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The performance of continuous miners in South African collieries*

by D.R. HARDMAN† and J.W. OBERHOLZER‡

SYNOPSIS

Based on information supplied by South African collieries to the Coal Mining Laboratory of the Chamber of Mines since 1978, the paper outlines the general performance of the continuous miners used and gives the results of more-detailed studies of the cutting, loading, and transportation processes.

On average, the continuous miners produced coal at a rate of 76 t per operating hour, which, at an average machine availability of 67 per cent, resulted in a production of 51 t per total hour. The cutting rates varied between 600 and 250 t/h but, owing to machine and system inefficiencies, the overall production rate varied between 92 and 48 t/h.

It is concluded that, if the collieries concentrated on improving their machine utilization procedures and operating practices, they could increase the overall production from their continuous-miner sections.

SAMEVATTING

Die referaat beskryf, aan die hand van inligting wat sedert 1978 deur Suid-Afrikaanse steenkoolmyne aan die Kamer van Mynwese se Steenkoolmynboulaboratorium verstrek is, in hooftrekke die algemene werkverrigting van die aaneendelwers wat gebruik word en gee die resultate van uitvoeriger studies van die sny-, laai- en vervoerprosesse.

The aaneendelwers produseer gemiddeld steenkool teen 'n tempo van 76 t per werkuur, wat teen 'n gemiddelde masjienbeskikbaarheid van 67 persent gelei het tot 'n produksie van 51 t per totale uur. Die snytempo het gewissel tussen 600 en 250 t/h maar weens masjien- en stelselondoeltreffendheid, het die totale produksietempo tussen 92 en 48 t/h gewissel.

Die gevolgtrekking word gemaak dat die steenkoolmyne die totale produksie uit hul aaneendelwerafdelings kan verhoog as hulle hul toespits op die verbetering van hul masjienbenuttingsprosedures en werkpraktyke.

Introduction

Although full-seam cutting machines were used in the early 1960s, the fixed-head drum type of continuous miner started to increase in popularity only from around the mid-1970s. Since then, however, the population has steadily grown from a few machines at one or two collieries to the present figure of about 110 machines spread over 18 collieries. Continuous miners were originally used in situations in which there were particular problems with conventional methods, and the sections were designed round the use of these machines. However, the situation has changed, and the continuous miner is now viewed as just another production unit. The performance of the whole production section depends on a number of factors of which the continuous miner is just one aspect.

During the past eight years, the coal industry has concentrated on investigations aimed at increasing the cutting capacity of the continuous miner. These investigations have included laboratory studies on the forces required to cut various coal seams, and field studies on seam cuttability and the use of an instrumented continuous miner. Machines are now being manufactured that incorporate the findings of these investigations in their design.

Since 1978 the Coal Mining Laboratory of the Chamber of Mines Research Organization has been monitoring the performance of continuous miners in use at South African collieries. The information collected includes statistics on production and breakdowns, and was collated from monthly returns submitted by the collieries. It is inevitable, therefore, that there are errors in the data, and careful checking procedures are required. The information finally obtained is considered to be of most use in the analysis of trends in the usage of continuous miners, rather than in the establishment of detailed performance characteristics.

Important parameters in determining the economic feasibility of a mining system are the expected production of the system and the production per unit time. In the light of this, the Coal Mining Laboratory has, in the past two or three years, focused part of its research effort on determining the factors that influence the productivity of continuous-miner sections. The results of these investigations have shown that there is a large difference between the cutting capacity of a machine and the production rate of a system. So marked is the difference that the losses to production while the machine is operating exceed the losses due to machine downtime.

For easier analysis of systems, the laboratory has established computer programs to simulate the operations of continuous miners in a variety of coal-extraction systems. A diagnostic model that has also been developed enables the user to identify aspects of a section that are

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† Director.
‡ Chief, Field Investigations Division.
Both the above of the Coal Mining Laboratory, Chamber of Mines Research Organization, P.O. Box 91230, Auckland Park, 2006 Transvaal.

detrimental to production.

This paper reviews the performance of continuous miners in general terms, and then gives the results of more-detailed studies of the cutting, loading, and transportation processes of a system.

