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A Review of Computer Simulation and Other Programs Developed and Used by the Coal Mining Laboratory, Chamber of Mines Research Organization

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The use of computers in the South African coal mining industry has increased during the 1980s. Applications at mine level commenced in the financial and personnel areas of payroll systems, mine accounting procedures and staff record keeping. More use is made now on mines of technical programs for purposes such as mine planning and mine survey calculations.

The Coal Mining Laboratory of the Chamber of Mines Research Organization has provided, for a number of years, a service to Chamber member collieries in regard to the application of technical computer programs. Programs presently in use for simulating production procedures and conveyor belt transport systems are described. In addition, reference is made to the collection, storage and analysis of data concerning the performance of continuous miners over a period of eight years. More recently a computer program for the simulation of the cutting action of continuous miner cutting drums has been developed. The use of this program to assist with drum design is explained.

The fact that many requests to make use of the programs are received from collieries is an indication of their acceptance by industry. Their interest in running the programs themselves on their own desktop computers has led to the need to convert the software for microcomputers.

Introduction

Colliery management is subject to continual demands to increase the productivity from underground sections. To counter the effects of rising costs and to remain competitive in the international coal markets higher rates of mining and better utilization of resources are called for.

Over the past ten years the South African coal mining industry has experienced significant growth. This growth was accompanied by the introduction of new types of mining methods. The mining industry not only increased in size but also became significantly more complex in nature. These new methods like longwall mining and the use of continuous miners have created the need for powerful and effective planning and control procedures to assist mine managements.

The Coal Mining Laboratory of the Chamber of Mines, as part of its research programme, is involved in devising ways to increase the production from mining sections. Computers play a significant role in this effort to improve productivity by helping to compare the effectiveness of the various mining methods and identifying the best.

Large computer-based data bases have been established to monitor the production from continuous miners and simulation programs have been used to predict and assess the

production potential from various mining layouts and belt conveyor systems. Programs to evaluate support methods as well as to design ventilation and water flow networks are also used.

In 1973 when the Research Organization started using computers to help solve problems the majority of programs were derived from sources outside the Research Organization. As time progressed, it was realized that these programs could not adequately cater for a rapidly changing and more complex mining situation. Consequently these were updated or rewritten to suit South African mining conditions. In this way, the programs that are in use now at the Coal Mining Laboratory, have been made into more useful tools by being user-friendly and by having the power and speed to be of direct use in solving real mining problems.

These programs can be classified into three basic groups

1) databank of historical data;
2) simulation programs for planning, design or control purposes;
3) programs as tools for planning or management control.

Historical data

Since the mid-1970s the number of contin-uous miners in use in South African collieries has increased significantly. To monitor the production from these machines a program of regular data collection was initiated in 1978 and the information was stored in a computerized databank.

During the eight years of data collection a total of over 6 000 machine months of information have been gathered and assessed. This data base allowed regular reports to be issued to the industry identifying various shortcomings in the machines which allowed the manufacturers to design machines more suited to South African conditions.

By comparing the historical production figures to the machine capacities it became evident that in the latter years factors other than machine capacity and machine availability were responsible for production losses. This finding was investigated by using the various simulation programs, and it was concluded that the method of operation was the determinant of a mining section's output rather than other factors such as machine breakdown time.

