A METHOD OF ASSESSING THE EFFICIENCY OF POWERED SUPPORTS IN SERVICE

By

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ABSTRACT

The paper describes a system for providing mine management with a continuous indication of the effectiveness of longwall coalface powered supports in controlling roof-to-floor convergence.

The system comprises on-face instrumentation monitoring convergence and support leg circuit pressures, a means of transmitting the output of that instrumentation to the surface for collection, and software which presents both a condensed analysis for rapid review of the current state, and extended analyses from which remedial action can be recommended if a problem is identified.

The results of a field trial are presented showing that meaningful results can be obtained.

INTRODUCTION

The increase in productivity of the longwall coalface can in part be attributed to advances in powered support technology, e.g. the absorption of lateral forces with lemniscate linkages, giving greater mechanical reliability, the provision of more roof cover and anti-flushing shields, and the total or partial automation of support advancing.

The result of many of the technological advances is the removal of the miner from exposure to the surrounding strata. While this is beneficial from a safety point of view, it makes it more difficult for him to "read" prevailing conditions and initiate remedial action if strata control begins to deteriorate. Indeed, it can be argued that there is generally little routine indication given to management of the swing in effectiveness of the supports in controlling the roof between the extremes of good roof conditions, and therefore unhindered production, and bad roof conditions with an attendant reduction in production.

This paper presents a system designed to provide such a routine indication. The basis of the system is a realistic appreciation of the manner in which a support develops reaction to roof-to-floor convergence, tempered with the realisation that management will only have time to review data presented in summary form. That data must be capable however of being "opened out" when a deterioration in support effectiveness is detected so that appropriate remedial action can be recommended.

THE USE OF PRESSURE AND CONVERGENCE MEASUREMENTS IN ASSESSING POWERED SUPPORT EFFICIENCY

The main function of the powered support is to control convergence between roof and floor of the longwall face. The force developed to resist this convergence consists of two components, viz an "active" component developed at the time of setting via the application of a setting pressure to the legs, and a "passive" component developed after isolation of the legs as they absorb convergence. The rate of development of the passive component has a theoretical and ideal maximum value per leg determined by the compressibility of the fluid column. This can be expressed in terms of pressure developed per unit convergence or as a pressure/convergence ratio. (Smart and Issac, 1982, Smart and Aki, 1986) The actual value of pressure/convergence ratio per leg will be less than the theoretical maximum as some of the convergence is usually dissipated as compaction of debris or penetration of roof and floor above and below the support. The pressures within the legs continue to be driven upward until a maximum value, the Yield Pressure, governed by the leg circuit yield valve is reached.

Setting Pressures and Yield Pressures are related along with the support fabrications to provide the development of forces thought to be necessary to control the convergence between roof and floor during the production cycle. Theoretical (and ideal) variation of leg circuit pressure (and hence force) during a typical production cycle is shown in Fig. 1 against convergence. Also shown in Fig. 1 is an example of the actual variation of pressure against convergence. Note that the designed Setting and Yield Pressures are not achieved, and that the pressure/convergence ratio exhibited between

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setting and yield is considerably less than the theoretical value. The net result of these deviations from the ideal is that the support system does not develop forces required to control convergence as quickly as it might.

The simplest way to quantify the deviation from the ideal, or "dissipation" of support development as it has been called, is to compare the areas under theoretical and actual curves. Thus:

\[
\text{\% Dissipation} = \frac{\text{Area under theoretical curve}}{\text{Area under actual curve}} \times 100 \quad (1)
\]

Alternatively, the efficiency of the support system in development convergence—controlling force may be determined thus:

\[
\text{\% Efficiency} = 100 - \text{\% Dissipation} \quad (2)
\]

This approach leads to general criteria for the relationship between support efficiency and roof to floor convergence, i.e. strata control, giving guidelines for both short and long-term support management decisions. The criteria are:

1. If a support system is used at the maximum practical efficiency (typically 75%) and strata control is good, then it is likely that the support system rating (and cost) has been optimized.
2. If strata control is good and efficiencies are low then the support system may be over-rated for the prevailing conditions.
3. If strata control is bad and support efficiencies are low, then strata control can be enhanced by improving the support efficiencies.
4. If strata control is bad and support efficiencies are high then the system is under-rated or poorly configured.

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Accepting that management should attempt to maximise support efficiencies and given that extracted section, convergence between roof and floor and support leg pressures require to be monitored for the measurement of support system efficiency, a more detailed analysis of the data enable the provision of the following more specific information to guide management toward their objectives:

The influence of setting pressure, pressure convergence ration and yield pressures on support efficiency

Under-achieving of setting pressures and hence a lowering of support efficiency can be caused by the inadequacy of the supply system, incorrect manual operation of control valves or faulty automatic setting systems. A low pressure/convergence ratio can be due to excessive accumulations of debris above and below the supports, or leaks in the leg circuits. This will again reduce support efficiency. Yield pressures achieved may be below or above the specified Yield Pressures. The lower Yield Pressures will detract from support system efficiency, while the higher Yield Pressures may initiate structural damage in the support legs and fabrications.

