting (Picks)
- Loading (Drum)

**Primary Measures:**
- Design of Cutting Drum (pick pattern, pitch, no of starts, ...)
- Rotational Speed, RPM
- High Pressure Water Jets (HPWJ) (pressure, volume, nozzle phased jets)

**Secondary Measures:**
- Extraction Cowl
- Extraction Drum
- Sprays or Venturi Sprays on Machine Body e.g. Shearer Cleaner

The main remedial measures are aimed at preventing the dust make or preventing the dust from becoming airborne.

**Design of the cutting drum.**

The lowest possible number of picks, a coarsely cut mineral, and a careful loading operation achieved by the shape of the end ring, the drum body and the loading vanes are a basic condition. The selection of the correct transverse handling speed ensures little deterioration of the material and loading on to the conveyor without whirling up dust. Comprehensive studies, observations and trials have enabled us to make this selection using formula algorithms.

**Reduction of the pick speed by a reduction of the drum speed.**

Reduction of pick speed has led to success in reducing dust make. The ranging arms which are now available can operate at a speed of 23 r.p.m. over the full range of motor ratings. However, further potential for this seems to be limited. The requirement for higher travelling speeds of more than 10 m/min in order to reach higher outputs cannot be met when operating at low drum speeds, particularly in thin seams and with small drum diameters.

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High-pressure water at every pick.

The success reached in the pressure range below 200 bar with regard to dust avoidance, pick wear and prevention of ignitions due to the hot pick trace is quite remarkable. The high-pressure water jet binds the dust when it is produced by the pick and moistens the coal intensively (fig. 5). Water consumption is not higher than in the past. The sector supply of water reduces the water consumption, if required. It will be our task in future years to introduce this technique with all its requirements and to adapt it continuously to the latest state of the art. For many machines this technique is already available, and a number of field trials have taken place.

The prospect of revolutionizing the cutting technique by high-pressure water jets will not be fulfilled. The success reached with the reduction of the required electrical power for driving the drum by the reduction of the pick forces is rather modest compared with the expense involved.

The other dust suppression measures are aimed at extracting the dust from the air, to suppress it or to guide the dust-laden air and keep it out of the working area.

A particular development recently made is the "dust extraction drum" developed in Great Britain. The success achieved in the U.K. and the U.S.A. speaks for itself. However, under the special conditions in the German mining industry this system has not yet
proved its efficiency. The very high ventilation speeds on German longwall faces and the special geological conditions – above all the cutting of dirt bands – play a role in this respect. However, we believe that for certain applications the use of this technique could offer some potential for reducing the dust make.

The technical facilities which must be provided on shearer loaders for dust extraction are similar to those required for high-pressure water supply. We have now developed a comprehensive range of booster pumps (fig. 6) and other high-pressure water components.

2. DRIVE CONCEPT OF SHEARER LOADERS – THE BASIS FOR SUCCESS

The drive concepts mainly comprise 4 basic designs at present (fig. 7):

a. Shearer loaders with one or two motors which are arranged in the longitudinal direction of the machine.

This commonly used, proven design features the central drive, the distribution of the power to two cutting drums according to the requirements, and a low electrical but high mechanical involvement.

At the beginning, these machines had a driving power of 170 kW, but they are now equipped with 1 or 2 motors having a rating of 300 or 380 kW.

The machines are hauled by 1 or 2 hydraulic haulage units which can be replaced by electric haulage units. Many ranging arms with different lengths and output speeds are available. The power density of these machines originally amounted to approximately 30 to 40 kW per cubic meter of the machine volume. The corresponding figure of the...
EDW-300/380-L now amounts to nearly 80 kW/m³ (fig. 8).

b. Machines with single electrical drive cutting motors at the ranging arm (fig. 7).
Each cutting drum, each haulage unit and the servo hydraulics of these machines have their own motor. The number of mechanical components is thereby greatly reduced and the design is compact and simple. The scope of the electrical and electronic components has been considerably increased. Power distribution no longer occurs between the two drums due to the single drives with the result that the installed motor power cannot be fully utilized in thin and medium thick seams. This machine, which was introduced 12 years ago, originally had 150 kW cutting motors, and now has 230 kW cutting motors. Higher installed power is feasible in the future. It is generally equipped with 2 electrical haulage units each being driven by a 23 kW d.c. motor (fig. 9).