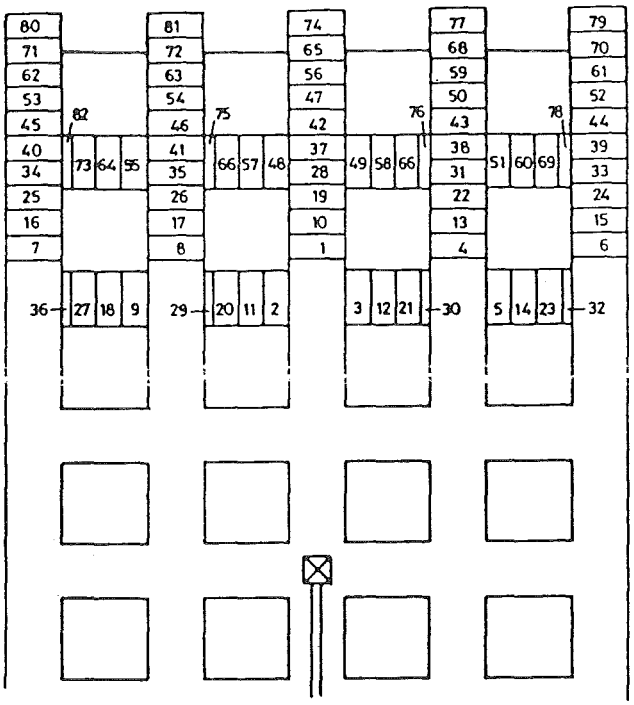
Simulation programs

Section production

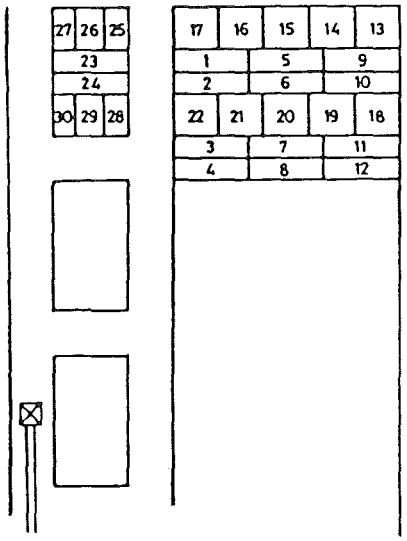
In 1973 the Chamber of Mines acquired the FACESIM program devised by Virginia Polytechnic Institute for simulating the production from a conventional mechanized bord and pillar section. However with the change in mining methods which was occurring at about that time the need for a more user friendly and more adaptable program became evident. In 1984 a suite of programs was developed that catered for the types of sections employed in the majority of South African mines. This COMSIM suite had a cut generating program as the basis and could simulate both drill and blast and continuous miner bord and pillar workings as well as stooping and rib pillar mining.
(Examples of cut sequences for these section types are given in Figure 1.)

The programs are easy to use and all input can be entered from the keyboard. Up to 20 different section layouts could be entered into the computer and assessed within eight hours.

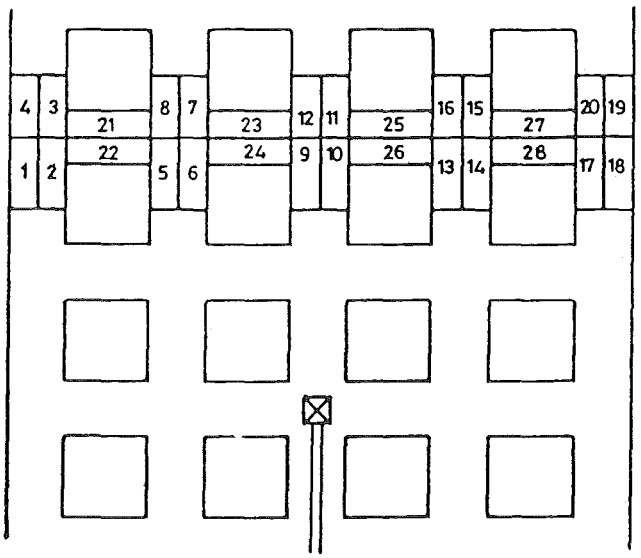
As the simulation programs cannot incorporate the cutting action of the continuous miner the need for a more comprehensive modelling method arose. During 1985 a deterministic model was developed which incorporated all the mining procedures in



Bord and pillar mechanized drill and blast



Ribpillar layout



Bord and pillar using continuous miners

FIGURE 1. Diagrams showing examples of theoretical cutting sequences generated by the COMSIM program

a continuous miner section. Use of this model indicated the importance of the coal transport system in the coal extraction process. Further work using the COMSIM suite showed how section output could be increased. This was done by using the principle of increasing only the section transport capacity with more effective mining layouts.

By decreasing the travelling distance of the shuttlecars some alternate methods of operating a section have been devised.