Population and Application of Continuous Miners

Since the mid 1970s there has been a steady increase in the numbers of continuous miners used on the coal mines (Fig. 1), with a present total of around 110. It is estimated that 75 per cent of these machines can be classified as in use, while the remaining 25 per cent are on standby or being overhauled.

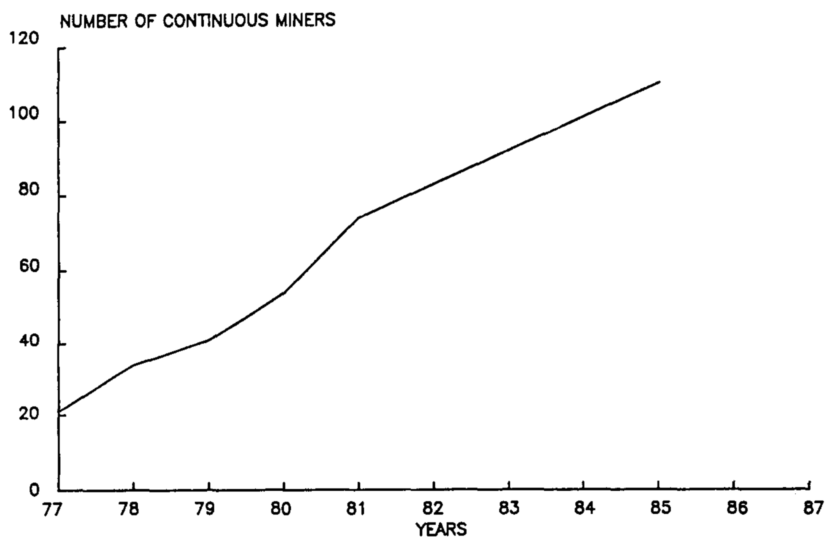


Fig. 1—Growth of the continuous-miner population

Coal produced by continuous miners totals around 30 Mt, which is approximately 20 per cent of the country's total coal production.

The machines are used in a variety of situations as shown by the following list, which gives the approximate distribution according to method of mining:

Bord-and-pillar development	54%
Rib-pillar section	16%
Longwall development	20%
Pillar extraction	10%.

Although most continuous miners are used in seams of medium thickness, say 2 to 3 m, there has been a slight increase in the number of machines in use in thicker seams. The following shows the present distribution of continuous miners in seams of various height ranges:

< 1,5 m	1%
1,5 to 2,4 m	16%
2,4 to 3,0 m	36%
3,0 to 3,4 m	28%
3,4 to 4,2 m	18%
> 4,2 m	1%.

Performance of Continuous Miners

The collieries supply monthly information to the Coal Mining Laboratory regarding the production, breakdown, and pick usage of continuous miners. Since 1978, when this data collection started, approximately 3800 machine months of information have been accumulated. The information supplied provides the main parameters for the determination of machine performance; these are the total hours available, the downtime hours that have an effect on the machine, and the total tonnage produced by the machine during the month. These parameters are used in the calculation of average production rates in terms of tons per total hour, tons per operating hour, and available production time.

Within the data accumulated so far there is a wide spread between the periods for which the mines have been supplying information; that is, some mines have been sending in information for the whole period, but others only for a short time. When the data have been sorted into groups, performance figures for various types of machines are obtained for the mines on which they are used. In the reporting of overall machine performance, the fact that machines have been in operation for different periods is ignored.

The use of monthly figures in the determination of average production rates dampens out the day-to-day fluctuations.

Relation between Total Hours and Operating Hours

Production time is obtained from the computer data set by the subtraction of the downtime from the available section time. Therefore, the relationship between the output per operating time and the output per total time gives the machine availability. The relationship is shown in Fig. 2 for the total machine months recorded in the data set. The average machine availability is 0,671 or 67,1 per cent for all the continuous miners on all the collieries that submitted data.

As would be expected with a large data set of this nature, there is a wide range of values for production rate. Fig. 3 shows tons per total hour and tons per operating hour in the form of a cumulative frequency curve. The values range from zero to 350 t per operating hour, and from zero to 215 t per total hour, with average values of 76 t per operating hour and 51 t per total hour.