The power density originally amounted to 90 kW/m³, at present it amounts to approximately 120 kW/m³ at an installed motor power of 511 kW. After the familiarisation with the comprehensive electrical equipment we have an extremely robust and reliable machine which can be easily repaired.
c. Machines with longitudinal motors and separate haulage drive (fig. 7).

The machine was developed due to the requirement by some customers for a powerful machine of low and compact design. It combines the high installed power - the power of one motor can always be fully utilized - with the advantages of the multi-motor drive. In the typical case it is equipped with two motors of 380 kW each at a voltage supply of 3.3 kV. It is also possible to install a 400 kW motor at 3 kV.

The special features of these machines are the very low height which allows for their use in a seam thickness from 1.4 m, the high installed power of 815 kW, the very high power density of approximately 120 kW/m² and the connection of the major units by tie rods (fig. 10). Due to this new technique of connecting the machine components the underframe and the single-type machine covers can be omitted.

d. Shearer loaders having their machine body beside the conveyor, "LN" machine (fig. 7).

Thin seam shearer loaders mainly work with the leading cutting drum for which the full motor power must therefore be available. In 1971 we built the first machine with a driving power of 170 kW and a power density of approximately 50 kW/m³. To date more than 80 machines of this type have been supplied to Great Britain.

Modern versions of this type are equipped with two mechanically coupled motors in the machine body and separate electric haulage drives. The requirement for a shearer loader which can be installed in seams from approximately 800 mm in thickness and has 300 kW available for the leading drum resulted in the development of this machine. Two electrical 17.5 kW d.c. haulage motors are installed (fig. 11).

Within a period of 14 years it has been possible to double the installed power of the "LN" shearer almost within the same body space.

We are convinced that these 4 basic concepts and their different versions allow for optimum equipment installation in virtually every case. However, the development is certainly not yet completed with the present day. Higher power density will be possible but the emphasis should be on increased reliability, service life and the reduction of maintenance.

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3. **TWO ASPECTS SHOULD BE MENTIONED IN**
   **CONNECTION WITH THIS COMPREHENSIVE**
   **SUBJECT FOR THE FUTURE.**
   - new synthetic lubricants
   - new materials for gear wheels and roller bearings.

In our opinion the basic concept of the shearer loaders for longwall mining will continue to exist in the foreseeable future. However, considerable progress will be made in the development of face end and roadheading equipment. Both areas have proved to be a bottleneck to a certain extent due to the increased face outputs.

Cutting into the new web (fly cut) and other stoppage times at the face ends are potential areas in which the performance can be increased and this has often been neglected. The installation of face end machines - e.g. the "ESA" - represents an attractive solution.

The many roadway headings required for longwall mining have resulted in completely new concepts. Also in this case the shortwall and "ESA" machines could offer a solution (fig. 12).

4. **HIGH OUTPUTS REACHED BY HIGH TRAVELLING SPEEDS AND HIGH HAULAGE PULLS - THE HAULAGE SYSTEM OF THE FUTURE.**

Since the introduction of the Ecotrack system, it has supplied 500 installations worldwide - a number which is self-explanatory.

With the increasing expansion of the "LN" shearsers the face side Ecotrack was developed, an open rack bar which withstands the forces induced by the "LN" shearsers. Lower torques at the normal axis of the shearer loader result in much lower travelling resistances and hence in an optimum utilisation of the haulage capacity (fig. 13).

**Fig. 12** Face Side Ecotrack System and Goal Side Ecotrack System

The requirement for high haulage pulls which are transmitted by the drive wheel onto the rack bar are being met by new materials, new manufacturing methods, and an optimum shaping of the drive wheel and the rack bar. This allows for tackling haulage pulls of 2 x 415 = 830 kN and travelling speeds of.
12 or 15 m/min for the cutting traverse and approximately 22 m/min for the flitting traverse. These speeds exceed the rate at which supports can be moved over at present.

5. MICRO-COMPUTERS, THE KEY TO AUTOMATION AND HIGH PRODUCTIVITY.

Micro-computers reduce the number of electronic units, cables and connections, they increase the operational safety, have a lesser current demand and therefore require only small power supply units. In a considerably reduced building volume they give the possibility for entirely new control, regulation and diagnostic concepts.

