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The Next Atlas Copco Generation of Tunnel-Rigs and Some Experience

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ABSTRACT: Now a new generation of computerised drill rigs has been launched and they are based on modern computer technology. The rigs have been well embraced by the market and more than 100 units have left the assembly line. The new generation has taken a quantum leap forward with respect to drilling accuracy, logging capabilities, reduction of manpower İn some types and serviceability. The Can bus technology, well proven in the automobile products, is an integrated part in the computerisation.

1 INTRODUCTION

From 1998 and up to today Atlas Copco has introduced a number of new drill rigs for underground excavation. These rigs are to a large extent the result a new design approach where Atlas Copco is working in close relation with skilled contractors and mining companies. This construction and mining business is generally considered as conservative. Only few of the advantages brought in by computerisation and atomisation other business have prospered from has been brought underground.

Atlas Copco introduced the so-called Robot rig already 1987. The sales of this rig indicate that it was not as good as we thought or the launching was too early. The arguments for this rig 1987 were to reduce manpower and possibly to improve production. The rigs that now have been launched will still require people for the operations and they will give a reasonably nice working environment but also a high and reliable good quality production. The drilling of the holes has turned out to constitute an ever-smaller share of the direct tunnelling cost and so time as well of the all the activities at the tunnel face. However the result of the drilling has a major impact on the other activities up at the tunnel face. The drilling has influence on the fragmentation as well as the over/under- break, required support etc. Although great attention is paid to penetration rate wear of drill steel and bits atlas Copco is paying an ever-greater interest in drilling can do to improve the tunnelling process as a whole. The input in this ongoing process is coming from our customers.

2 THE NEW RIGS

All the new rigs have been launched and consequently they are properly documented on video, CD-ROM and still also on paper. Still the paper will present a few pictures of the rigs. This time it has been possible to adopt a modern design of the ngs differing from the latest launches of what were called new rigs. In fact they are better characterised as upgrading of existing rigs as new features were added where space was available. In this case all components have been in the planning process right from the beginning. They are however to some extent based on old but competitive components like the BUT 35, which has been modified and reinforced. The hydraulic and the electric systems are completely different. The design-ambition has been in all details to go for simplicity in service and good ergonomics. Air condition in the cabin can operate both during drilling and tramming and not as before only during drilling. The new L2 rigs are shown in the pictures below.

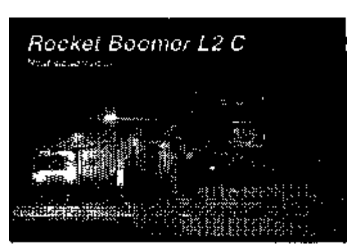

Photo 1. Rocket Boomer L2 C.

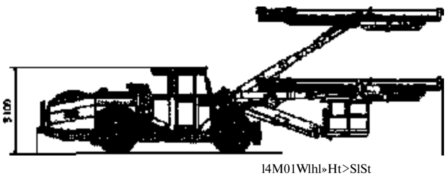

Figure 1 Rocket Boomer L2 C

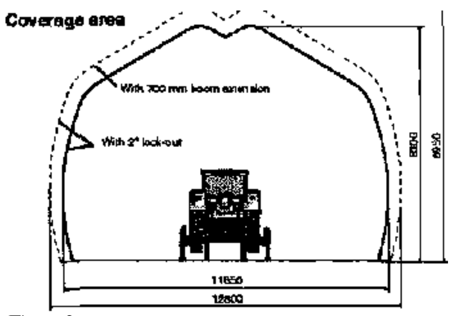

Figure 2.

Modular System - Rocket Boomer L2 C

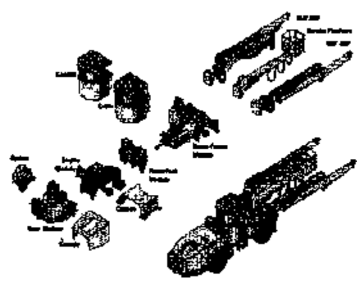

Figure 3.

