*.

MAINTENANCE MANAGEMENT BY THE APPLICATION OF MACHINE HEALTH MONITORING WITHIN THE U.K. MINING INDUSTRY

İNGİLİZ MADENCİLİK ENDÜSTRİSİNDE MAKİNA SAĞLIĞI KONTROLLARINI UYGULAYARAK MAKİNA BAKIMI YÖNETİMİ

Michael John RICHARDS(*)
Bilhan ELMACK*)

ÖZET

Bu bildiri, İngiliz madencilik endüstrisinde makina sağlığı kontrollarını esas alarak makina bakımı yönetiminin ana hatlarını açıklamaktadır. Bu genel başlık altında ocaklardaki mühendislik organizasyonu, makina sağlığı kontrollarının ana amaçları, ocaklarda ve bölgesel laboratuvarlarda kullanılan başlıca kontrol teknikleri sunulmuştur. Bu bildirinin yazarlarınca laser ışınlarının parçacıklardan saparak dağılması prensibine dayanarak geliştirilen, dişli kutusu elementlerinden aşınmış ferritik parçacıkların boyut dağılımı analizi, Nottingham Bölgesi Thoresby Ocağı'da gerçekleştirilen bir örnek çalışma ile sunulmuştur.

ABSTRACT

This paper outlines maintenance management by means of machine health monitoring within the O.K. mining industry. Under this general concept the technical management organisation of a colliery, objectives of the machine health monitoring and routine condition monitoring techniques used at collieries and Regional Laboratories are presented. A machine health monitoring technique called particle size distribution of ferrous wear debris by means of laser beam diffraction which has been developed by authors is explained together with a case study from the Thoresby Colliery of British Coal Nottinghamshire Area, O.K.

(*) B.Sc, Ph.D., C. Eng., H.I.Min.E., Lecturer;

(**) B.Sc, (Mech. Eng.), The University of Nottingham, Dept. of Mining Eng., University Park, Nottingham, NG7 2RD, England.

1. INTRODUCTION

Since the 1970's Headquarters Technical Department of British Coal (HQTD, formerly known as MRDE) have developed machine health monitoring systems for mining. These systems have now been applied to every colliery of British Coal (Lester and Brooks, 1987). Improved face performance and technical management have resulted. The application of machine health monitoring together with microprocessing packages widespread at colliery level play a major role in this. Consequently, there has been a decrease in the number of faces and manpower while maintaining production levels.

2. ORGANISATION OF MAINTENANCE MANAGEMENT

2.1. Objectives of Machine Health Monitoring

During the 1950's it was believed that the best way of maintenance to meet requirements of production was to establish planned preventative maintenance. Many years of experience has shown that this type of maintenance does not fully provide all the requirements of underground mining. Thus, in the early 1970's HQTD concentrated on the development of machine health monitoring procedure. The objectives of machine health monitoring based maintenance are as follows (Lester and Tregelles, 1984; Jarvis, a986):

1. To eliminate planned preventative maintenance.

2. To reduce the risk of unexpected component failures resulting breakdowns which lead to losses of production and revenue together with forming a safety hazard.

3. To provide sensory indication that components are functioning within their rated capacity and provide a suitable warning if these predetermined standard conditions and indices are exceeded.

4. To use technical and operational staff more efficiently by being able to maintain directly, and not by breakdown, and by extending the skill of the craftsman to a higher technical level.

5. To improve the reliability and cost effectiveness of existing machinery and to provide useful information for future developments and new designs.

6. To reduce maintenance costs (material and labour), downtimes and reduce the heavy loads on workshops causing delays in repair by avoiding catasrophic failures.

7. To meet the requirements of advances in technology and growing face mechanisation together with more complexity and power in coalface machinery.