Influence of Cutting Height

The sumping part of a cutting cycle by a continuous

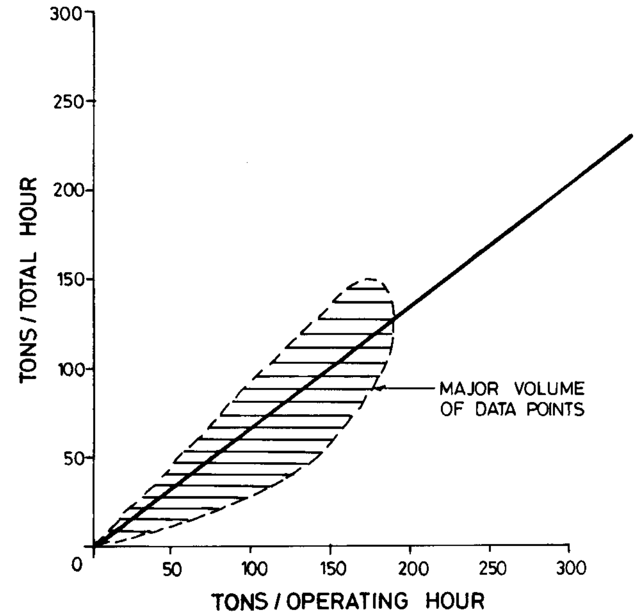


Fig. 2—Relationship between output per total hour and output per operating hour

miner is less productive than the shearing part. Therefore, as the height of the seam increases, the overall cutting rate of the machine should increase because of the increased amount of coal available for shearing. This trend is indicated in Table I, which lists the tons per operating hour and per total hour, and the percentage production time for five ranges of cutting heights. Fig. 4 shows the variation in the tons per operating hour within each height range.

The data show that, within the heights covered, the production rates of continuous miners are far lower at heights below 1,5 m, and far higher at heights above 3,4 m, than the rates obtained for the middle three height ranges. Except for the lowest height range, which has the lowest percentage production time (or machine availability), there is only a slight difference in the percentage time that the machines are available for production.

TABLE I
PERFORMANCE AT DIFFERENT CUTTING HEIGHTS

Height m	No. of machines	Output per operating hour t	Output per total hour t	Production time %
<1,5	1	38	21	60,5
1,5 to 2,4	13	76	52	68,4
2,4 to 3,0	30	85	58	68,4
3,0 to 3,4	23	82	57	72,9
>3,4	15	112	81	73,4

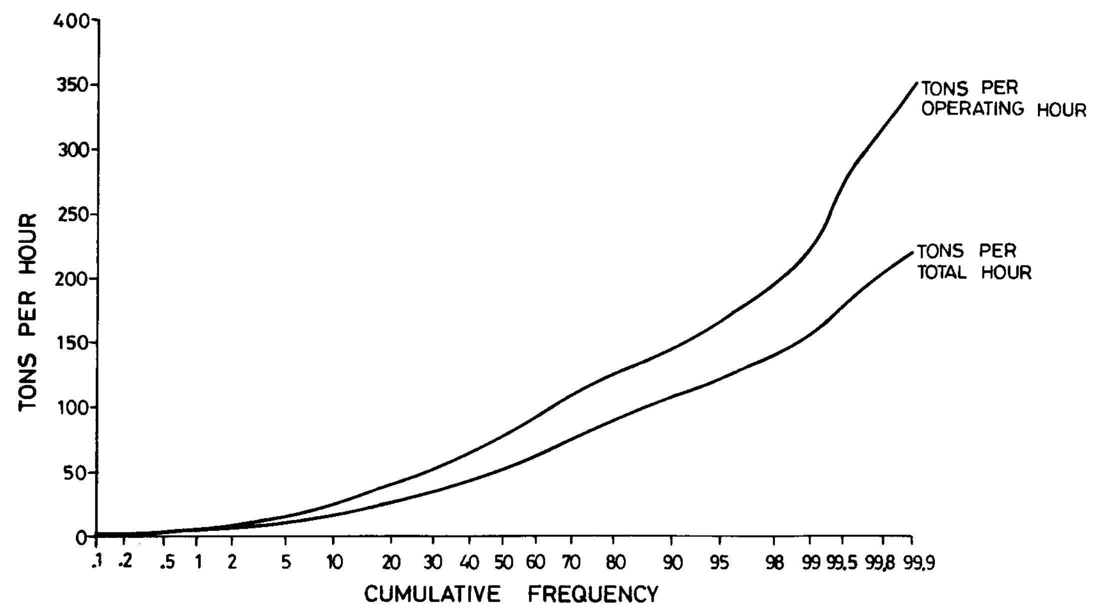
In addition to the variations in sumping and shearing rates, the overall production rate in a low-seam section is adversely affected by the time the continuous miner spends on tramming between faces compared with the time spent on cutting. It is considered that the lower availability of machines working in low seams is indicative of the more arduous conditions under which the machines have both to work and to be repaired.