3 THE RIG CONTROL SYSTEM

3.1 *History*

With exception for the former Robot rig all Atlas rigs have in principle been based on the so-called PLC system. The large radial net-work systems that were used could handle both analogue high speed signals but hosted also many processors for advanced digital communication plus man machine communication. Parallel interfaces were used meaning that the computer was centrally located and hooked up to each sensor and transmitters. The cable is supplying analogue signals that are converted digital and vice versa. When automating a process hosting a single or only few steps this is probably still the fastest way to meet the requested target. The draw back is in cases where the system can manage a defined application it will in practise mean overkill. This means that the system will be large and expensive. Some signals require high precision (14 to 16 bits) and some requires high speed while others do not demand any of that. This mixture is difficult to optimise in commercial systems and makes standardisation difficult for different rig-types. Beside this the radial nets requires intense cabling.

3.2 *The new rig control system*

The car manufacturing industry faced the control system problems discussed above especially for the luxurious cars that were equipped with very high numbers of electrical motors giving weight of the cables in the range of 100 kg per car. The ultimate solution would be one power-cable servicing all the electric units plus a switch analogue or digital ruling the use of the electric power. The digital signal should be superimposed on the power-line. A computer would than listen to superimposed signals and sent out instruction in the same manner. This ultimate solution almost came true. The single cable had to be expanded to three as two tiny wires had to be added to cope with the signalling but they are hooked up as a chain like the power line. There are cases where one power-line is unacceptable due to safety aspects and this means that the 3 lmes will be 4 (four), it would have been convenient if the industry had agreed on "one" language for communications in the signalling lines. The result was a number of dialects but luckily many components can deal with the majority of the dialects. The system was given the name CAN Bus (Controlled Area Network). A system of this kind is flexible easily expandable. Anywhere a new unit can be added without adding another cable. It Is foreseen that most passenger-cars, trucks and construction vehicles will have this system within a ten-year period.

The system described above is now implemented on the new generation of Atlas Copco CAN Bus drill rigs. The so-called DCS rigs where the rig activities are controlled by direct activation of the hydraulic valves are though still available for customers looking for simpler rigs.

For tunnelling rigs the flexibility of the system is highly utilised. The system can be adapted to the number of booms, the level of automation and adding new functions without being forced to install a heavy and expensive computer in the small and less complex rigs. To improve the reliability of the system, needed for a multiple boom rig operating In the full automation mode, a two level circuit communication system has been implemented. The upper level talks to the whole rig and the identical lower one is talking to the boom. That means also that each boom has its own circuit. The advantage of this set up is that a lower level fault affecting one boom will not have any consequences for the other booms. All the signalling on angles in the joints is restricted to the boom circuit and the upper level system advises only on the basic position of each boom.

A failure in the cables due to rock-fall or squeezing against the wall of a boom will not hamper the activities of the other booms.

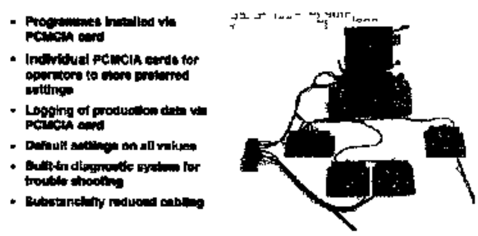

Figure 6.

The modules are all developed solely for the rigs and they are exposed in figure 6 above. It is believed that the figure shows how small the units are. It has been possible to give them a very good protection towards magnetic and electric disturbing influence. Below in figure 7 and 8 is shown in the form of a block-diagram the hardware of the Bus system for a standard 2-boom rig and a 3-boom rig with a service platform and rod adding system (RAS).

The software is split into a number of units (blocks) and the individual blocks can be added, deleted or modified. Figure 9 shows an access menu and a service menu. Access is given by pressing buttons on the screen.