2.2. Technical Management Structure of a Colliery

The technical management structure of a colliery may be divided into two tiers according to the operational style. The first (top) team consists of the Colliery Manager, Deputy Manager, Unit Mechanical and Electrical Engineers. The second (running) team covers the Deputy Manager, Deputy Mechanical and Electrical Engineers, Shift Charge Engineers (Mechanical and Electrical) and Colliery Overman (Schofield, 1987). One of the Deputy Engineers is appointed and given full responsibility for operating the machine health monitoring activity, and he normally leads the running team.

The running team meets daily to discuss the previous 24 hours operations to determine causes, and to devise the best solutions and recommendations to implement the solutions for existing problems. The philosophy of these meetings is taking immediate corrective action through machine health monitoring against technical problems in co-operation rather than individually.

The top team meets weekly to examine delays occured in the previous week in an executive approach. The role of this team is the supervison of the running team to improve performance and reduce delays. The discussions also include costing, training, production, records and reporting procedures together with the factors relating to improvements of performance of faces. This new structure of team management resulted improvements in the performance of monitoring and extracting real solutions to problems releated to both the short and the longer term of machine effectiveness and reliability.

3. MACHINE HEALTH MONITORING PROCEDURE

In order to take full advantage of machine health monitoring, since 1981 a systematic monitoring procedure has been developed by HQTD. In this procedure there are four steps to be followed (Grason and Lester, 1985):

1. Planning and design.
2. Commissioning.
3. Routine condition monitoring.
4. Mechanical fault diagnosis and final inspections at National Workshops.

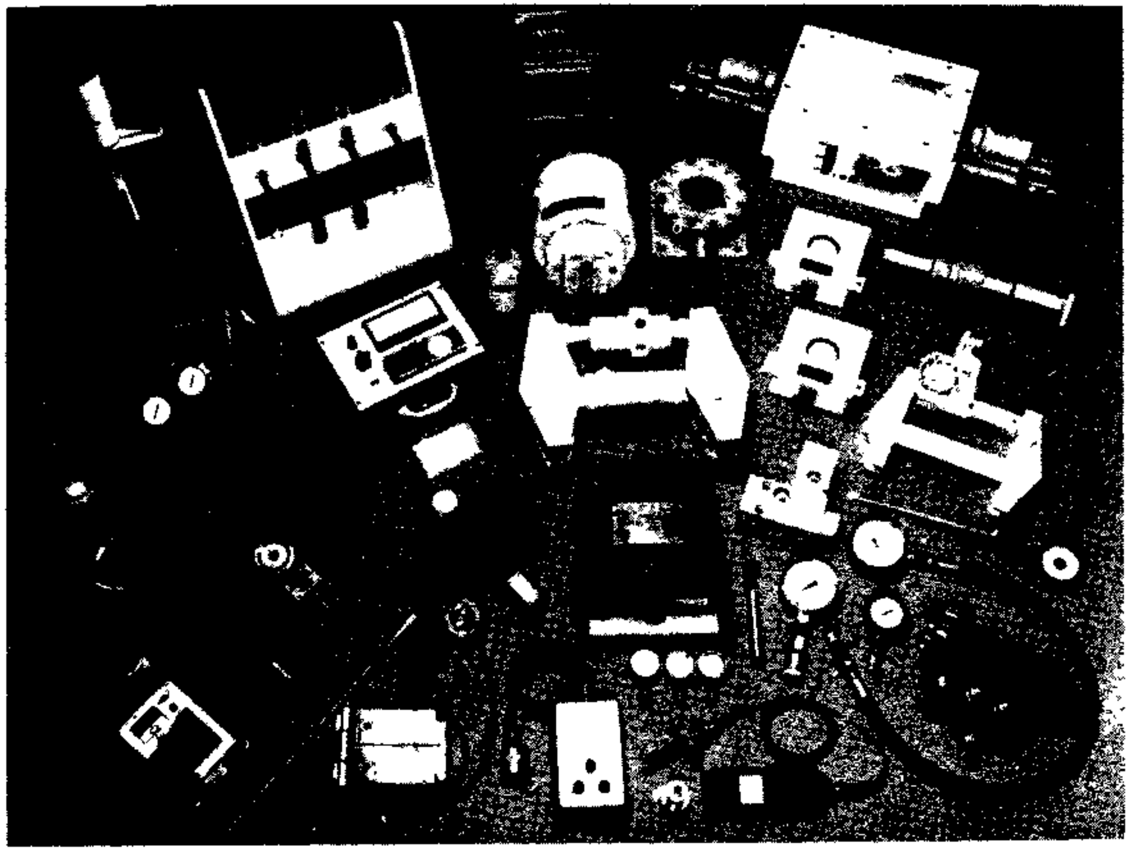
4. ROUTINE CONDITION MONITORING TECHNIQUES