Comparison of Machines and Collieries

To preserve confidentiality, the identities of collieries and machines in the computer data file are stored in a coded form. For the various capacities of machines at different collieries, Table II lists the average output per operating hour and per total hour, and the percentage production time. The mine codes were allocated on a purely random basis. For the machine codes, the first digit denotes the manufacturer and the second digit denotes the size of the machine, 1 being the smallest capacity. Machines from different manufacturers have been equated on the basis of comparable capacity rather than on physical size, although the former is normally related to the latter. All the machines are of the drum-type continuous miner.

Fig. 5 indicates the range of outputs per operating hour and of production time per month for similar types of machines on two mines. Despite the close similarity between the production rates of machine type 12 used at the two collieries, there is a large difference in produc-

Fig. 3—Range of production rates for all the continuous miners on all the collieries



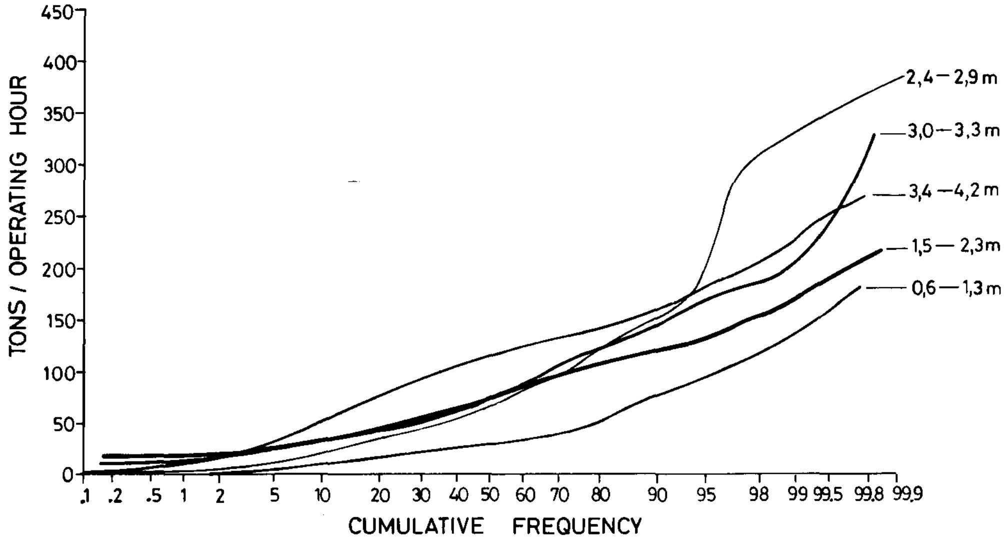


Fig. 4—Range of production rates for continuous miners at different cutting heights

TABLE II
AVERAGE PERFORMANCE OF CONTINUOUS MINERS AT VARIOUS COLLIERIES

Mine code	Machine code	Output per operating hour t	Output per total hour t	Production time %
1	11	72,0	51,9	72,8
1	13	143,2	114,2	80,2
1	12	104,0	77,5	75,7
1	41	136,1	77,4	58,5
1	21	54,6	40,5	74,2
1	32	114,6	84,0	73,4
2	42	85,4	67,7	78,3
2	12	102,4	75,2	76,8
2	32	76,8	52,0	69,7
3	11	57,0	42,0	73,0
4	12	98,7	71,7	73,2
5	12	124,0	104,9	84,5
5	32	56,1	36,2	63,6
6	12	56,6	41,1	72,9
7	12	100,7	69,1	68,4
8	12	77,3	56,3	71,7
9	22	69,2	35,5	54,8
9	12	90,6	54,0	63,3
9	13	84,1	50,1	67,7
10	31	124,7	85,8	69,7
10	12	110,5	81,0	73,6
11	31	49,4	35,2	73,2
11	22	52,2	38,6	75,9
12	12	158,0	117,0	75,1
13	22	67,7	47,8	73,9
14	12	167,7	110,5	66,1
15	12	112,5	94,6	83,8
15	32	92,9	64,7	70,4
16	31	101,0	61,2	60,9
16	11	88,3	65,4	73,4
17	11	106,3	59,3	60,7
17	12	104,6	62,5	61,6