Roof-to-floor convergence per cycle and weightings

On faces liable to periodic caving, increase of measured convergence rates above or below an acceptable norm may give indications of the onset of weightings. Allowing management to instigate appropriate emergency procedures, e.g. “cutting through” the weighting. Extracted height and horizon control

A cycle by cycle record of extracted height can be used to examine the consistency of horizon control and ensure that the support system is operating within its designed range. Deviation of the production cycle and the rate of face advance

While the primary interest is from a production performance point of view, rate of face advance may influence strata control, high rates being beneficial in weak roof conditions, and possibly detrimental in geological conditions which tend to exhibit a periodicity in caving.

SYSTEM REQUIREMENTS

It was envisaged that the instrumentation required to implement this approach in a routine manner on a longwall face would be:

1. Pressure transducers on all leg circuits.
2. Pressure transducers on hydraulic supply lines.
3. Self-advancing convergence transducers at five points along the face.

All transducers to be scanned at a maximum of 4 minute intervals, with ideally a resolution of 12 bits. Data to be transmitted to the surface in a raw or condensed state depending on location of computing power.

The major innovations required were the self-advancing convergence transducer, data collection and transmission systems, and data-processing software.

An opportunity arose to bring all elements of the system together to monitor support system performance on C4 face, Wistow Colliery, by supplementing an installation monitoring support leg pressures and closures in order to provide an early warning of “weightings”.

THE "BOLT-ON" SELF ADVANCING CONVERGENCE TRANSUCER

Development of this device was fundamental to the success of the project, the "bolt-on" qualification obviating the need to modify support fabrications. A photograph of the prototype device mounted on a 4x200 T support in the laboratory is shown in Fig. 2.

A "roof cam" was mounted on a spindle which was clamped to the underside of the canopy. An upward force was applied to the roof cam by a gas spring acting on a lever attached to the spindle. The roof cam contacted the clean roof in between support canopies, avoiding any accumulation of debris above the support canopies. Similarly a "floor cam" was mounted on the base and a downward force applied using a gas spring. The downward force was thought to be sufficient to cause the floor cam to cut through loose floor debris with a lump size up to 100 mm and contact the competent floor underneath.

A telescopic strut was slung between the canopies and equipped internally with a wire-driven displacement transducer. Aligned as near as possible to the contact points of the cans on roof and floor, the output from the displacement transducer therefore provided a measure of the distance (and changes) between clean roof and competent floor.

Mounted on the supports in this manner, the transducer was obviously advanced with the support, although buffers had to be provided ahead of and behind the roof cam to prevent the gap between adjacent canopies closing sufficiently to trap the cam.

A scaled-up version of the device shown in Fig. 2 was produced to fit the 4x650 T supports installed on C4’s face at Wistow Colliery. Due to the weight of the large floor cam the lower gas spring was eliminated, while the upper gas spring bearing on the roof cam was replaced with a conventional coiled spring working in tension.

DATA COLLECTION, TRANSMISSION AND PROCESSING

The MINLOG System (Bigby, 1988) was used to collect data and transmit it to the surface. A schematic of the system is shown in Fig. 3. The transducers listed in Table 1 were installed on C4’s face, the spread of supports being selected to cover the central region of the face i.e. the...
region most liable to exhibit weightings.

The transducers were conditioned by an interface unit from MEDE Underground Monitoring System (Bigby and Cocker, 1982), the analogue output being fed into an ostation of the MINOS Environmental Monitoring System, where they were converted to 10 bit digital code for transmission to the MINOS primary computer on the surface. Therefore the raw data was displayed on a MINOS screen, and an IBM XT microcomputer processed and stored the data at 1 minute intervals, deriving convergence rates to give an indication of its screen of "weightings" according to the following criteria.

Provided the leg circuit pressure was greater than 35 MPa, no support reset occurred during the period being examined and the data was within range, then a WARNING would be flagged for a convergence rate greater than 5 mm/hr, but less than 10 mm/hr. An ALARM would be flagged for convergence rates greater than or equal to 10 mm/hr. Supplementary codes were also produced, a complete list being given in Table 2.

Periodically, data was transferred to a second microcomputer by floppy disc, and further processing and analysis performed using a version of the software written originally to process data logged directly on tape by the MEDE Underground Monitoring System. The software, called NDEP, provided both numerical and graphical access to the data.

The numerical option enabled the data converted to engineering units to be output to either the WU or printer. The number of scans and channels could be selected. Alternatively the output of analyses performed by algorithms on the data could be output as shown in Table 3. Due to the extended time taken to approach the high pressure positive setting limit, an attempt was made to divide each cycle into the three phases given in Table 3. This was done manually using the cursor and the graphics option described below. Three distinct phases were not
always obvious however, especially in the short-duration cycles.

A comprehensive graphics package was also provided. One or two graphs, each with 4 channels plotted against time, could be produced in A4 format. The scaling of the X axis was controlled by specifying the number of scans to be plotted, while the upper and lower limits of the Y axis scale could be selected manually. An example of this type of graph is shown in Fig. 4.