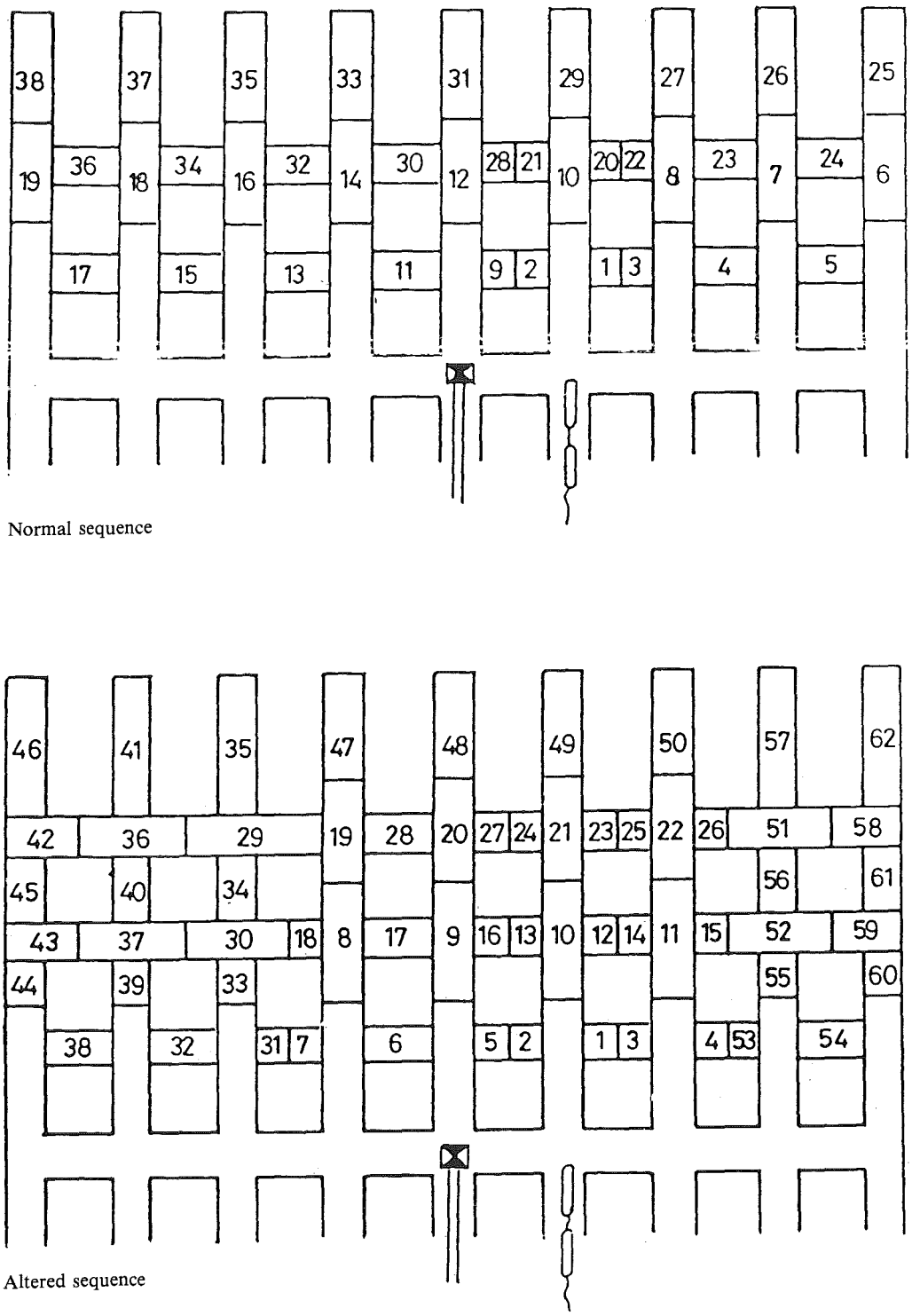


FIGURE 2. Diagram of cutting sequences comparing a normal sequence with an altered sequence

(Figure 2 compares the changed sequence with a normal sequence for a similar section layout.) In this example the basic layout of the section, as determined by strata control considerations, has not been altered nor has any increase in equipment or personnel been required. The change is in the sequence of cutting with the middle part of the section now being extracted first and followed by the sides of the section.

In this way the tonnage per km of shuttle-car travel has increased from 63,6 t/km to

100,9 t/km. A 13% increase in production was predicted by the computer when this method was used and results of an initial underground study of this method corroborated the findings.

By using the programs it can easily be shown that keeping the number of roadways to a minimum is more beneficial to production in a continuous miner section than having a large number of roadways.

The use of this program has led to mines using it to increase their section production without any additional capital expenditure. The program has been so successful in its application that the demand from the mines has necessitated a personal computer version for distribution to the mines. It is foreseen that this latest program will be available to the industry before the end of the year.