tion rate for machine type 13. In fact, the lower-capacity machine (type 12) on one colliery performs at a higher rate than the higher-capacity machine (type 13) on the other colliery. It can therefore be inferred from Fig. 5 that the former colliery uses its machines more efficiently than the latter. This is confirmed by the graphs of production time per month (machine availability) in Fig. 5, which shows that the two different machines at the one colliery are available for a much higher percentage of the time than similar machines at the other colliery. Given that the physical conditions of the two collieries are similar, the results shown in Fig. 5 confirm that different operational and engineering procedures can greatly influence the performance of a machine.

Fig. 6 shows the variation in tons per operating hour and in production time per month for one type of machine at six different collieries. Fig. 7 shows similar information but for the different machine types averaged over all the collieries in which they are used. It is noticeable in Fig. 7 that, apart from one exception, the production time per month of the various types of machines is very similar.

Comparison of Mining Methods

The available information on the performance of continuous miners in various coal-extraction systems is restricted by the limited application of some of the methods. The results of a study done at one colliery are shown in Table III. The machines in use at this colliery were all of the same basic rated capacity, the management and engineering procedures were consistent, and the seam conditions varied very little. Any variation in the results therefore, particularly the output per operating hour, is due to the mining method, with only minimal external influencing factors.

Cutting Rates of Continuous Miners

The preceding section indicated the average performance and the range of performance of continuous miners from information extracted from a large data set. A large variation in performance is inevitable, but it is interesting to note than on only a few occasions did the production per operating hour exceed 200 t. This value