A blocking out facility was also provided in one application of this facility, the cursor being used to select the start and end of a range of scans which were of particular interest. The graphs could then be re-drawn enlarged by specifying this range to fill the X axis.

In a second application, the cursor was used to manually denote the scan numbers at the beginning and end of production cycles and phases obvious on leg circuit pressure versus time graphs. The "key" scan numbers were then stored and used by the algorithms referred to above.

In a third application the cursor could be used to select two scans of a parameter and the software would determine the average rate of change of that parameter.

Graphs of up to four channels could also be plotted against time showing the codes attributed by the MINLOG software, as in Fig. 5.

Finally graphs could be provided of the theoretical and actual relationships between pressure and convergence for any identified production cycle from the beginning of phase 1, as shown in Fig. 6.

Thus a data analysis facility was established which, via MINLOG software, provided management with immediate warnings or alarms with regard to weightings and, via MINAP software, provided almost immediate information regarding the utilisation of a small but representative number of supports.

**ANALYSIS OF RESULTS FROM CA’S**

This analysis is confined to results obtained at the face advanced from 60 m to 130 m from the start position, this being the operational life of the installation within the time span of the contract on which the instrumentation was developed. (Smart et al., 1987) While an early persistent problem with data acquisition was encountered, the installation provided sufficient information to demonstrate the value and feasibility of the approach to optimising support system utilisation.

**Support efficiency and configuration**

The abnormal long time taken to reach the high pressure positive set limit complicated the relationship between pressure and convergence. The distance between roof and floor increased during this first phase, giving negative pressure/convergence ratio. During phases 2 and 3 the pressure/convergence ratios generally reversed to positive values.

Theoretical and actual pressure/convergence relationships could only be compared to determine support efficiency from the beginning of phase 2. Due to fines compaction by the high support densities achieved by this time, the actual and theoretical pressure/convergence ratios were comparable, giving high efficiency values for the front legs, e.g. 89% for Fig. 6.

Support setting time could be significantly improved in such cycles by increasing the rating of beyond the 8 gal/min to at least 24 gal/min. A second factor could have contributed to the delay in achieving the designed setting pressure. The roof, especially toward the rear of the support, was often incapable of withstanding the setting loads being imposed on it. The canopy tended to gradually penetrate the roof, allowing the legs to extend and absorb high-pressure positive set fluid.

This could be alleviated by dropping the designed setting pressure on all legs to a value that the broken roof towards the rear of the canopy could carry, or by compromising and dropping the setting pressure in the back legs only, leaving the forward legs to react through the canopy on the more competent roof strata nearer to the face.

**Roof-to-floor convergence per cycle (Weightings)**

There was no evidence of weightings, although convergence at the centre of the faceline may have followed a cyclic pattern, ranging from 5 mm to 25 mm per production cycle.
Table 3: Example of processed data.

<table>
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<tr>
<th>Data File</th>
<th>Cycle Time</th>
<th>Min P</th>
<th>Max P</th>
<th>Height (ft)</th>
<th>Clogr</th>
<th>Dug Rate (min)</th>
<th>PC ratio</th>
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<td>459.0</td>
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<td>0.44</td>
<td>0.93</td>
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Fig. 4 - Plot of multiple graphs vs. time.

Fig. 5 - Plot of graph vs. time with MINLOG codes.

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Fig. 6 – Typical pressure/convergence relationship, CL’s Wistow.

Extracted height/horizoncontrol

The self-advancing convergence transducer
showed there to be a variation of 0.3 m in the
nominal extracted height of 2.1 m.

Support ratio

The high outputs and the lack of any
weightings suggest that the support ratio was
at least adequate for the prevailing geological
conditions over the face advance reported. The
supports were not used as conventional 650 T
supports with a 80T set to yield ratio however,
due to the extended time generally required to
achieve the high pressure set.

CONCLUSIONS

The self-advancing convergence transducer
performed well. Given that it was a bolt-on
fitting and survived ultimately for a total face
advance of 600 m with minimal servicing, the
success of a device which exploits fixing points
designed into the support fabrications is even
more assured, especially as the most difficult
task was to fix buffers to prevent the roof can
being pinched between adjacent supports.

Some further attention must be given to the
downward loading of the can however. The Wistow
can was so heavy that its weight alone was
thought to be sufficient to keep it in contact
with the competent floor horizon. There were
occasions however when comparatively large
pieces of debris (150x70x70 mm) defeated this
action.

The facility to transmit data to the
surface for processing and interpretation has
produced meaningful information re support
utilisation and configuration, that information
being made available in a condensed form for
rapid scanning by management and in more
detailed forms for analysis on the
identification of a problem.

Most encouraging of all, management was
receptive to data which provided an otherwise
absent indication of the effectiveness of their
longwall powered supports.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the
financial support provided by British Coal and
the European Coal and Steel Commission for the
work presented in this paper. The assistance of
the management and men at Wistow Colliery is
recognised, as is the permission given by
British Coal to publish the paper.

The views expressed are those of the
authors and not necessarily those of British
Coal.

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