With the increasing expansion of the electrical haulage units control, monitoring and diagnosis become easier. Regulation concepts such as the Eicotronik are standard and guarantee an optimum utilization of the machine capacity.

Due to the regulation of the travelling speed, which might lead to stopping and reversal of the machine, the cutting motors always operate at nominal power (fig. 14). The suitability of this concept for remote control and automation has already been proved.

For cutting the roadway in line with the face a profile and alignment control system is used. A laser determines the direction, measuring systems detect the angular and parallel deviations, inclinometers detect the longitudinal and transverse inclinations and angle encoders the position of the ranging arm. The assessment of these measurable variables and the comparison with the nominal values enables the micro-computer to cut the given profile with a precision of 5 cm.

As a further step to automation the height control system has been developed for cutting drums and installed underground. During a recognition traverse the nominal data are acquired and they are then repeated by programmed control. Depending on the conditions on a face it is possible to amend the nominal data partially or
completely by a new recognition traverse. A compensation for the longitudinal and transverse inclinations is integrated as is a step limitation of the cutting height to 5 cm which ensures that the roof supports can be advanced without any problems. Other systems which guide the shearer loader automatically according to the seam line are on trial. The existing systems are based on the measurement of the difference of the natural radioactivity between coal and adjacent strata or on the measurement of the pick force differences when cutting coal or adjacent strata.

Trials carried out in the Federal Republic of Germany have shown that the systems could not be applied individually because the necessary difference in the radioactivity or the rock strength does not always exist.

The research efforts in the Federal Republic of Germany are aimed at the "sensor controlled shearer loader". Not one measuring signal alone but the evaluation of a multi-sensor system determines the values for the automatic height control.

Availabilities of shearer loaders of significantly more than 90% can be reached with diagnosis and maintenance of high standard. Our micro-processor controlled machines have a diagnosis system which allows for selecting measuring points and for comparing nominal and actual values on a clear text display, so that the causes for faults are readily found (fig. 15).

In the case of trouble, the possible causes are assessed in a logical order by means of a trouble shooting program. Remote diagnosis is possible in the same sense as local diagnosis.

The information on the screen of the control station is naturally more complete.

While formerly the maintenance of the machine made it necessary to study a long list, this is now possible at site by means of the micro-processor and the clear text display. The maintenance points are individually indicated and acknowledged by the personnel. Those points which have not been attended to appear as the first ones in the next shift.

![Computer Diagnosis](image)

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6. **Radio Control as a Means of the Machine Control** is now extensively used under normal face conditions (Fig. 16).

The operator can:
- precede or follow the machine
- observe the seam and adjacent strata
- ensure the seam is well ahead of the machine
- make corrections in time
- remain in a relatively dust-free zone
- vary the machine speed to the conditions prevailing at the time in order to reach high productivity.

![Radio Control](image)

**Conclusion**

Longwall coal cutting machines are likely to remain of similar configuration into the 21st century. There is significant room for evolutionary change to:
- cutting elements and drums,
- compactness,
- reliability,
- micro-processor control.

1. Cutting elements and drums have improved significantly with computer aided design and changes in the future will occur due to better understanding of the principles of coal breakage and movement.

2. The opportunity to pack more power into cutting machines will continue. While we have $3.3 \text{ kV}$ machines today in Australia in fairly compact design in the $380-1080 \text{ kW}$ range, changes in voltage and machine design will enable the recent trend to continue.
3. Machine reliability can improve further. While 95% availability has been achieved, more complex machines give rise to the prospect of downtime in the very hostile environment underground. This problem has been noticeable with micro-processor components but is being overcome.

4. Micro-processor control will become more common as systems become more understood and more reliable.

5. Coal cutting machines on longwalls have a demonstrated capacity to at least equal the performance of other elements of a longwall system. In addition, there are clear ways in which further improvement in performance is practicable.

It seems clear at present that, where applicable, retreat longwall systems offer the opportunity for highly productive coal extraction competitive with open-cut operations and as a result these systems will increase their share of overall production in Australia. In these circumstances it is postulated that shearer-loaders will provide the bulk of coal cutting machines for the industry.

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