Routine condition monitoring was initially based on commissioning techniques which adapted and in some cases simplified these techniques, so that regular measurements on coalface machinery could be carried out. The measurements are manually recorded, but subsequent storage, data retrieval and analysis are carried out through the colliery information system package developed by HQTD. The package covering various subsystems provides extensive analysis and data processing of the delays, breakdowns, routine maintenance, machinery repair and replacement (Jarvis and Lewis, 1984).

The application of routine condition monitoring covers a wide range of instrumentation and techniques. Main systems which have been developed and evaluate^ by HQTD are presented in Figure 1. Routine condition monitoring procedure at British Coal may be divided into the following three main categories (Richards and Elmacı, 1988):

1. Performance monitoring:
   a. Armoured face conveyors,
   b. Power loaders,
   c. Powered support systems,
   d. Roadway drivage machines.
2. Vibration and shock pulse monitoring.
3. Lubricating oil analysis and debris testing.

Figure 1: Routine condition monitoring equipment (by courtesy of E. E. JARVIS).



S. THE 0SE OF DEBRIS TESTING

Out of all the machine health monitoring techniques the debris tester has proved to be the most suitable system to be used at colliery level for the monitoring of the lubricated coal winning machinery. The main reasons it has been accepted so quickly may be listed as follows:

1. As described in authors previous paper (Richards and Elmaci, 1988), the instrument is easy to operate with the minimum of training and cheap to purchase. At present, a colliery craftsman can process over 50 lubricating oil samples from various machines a day.

2. The majority of the components in British Coal transmissions are made from ferrous material and almost all the wear debris particles are magnetic (Price and Yardley, 1984). Thus, almost all the particles are within the response of the debris tester to measure the ferritic debris worn out from gear transmissions.

3. The procedure of debris testing (Richards and Elmaci, 1988) ensures that there is oil in the gearbox and it is of a consistency where by it will flow and lubricate the components as intended.

4. The visual examination of the sample indicated the degree of contamination of the oil and the presence of water. Previously, it was impossible to control oil cleanliness and the presence of water sufficiently as the gearboxes were splash lubricated without filtration. Thus, contaminants and water were getting easily through seals and remaining in until the next scheduled oil change. Although, the oil consumption has increased with debris testing it was provided to check oil level and cleanliness during sampling and testing period.

5. A survey at Hem Heath Colliery has shown that savings achieved by planned plant replacements by the use of debris tester were as follows (Lester and' Brooks, 1987):

a. Anderson Strathclyde 500 hp. shearer power pack;

approximate tonnage lost (tonnes)	3 000
manpower cost for planned change	£ 2 655
lost revenue for breakdown	£ 130 000
total saving	**£ 127 345**

b. Anderson Strathclyde 500 hp. shearer gearhead;

approximate tonnage lost (tonnes)	3 500
manpower cost for planned change	£ 4 365
lost revenue for breakdown	£ 140 000
total saving	**£** 137 655

It should be pointed out that an average debris testing system only costs 3700 pounds to purchase and typically for 120 samples per week it would cost approximately 1000 pounds to run per 48 week year period (1988 prices).