Conveyor belts

Another aspect of coal mining that has been catered for in the simulation programs is the conveyor belt system. A belt system is the most common means of transporting coal out of a mine and is the ultimate determinant of the mine output capacity.

With the need for higher production, conveyor belt systems have been subjected to increased loads often greater than the original designed capacity. In many instances to increase the capacity of belts after they have been installed proves to be highly expensive. It is therefore important that belts be designed to cater for the present as well as future requirements. However, to have under-utilized capacity in the belt system is also an expensive exercise that can affect the profitability of the operation. In practice it has been found that it is not the incidences of continual overloaded belts that cause the problems but rather the accumulation and distribution of short period peaks that are the causes of belt system overloads.

A new BELTSIM program was written to enable mine management to design an optimum belt system in terms of both utilization efficiency and flexibility which will accommodate future alterations. It uses the principle of combining the flows of coal from the various sections. These flows of coal are represented by flowrate profiles which can be determined from underground observations but can, in the case of a mine that has not been established, be predicted by using one of the COMSIM suite of programs.

BELTSIM is aimed at giving the user a more representative output in terms of what really happens in a mine. In practice, the joining together of coal streams should not result in continued periods of spillage. The presence of automatic detection devices or a manual conveyor attendant should result in the stopping of spillage, or belt overloading. The program reacts in exactly the same way, simulating the real life situation by stopping the belts, and thus showing the effects of design problems in the form of production losses.

This program is being used by the planners of new mines to design their belt systems and to determine the size of the underground bunkers required to remove the peaks in the coal flow. In addition the program is being applied to existing mines to resolve problems with existing belt systems and to diagnose the case so as to formulate the best solution. As with the COMSIM suite this program will shortly be available in a form so that it can be used on a personal computer by mining personnel.

Cutting drums

Another area which is currently being investigated at the Coal Mining Laboratory

is that of the simulation of the cutting drum of a continuous miner, longwall shearer or other similar machine which operates by cutting coal from the face by the use of rotating picks. This program predicts the pattern to which a particular cutting drum design cuts the coal face, the average force levels which are generated during cutting, and the cyclic force levels generated. The name given to this program is CUTSIM.

The CUTSIM program has proved useful as a diagnostic tool where problems on current cutting drums have been assessed, as a design tool to create new cutting drum lacings, and as an educational tool for mining machine operators. The effect of running a machine with varying conditions of cutting elements can be clearly illustrated. A