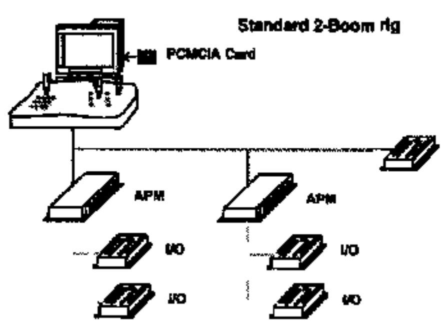

Figure 7. Block diagram for a standard two boom ng

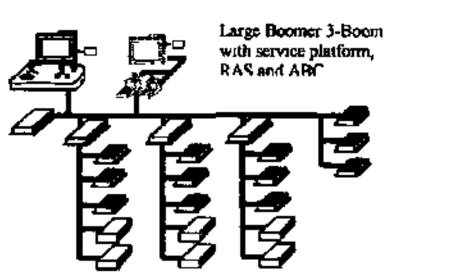

Figure 8. Block diagram for a three boom rig equipped with a service platform and rod adding system (RAS).

Our knowledge on how to start the drilling of the hole, means to avoid to get stuck with the drill steel and to get loose if stuck is incorporated in the system. The combination of this and the double dampened drill machines 1838 and 1432 is the explanation to the experienced favourable drill steel costs.

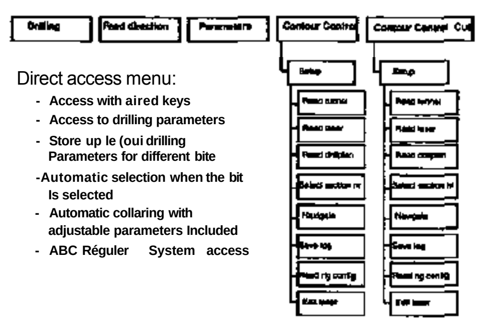

Figure 9

The operator's menu

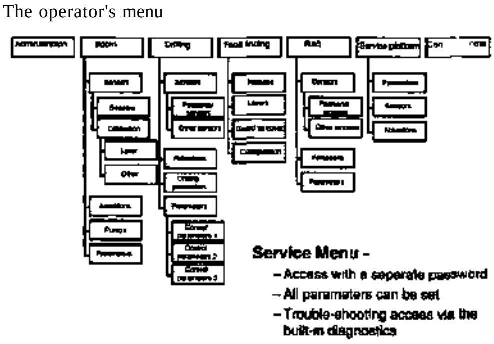

Figure 10. The service menu.

3.3 *The advanced boom control system. "ABC"*

ABC İs a shortage for advanced boom control. It is an important part the new rig control system "RCS" and ABC is available in three levels of automation and what these levels means will be described below.

ABC Basic: The operator is moving Booms and feeds and the orientation of the feed is shown on the screen placed in the cabin of the rig

ABC regular: This mode was earlier called "Contour control". Drill pattern, laser lines are being designed by use of a PC software tool named "Tunnel Manager". The result of the design work is loaded into the tunnel rig by use of a PC card. During drilling the operator is informed on where each boom İs located and where each blasthole has to be drilled. He will than guide the boom and feed into the correct position. During the drilling of the hole monitored drill data are collected without being shown on the screen. The recorded data can then be plotted or stacked in another form for later evaluation.

ABC total: This mode was earlier called "Auto" or "Robot". The planning of the round as well as the monitoring of the drill data is the same as for ABC Regular and is carried out using the same PC tool. The difference İs in the automation of the drilling process. The movements of booms and feeds is controlled by the RCS-technique (rig control system). The operator does not necessarily have to participate in the drilling process. There is built in extensive checking to ensure that collision of booms won't occur.

4 THE PURPOSE OF THE "NEXT GENERATION RIGS"

The new rigs will mean numerous improvements in the drilling and quality of the drilling result, which eventually will lead to lower overall cost. Some of the advantages are listed below.

-The operator can master the whole rig from one panel and that means that he can communicate with any of the booms

This means that only one operator is needed for both or all three booms if ABC Total is used. This statement is valid even for short holes as the moving of the boom and feed to a new position is done without any activity from the operator. The saving in this case İs one-operator times three shift. This is in a normal tunnelling situation a considerable saving. Another saving is the fast positioning in the Total mode, which also will be shown below. Positioning of the perimeter holes may result in skidding of the drill-bits on the rock-surfaces and the Total mode may have to be changed to Regular and requesting action from the operator.