6. At current levels of coal face performance, when machines are on duty, every minute a machine is broken down, will result in losses in proceeds of up to 800 pounds a minute (Goddard, 1988). This was mostly avoided and in 1987/8 up to 70% of major maintenance, involving machine section changes, were predicted by using routine condition monitoring procedure with associated maintenance implemented outside production periods (Coal News, 1988).

At present, debris testing itself together with an optical microscope and the wear particle atlas, prepared by HQTD for investigation of samples giving high readings, provide required monitoring information for the management to run lubricated machinery efficiently. The samples which are given high readings, and containing high amount of large debris are normally sent to Regional Laboratories for further analysis. The laboratories are equipped with more complex analysis systems including x-ray scanning microscopy, atomic spectrometry, semi automatic image analysis and ferrography.

6. PARTICLE SIZE DISTRIBUTION BT MEANS OF LASER BEAM DIFFRACTION

Despite all the improvements, in 1986/7, 40% of the total maintenance costs were attributed to the repair and overhaul of majoi coal winning machinery (Goddard, 1988). At present, developments arc associated with the automation of data collection and processing machine performance and reliability control, delay analysis, on-line lubricating oil and wear debris monitoring to improve routin condition monitoring procedure at colliery level.

The purpose of this research was to establish a monitoring technique at colliery level to determine wear debris particle size distribution to be used in conjunction with the debris tester, in order to present the severity of wear in gear transmissions more accurately. The technique involves the Malvern 3600 Particle Sizer which uses the principle of Fraunhofer Diffraction from the particles. The diffraction pattern is formed when particles are illuminated by a parallel beam of monochromatic, coherent light to determine the particle size distribution. The analysis of the principle of the process may be found in standard texts on optics.

7. CASE STUDY

7.1. Experimental Procedure

The examination of used lubricating oils from the right hand of two 270 hp. Anderson Strathclyde double ended ranging drum shearers was undertaken which are in use in the Thoresby Colliery of British Coal Nottinghamshire Area. The monitoring technique consists of following five steps;

1. sampling (once a week),
2. filtration,
3. debris reading,
4. collection of ferrous particles from the oil sample,
5. particle size distribution by the Malvern 3600 Particle Sizer.

The details of this procedure has been outlined in a previous paper by the authors (Richards and Elmaci, 1988).

7.2. Presentation and Interpretation of the Results

In this paper the particle size distribution results are presented by the cumulative weight of particles under a defined size of fifteen size bands. From these results the percentages of 25, 50 and 75 were selected to show the wear debris growth against machine running time. The gear head was monitored from the date of installation to the final inspection at the Bestwood National Workshop, in order to determine the deterioration due to wear. The results were interpretted according to the following chart (HQTD, 1984):

1. Sudden increases in weekly debris readings are most often caused by coal contamination producing fine abrasive wear debris, less than 5 mic. This may also be noticed by visual analysis of the sample. Under these circumstances, the oil should be changed. If the readings fall, the increase was most probably caused by abrasive contamination. On the other hand, if the readings fall slightly, remain or increase, the problem may be contamination caused by seal failure. This will be confirmed if no particles are larger than 25 mic..

2. It is known that the larger the wear debris, the greater deterioration and the worse severity of the wear. HQTD has defined following four size ranges for wear debris particles:

Fine : less than 5 mic. (normal rubbing wear and abrasive wear by contamination with coal dust).

Small : less than 25 mic. (general wear and effcient operation).

Medium: 25 to 60 mic. (fatigue pitting or severe sliding wear that may be a warning of an unacceptable deterioration that may lead to failure).

Large : Over 60 mic. (severe wear and fatigue, which may indicate substantial damage occuring in the section).

In Figure 2 debris readings and particle sizes as percentages of 25, 50 and 75 are plotted against running time of a gear head. The oil changes (maximum 8 gal.) and top ups are shown at the top of the figure to interpret the results clearly. The intervals between samples are not consistent due to holidays.