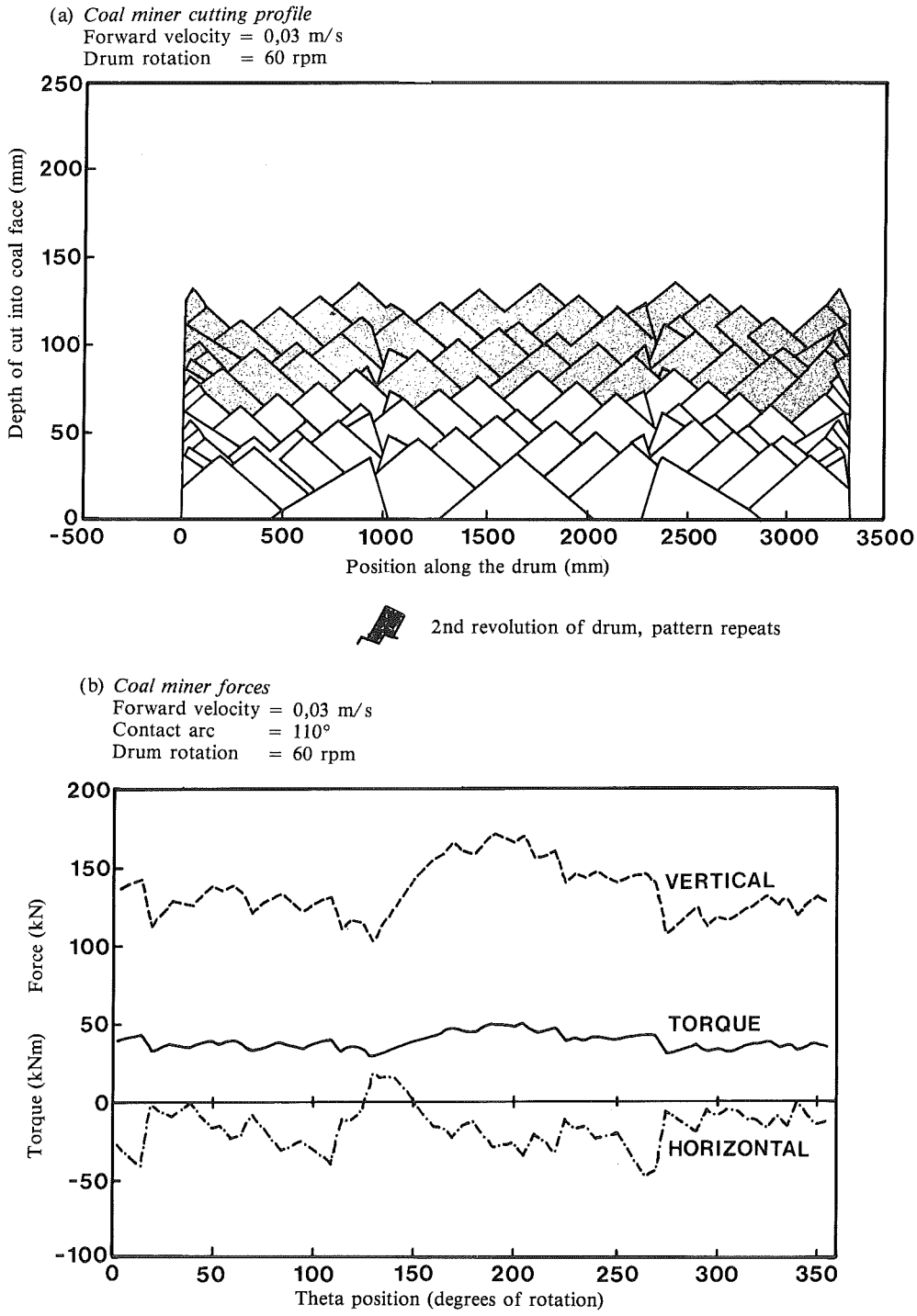


FIGURE 3: Profiles of a manually designed continuous miner cutting drum

further area of application for CUTSIM has been the determination of the effects on continuous miner performance of using worn picks. It has long been known that cutting with worn picks has a deleterious effect on machine performance in terms of mining rate, product size and machine vibration. The vibration can lead to increased downtime. CUTSIM has proved ideal to perform the fundamental studies needed to quantify these effects.

An example of the use of CUTSIM in predicting the cutting pattern and the forces developed by two different cutting configurations is given in Figures 3 and 4. The cutting pattern shown in Figure 3(a) covers two revolutions of a continuous minor cutting drum as the drum moves forward cutting