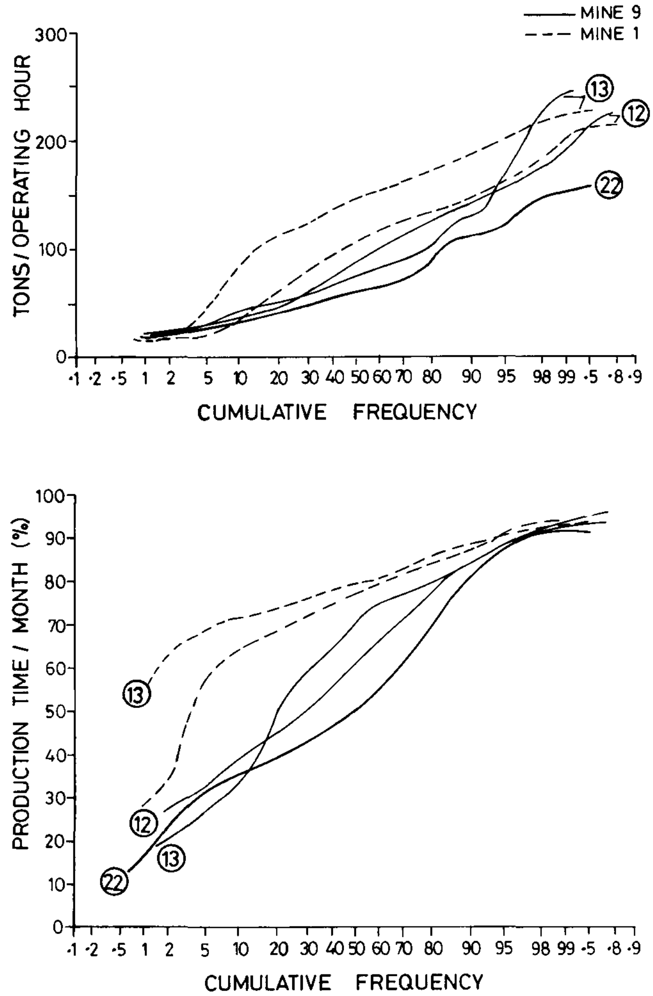


Fig. 5—Performance of two similar continuous miners at two collieries

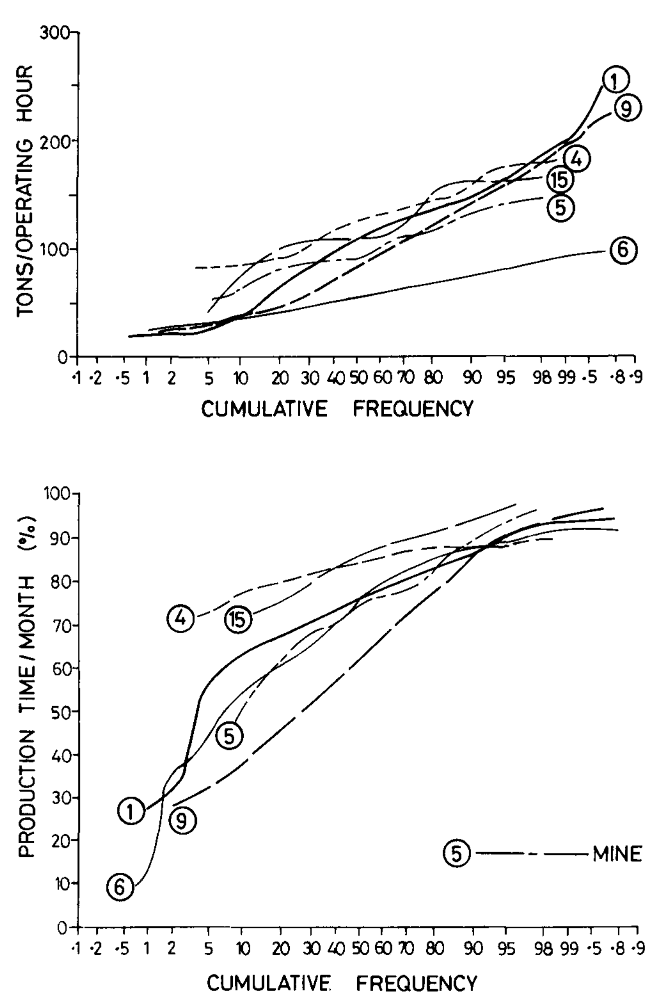


Fig. 6—Performance of continuous miner 12 at six collieries

TABLE III
PERFORMANCE BY MINING METHOD

Development	Production time %	Output per operating hour t	Output per total hour t
Bord-and-pillar	59	82	47
Rib-pillar	78	96	75
Longwall	73	50	33

is, in fact, exceeded in only 5 per cent or less of the total results, indicating that there is a considerable loss in production efficiency between the cutting drum of a continuous miner, which can be rated in excess of 600 t/h, and the section conveyor.

In an attempt to determine where production losses occur, detailed studies were carried out at five different collieries. These studies included, firstly, the determination of the sump and shear cutting rates over a number of cycles by use of a device that automatically records the linear advance of the continuous miner. The weighted average of these two individual rates gives the 'cutting rate'. Secondly, a rate termed the 'face cutting rate' was determined, which includes the less-productive or non-productive elements involved in the stages of trimming floor, raising the boom, and some machine manoeuvring. Thirdly, the output per operating time was derived, which takes cognizance of shuttle-car delays and continuous-miner tramming. Lastly, the overall production rate, in tons per total hour, was obtained, which includes all the delays in the production of coal. The results are shown in Table IV, and graphically in Fig. 8.

It is apparent from these results that the effect of section downtime on production, i.e. the reduction in production rate between the output per operating hour and the output per total hour, is small compared with the other influencing factors.

The difference between the rate of face cutting and the output per operating hour indicates the effect of section geometry on shuttle-car and continuous-miner tramming times. It also includes delays for roof bolting and pick changing, i.e. operational delays throughout the section. The reduction from the cutting rate to the face-cutting rate shows the magnitude of the losses due to inherent machine delays such as those necessitated by floor trimming, boom raising, roof trimming, and machine manoeuvring while a shuttle car is present. The value for face-cutting rate also incorporates operator inefficiencies associated with non-productive periods of the cutting

TABLE IV
COMPARISONS BETWEEN CUTTING AND PRODUCTION RATES

Machine code	Mine code	Height m	Cutting rate t/h Sump	Shear	Total	Face rate t/h	Output per operating hour t	Output per total hour t
12	9	3,1	192	359	282	200	112	75
22	13	2,8	458	713	605	284	68	48
12	10	2,8	231	274	254	154	89	72
12	4	2,8	217	568	394	239	91	69
11	16	1,7	218	441	307	204	108	92