From the date of installation the majority of wear debris was around 20 mic. as the components bedded in. There was no increase in debris readings which showed the sign of normal wear. In general, during the normal running phase of a machine's life relatively large particles and steel flakes up to 360 mic. in size may be found (Bedford, 1986). Through the monitoring period only the following actions were required to keep the production without any break:

Week 1-5: As the running temperature was high and causing loss of oil, increasing the chance of component deterioration, the oil was changed 3 times in week 1 and once in week 4. During this period in weeks 2, 3 and b, particles varied up to 261.6 mic. (running in period). However, the debris reading did not increase and the majority of particles were smaller than 25 mic.

Week 15-19: During this period the majority of wear debris was larger than acceptable level of 25 mic. However, after topping up from week 18 the trend turned down and debris readings were low (0.5). In week 19 the majority of particles smaller than 25 mic.

Week 21: The debris reading increased suddenly from 0.5 to 2.3, but the majority of particles were smaller than 6.4 mic. and the sample was contaminated by coal dust. After an oil change the debris reading failed to 0.8.

Week 26: From this week debris readings increased steadily despite an oil change. The majority of particles were around 3.5-6.5 mic. which was a sign of possible grinding and three-body abrasion. Furthermore, the samples were badly contaminated by coal dust which continued until the head was removed.

Week 33: Although, it was not urgent to remove the head and the troubles could have been avoided by changing the oil, the management took the decision to remove it, in order to inspect the actual condition of the components, and to refurbish the head by minor repairs before its condition got worse.

7.3. Inspection Results

Following results were observed from the inspection:

1. Casting, covers, pipes and joints were corroded. All other external sections found to be normal without any damage.
2. Normal wear found on all seals except the oil seal of bevel gear shaft assembly. This seal was damaged through heat.
3. Retaining pins for bevel gear bearing were damaged.
4. Teeth were worn on the rack on the selector mechanism.
5. Cluster gear was heat affected and chipped on one tooth.

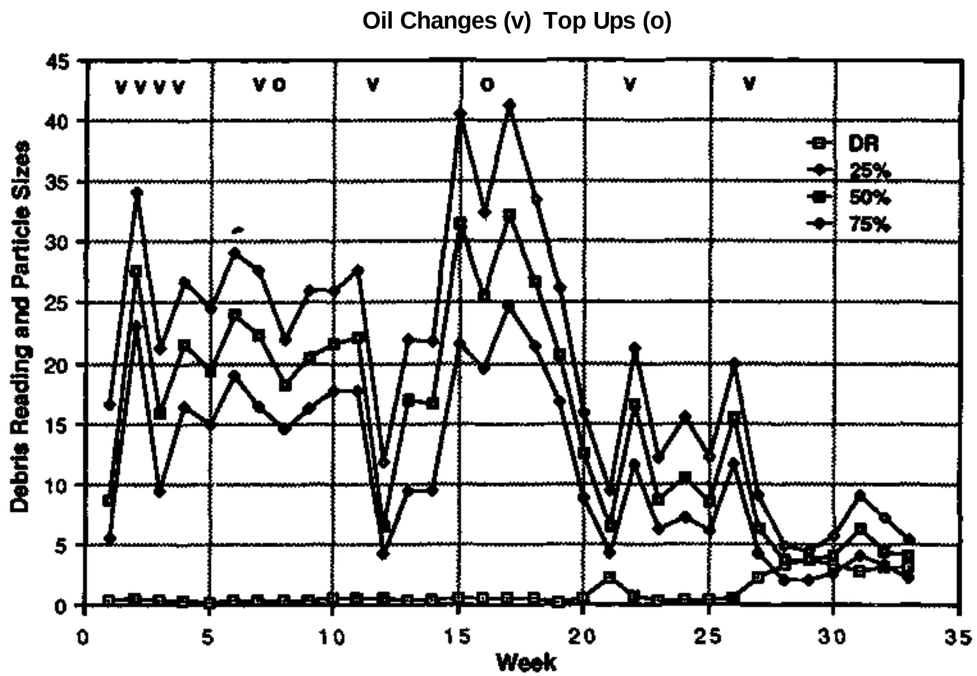


Figure 2: Debris readings and particle sizes as (25,50,75)% against the running time of a gear head of a A.S. double ended drum shearer.