The two drilling functions "Rotation pressure controlled feed force and Feed pressure controlled impact works even better in the digitised form as the fine tuning of the function is far easier done. A number of sites have indicated that jamming of the drill steel no occurs and this is certainly a time saving result and the drilled holes are expected to be straighter.

-There is a high degree of repeatability at positioning of the booms, as the digital system does not allow any drifting of the signals.

There are a number of factors that will contribute to the faulty placing of the boom, like the ambition of the crew and management, the quality of the survey work, acceptance of the new system, flexibility of booms and feeds, the boomer signalling system, and the character of the rock,. The digitised signalling will eliminate the drifting in the drifting and this gives a better accuracy. Furthermore the Total mode gives better accuracy in the positioning as the booms and feeds are automatically heading for a pre-set position and not moved by lever to a spotted point on a display.

Some results on overbreak is discussed in the cases below.

-Higher availability of the drill rig is expected.

The running costs are expected to be lower as the proper follow up of the machine performance and direct fault finding will improve the availability of the rig. The fault tracing İs simply made in the software. When operating in ABC Total the moving of booms and feeds are to a large extent controlled by the computer and that should result in a lower frequency of collisions between booms and wall and other objects. Consequently this would contribute to a higher availability.

-Monitoring of the ground ahead of the face

The ABC-system in Regular and Total means that the MWD (Measuring While Drilling) parameters can be logged without input of any extra efforts. This is valuable for those capable of interpreting the results of the parameter monitoring.

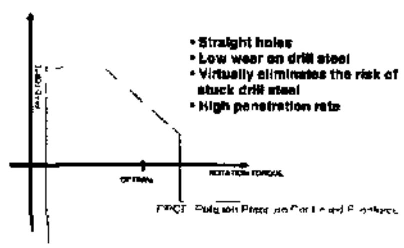

Figure 11 The principle performance of the RPCF system. The feed force is depending on the rotation torque according to the function as shown.

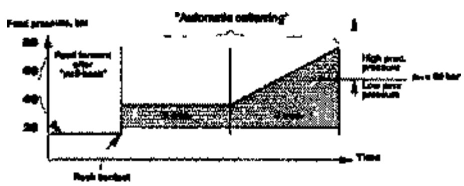

Figure 12 The sequences at the drill start and restart after a pull back of the drill-steel.

5 EXPERIENCE FROM THE CAN BUS RIGS BEING USED FOR TUNNELLING WORKS FOR MTRC IN CONTRACT 611 AND THE WEST RAIL PROJECT CONTRACT DB 350

5.1 *MTRC Pak Shing kok Tunnels*

The Hong Kong MTRC Pak shing Kok Tunnels comprise a complex of 5 interconnected tunnels driven as 9 tunnels totalling 6 km. The tunnels have a cross-section of some 35 m2. They are located in crystalline pyroclastic rocks resulting in a high wear of the bits.

For the drill and blast operations the Contractor Hyundai-Kier Joint venture had employed three (3) units of the Atlas Copco drill rig L2C, which is a two-boom ng with a Can-bus based control system. The rigs are equipped with the boom navigation ABC regular, meaning that the operator guides the booms and feeds to the correct position using the pre set drill pattern that is presented on the display. "The feeds are given a length to host up to 14 feet rods resulting in a max hole depth of 4,20 m.

What results have been achieved on this tunnel project over the monitored reaches? As said above the rock İs hard abrasive and not as brittle as regular hard crystalline basement rock. That means that the penetration will not be the best and the wear will be high. The average penetration is in the range of 2,5 meters/min. The service life of bits, rods and shanks have been roughly estimated to 400 m, 8-9000 m, and 8-9000 m respectively. These results are considered as good taking into account the penetration rate.