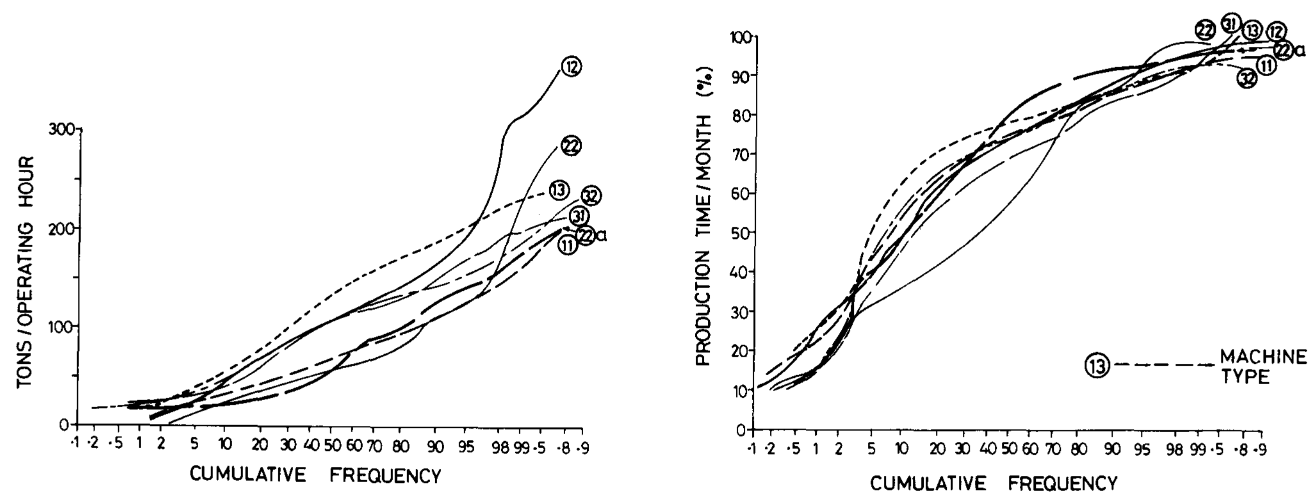


Fig. 7—Average performance of the continuous miners at all the collieries

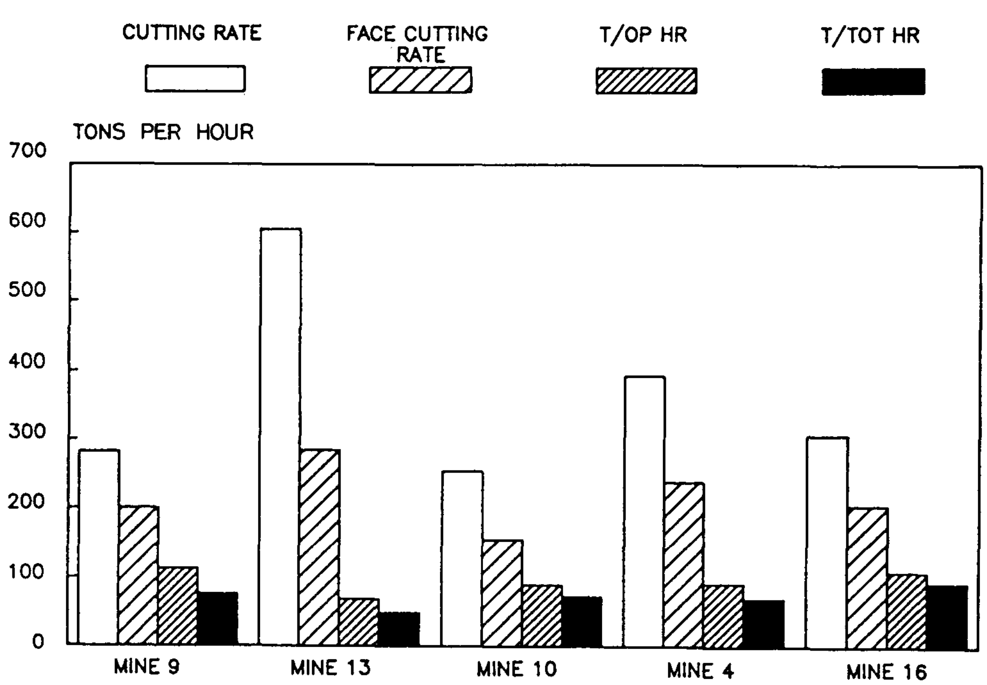


Fig. 8—Results of detailed studies at five collieries

operation.