6. Motor gear and pinion were both heat affected and worn. Colour changes due to heat and pitting were observed.

As seen from the above results the condition of the section was still at an acceptable level to be run. However, the motor gear would have caused trouble due to heat effects and the bevel gear bearing would have failed. It should be mentioned that gearboxes returned before failure have been found to be cleaner, easier to dismantle and possibly cheaper to repair than units that were returned due to failure (Bedford, 1986), and also avoids unexpected breakdowns.

8. CONCLUSIONS

British Coal has applied considerable effort to the improvement of maintenance management and development of an advanced machine health monitoring system, involving various techniques on-line and at laboratory level since early 1980's. The productivity has increased considerably since initial trials despite the decrease in the number of collieries and manpower. There has been a noticable decrease of maintenance costs since the introduction of the machine health monitoring procedure and technical management in a team form rather than individuals.

The new structure of team management resulted in improvements both in the short and the longer term of machine effectiveness and reliability. In the short term, during coal producing shifts, delays and unexpected breakdowns decreased. In the long term due to controls economic life of machinery increased. Despite all the improvements the reliability is still a great concern and British Coal continues to seek better design standarts and reliability for coalface machinery to ensure to keep high productivity at the lowest cost.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. T. Atkinson for his encouragement, Mr. L. Crellin Chief Engineer for the Nottinghamshire Area of British Coal for permission to supply the samples and all the information and Mr. E. E. Jarvis Senior Mechanical Engineer of the Maintenance Department of HQTD for his advices. Thanks are also due to all the personnel of Thoresby Colliery for their helpfulness and kind co-operation.

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

REFERENCES

BEDFORD, S. A., 1986; "Wear Debris Analysis", B.Sc. Thesis, Dept. of Mining Engineering, University of Nottingham, March, 128-130.

COAL NEWS NOTTINGHAMSHIRE, 1988; "Keeping Machines Alive and Well", No 323, July, 16p.

COOPER, G. and ALEXANDER, W. J., 1987; "Engineering in the Mining Industry", Mining Technology, Vol. 69, No 803, pp. 261-265.

GODDARD, B., 1988; "Machine Reliability: The Key to Success", Colliery Guardian, Vol. 236, No 8, 274-276.

HQTD, 1984; "Wear Particle Atlas", British Coal, 14p.

JARVIS, E. E., 1986; "Improving Maintenance by Routine Condition Monitoring", Colliery Guardian, Vol. 234, No 8, pp. 382-388.

JARVIS, E. E. and LEWIS, D. C., 1984; "Routine Condition Monitoring", Mining Engineer, Vol. 144, No 275, pp. 111-118.

LESTER, M. F. and BROOKS, A., 1987; "Debris Testing Progress and Further Developments", Proc. of an Int. Conference on Condition Monitoring, Edit. M. H. Jones, Swansea, pp. 372-390.

LESTER, M. F. and TREGELLES, P. G., 1984; "Machine Condition Monitoring; The Way Ahead", Mining Technology, Vol. 66, No 769, pp. 359-369.

RICHARDS, M. J. and ELMACI, B., 1988; "Wear Debris Particle Size Distribution in Mining Machine Health Monitoring", Proc. of the Sixth Coal Congress of Turkey, May 23-27, Zonguldak, pp. 43-55.

SCHOFIELD, I. H., 1987; "The Introduction of Routine Condition Monitoring to the North Yorkshire Area of British Coal", Mining Technology, Vol. 69, No 803, pp. 267-277.