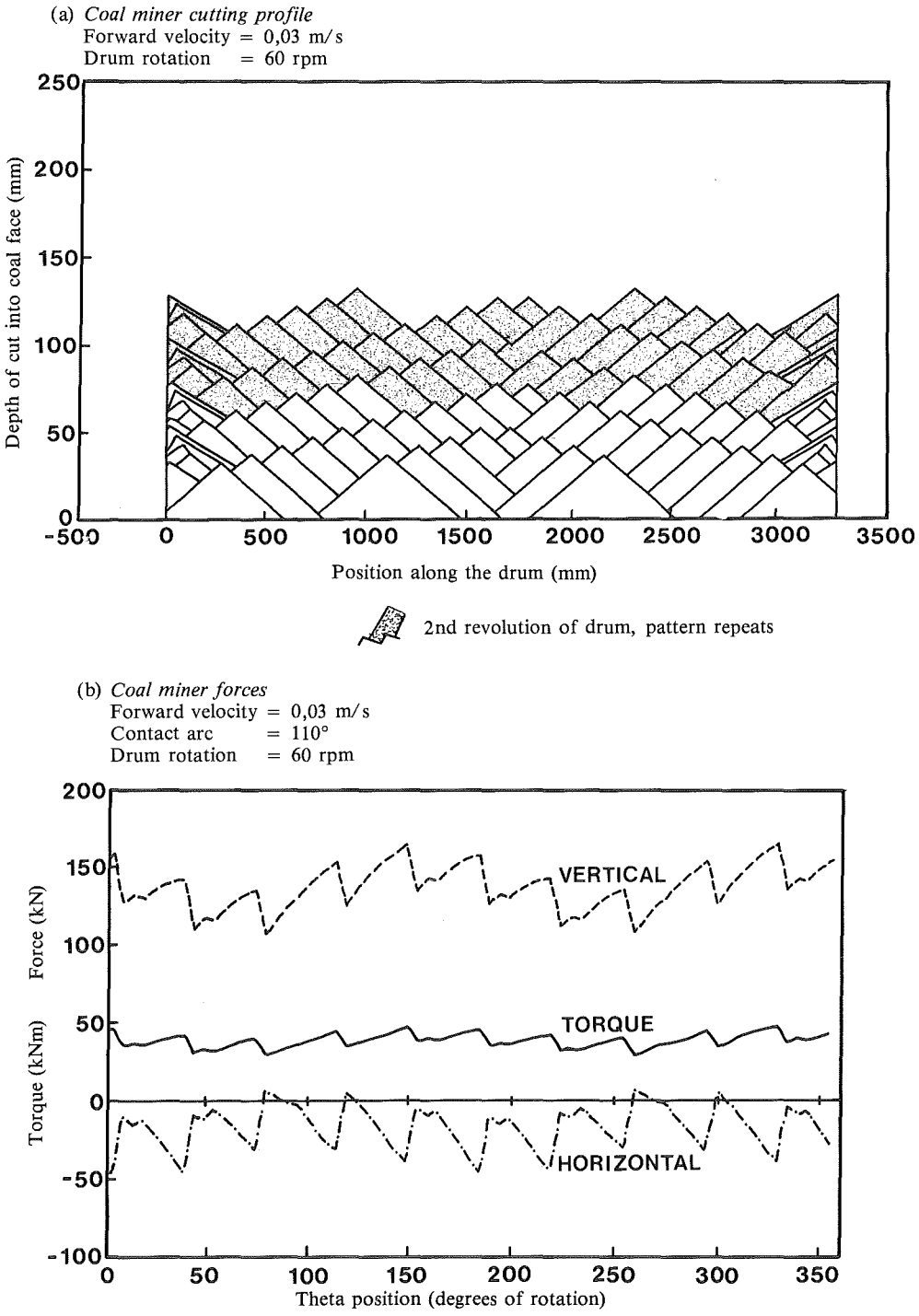


FIGURE 4. Profiles of an adapted continuous miner cutting drum

through the coal. Each rectangle, or triangle, represents a pick position of the cutting drum and the area of the rectangle, or triangle is indicative of the amount of coal cut by each pick. The large variation in the areas of the rectangles, or triangles, in Figure 3(a) shows that some picks are cutting far more coal than others which will also result in large variation in individual pick cutting forces. The total forces experienced by the drum when cutting according to the pattern shown in Figure 3(b). Figure 3 was derived from a 'manually' designed cutting drum and for comparison Figure 4 shows the results from a CUTSIM designed drum. Figure 4(a) indicates that there is a more even distribution of coal cut by each pick and Figure 4(b) shows a smaller variation in forces experienced in the cutting drum. Similar programs have been developed by other organizations in recent years but the ability to simulate a full continuous miner drum necessitated the writing of CUTSIM at the Chamber of Mines.

Future applications

The final factor in deciding between various mining methods is the cost. However because of the complexity and size of a mine planning exercise more than one design should be considered. The evaluation of a number of design alternatives becomes onerous in terms of time and cost when the exercise is done on a manual basis.

To assist the mining industry, a program is presently being developed that will enable the costs of any mining section to be determined in a quick and accurate manner. This program will not only incorporate all the costing aspects but will also allow various key efficiency factors to be obtained.

The effect of costs of various production levels will also be incorporated. This will allow the user to do sensitivity analyses to determine those factors to which his particular operation is the most sensitive. Once this program is in operation it is foreseen that a significant input to increasing the profitability of collieries can be made.

Conclusion

In establishing these computer programs the Coal Mining Laboratory is assisting the collieries in their effort to increase productivity. Use of these computer based tools allows mine management to make more accurate predictions as well as to allow them to investigate a greater number of options than has previously been possible.

The use of these programs assists mines in times when benefits are not only scarce but difficult to obtain form the more traditional sources.