Although the actual cutting rates are, with one exception, well below the capacity of a continuous miner, it can be seen that, for more coal to be produced, consideration must be given to operational procedures and system layout, and not only to an increase in the cutting rate.

Conclusions

It has been shown that, on average, continuous miners produce coal at a rate of 76 t per operating hour, which, at an average availability of 67 per cent, results in a production of 51 t per total hour.

Specific studies showed that the cutting rates of continuous miners varied between 600 and 250 t/h, but, owing to machine and system inefficiencies, the overall production rate varied only between 92 and 48 t/h. This large difference between the two rates is due mainly to the section designs and machine operating procedures, machine downtime having the least influence. By concentrating on machine utilization procedures and operating practices, coal mines have the potential for increasing the overall production from their continuous-miner sections.

Surface engineering

The Second International Conference on Surface Engineering is to be held in Stratford-upon-Avon (England) from 16th to 19th June, 1987. The topic of the Conference is 'Optimizing the Surface'.

The properties required of a surface are often very different from those required in the bulk of a component or structure, and it is therefore sound economic and technical practice to use materials at the surface that meet the desired surface properties. In some cases, the bulk material itself can be chemically or physically modified at the surface to provide, for example, wear or corrosion resistance without changing the dimensions of the component; in other cases, coatings up to several millimetres thick may be required. Other uncertainties arise when considering which type of coating to use for any given job—often there are several materials available, each differing in formulation, but how can a designer or engineer choose between them? Also, given a particular surface modification or material, which is the best process to use? These, and many other considerations, generate much confusion in the minds of the user, whose ultimate interest is in the performance and life of a surface, but there is no compilation of data or experience to which he can turn to resolve the many conflicting aspects of design implications, materials, processes, specific economics, manufacturing constraints, etc.

This Conference will promote the establishment of the required corpus of knowledge. Whilst it is appreciated that no single conference or publication can cover so enormous a field, the format of an international conference, plus the discussion and interchange of ideas that it generates, is an excellent way to initiate action and to encourage others to work towards the same goal.

The First International Conference on Surface Engineering held in 1985 was an outstanding success due largely to the fact that it brought together papers on a wide range of processes and materials in a manner that allowed some comparisons to be made between them. Equally, however, it demonstrated the increasing demand on the part of the user—the one who ultimately pays—for a consciously directed effort to enlarge upon and formalize those comparisons. Therefore, this Second Conference in the series, again organized by The Welding Institute in collaboration with the Surface Engineering Society, will be aimed at assisting the user to achieve the most suitable form of surface for his particular application.

Progress in the task of tailoring a surface to suit the requirements has been swift and broad in recent years. It is hoped that these developments will be discussed at the Conference in such a way as to enable them to be compared with more traditional approaches, thus providing up-to-date and comprehensive information that will enable the user to achieve his objectives.

The following topics will be addressed at the Conference:

- Surface properties
  - —consideration of surface characteristics required to meet service performance
  - —optical, magnetic, mechanical, and frictional properties
  - —wear/corrosion properties
  - —electrical or thermal resistance/conductivity
- Comparison of materials
  - —chemical, physical, metallurgical modifications
  - —metals, ceramics, plastics, composites
- Comparison of processes
  - —surface modification
  - —thin-film and coating techniques
  - —thick coatings and cladding
  - —pre- and post-treatment
  - —testing
- Economics of surface engineering
  - —capital and running costs
  - —recovery and reclamation
  - —implications for component design
  - —implications for the whole system
- New materials and processes
  - —to include a comparison with those existing
- Future trends.

The main emphasis will be on giving the user and the designer a means of looking at the overall picture of surface engineering, and to assist them in choosing the best combination of materials and processes to suit the particular set of circumstances.

Further information is available from

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