There was one operator for the two booms and the total time for the rig including mob and demob for a 70 number of holes and 4 m round was 1,5 to 2 hrs. As the manual moving of the boom from one hole position to the next generally takes about 40 to 50seconds the operator was busy with the levers two thirds of the drilling time

The tunnels are to be concrete lined and İt is therefore very important to keep over-break at a low level. A summery of the results from all the tunnels are shown in the table below, which has been provided by the owner MTR. In order to simplify the reading a bar diagram has been produced on the given figures and is also shown below. The contour holes are placed 10 cm outside the theoretical line at the face and 30 cm at the bottom of the hole. The conclusion from reading this bar diagram is that there is a risk for embarrassing under-break if the ambition to squeeze overbreak to too low .Bar no 6 which represents tunnel no 6 has much larger under-break than the other tunnels.

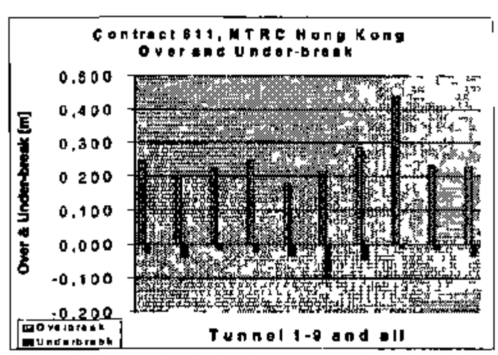

Figure 13 Over- and underbreak on monitored reaches of the MTRC Pak Shing Kok Tunnels The first 9 bars represent tunnels 1 through 9 and the tenth a summery of the 9 tunnels

Tunnel no 6 was die first to be excavated and the ambition was to keep overbreak low by allowing smaller margins than said above and the consequence was too much underbreak. Some of the underbreak is explained by apphcation of too much shotcrete for primary support.

Table 1. Overbreak and underbreak at the tunnel for Contract 611 Hong Kong *(Please note that the surveying is not yet complete)*

Tunnel no	Length [m]	Survey %	Over-break [m]	Under-break [m]
1	856	67	0,25	-0,027
2	504	73	0,20	-0,038
3	550	94	0,22	-0,017
4	1044	43	0,25	-0,022
5	1004	39	0,18	-0,029
6	324	45	0,22	-0,096
7	746	48	0,29	-0,042
8	380	3	0,44	-0,008
9	600	21	0,23	-0,014

Certainly better results with respect to overbreak has been achieved on other projects but it is always a matter of the ambition of the management and the incentive and skill of the labour. For tunnel 5 overbreak been is shown for a 150 meter long reach in the figure below. There are noticeable variations that may be explained by the geological conditions. Simply overbreak caused poor ground.

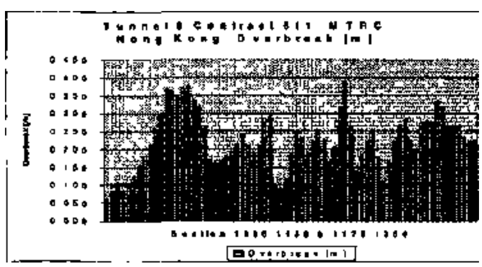

Figure 14 Overbreak, chainage by chatnage at 2 m centre for 150 metre reach of tunnel 5. The variation in over-break is noticeable.

5.2 *West rail contract DB 350*

The West rail contract DB 350 comprises a double track tunnel of 5 km located in the so-called Repulse bay formation, which mainly is built up of crystalline pyroclastic rocks. The joint venture companies Nishimatsu and Dragages split the tunnel in half-and-half. Nishimatsu is using the new generation WL3C Can-bus rigs for the drilling work.

The tunnel design, which is produced by the joint venture, is a double track tunnel with a cross-section of 110 m2. A concrete wall In the centre separating the two tracks from each other. The cross-section somewhat distorted is shown in the figure 15 below.

The two WL3 Can-bus rigs are given feeds bo long that up to 5,8 deep holes can be drilled. The drilled length of the rounds varies generally from 5 to 5,8 meters. In poor rock these long rounds are shortened. This is important to bear in mind when overbreak is discussed below. This rig is equipped with ABC Total, which means that the holes are drilled and the booms and feeds are moved to a new position automatically.

For the drilling two rigs are positioned next to each other at the tunnel face and each rig drills 77 holes giving totally 154 for the 110-m2 face plus three 4 inch holes for the parallel cut.. The contour holes are than given a spacing of 35 to 40 cm. Generally all the holes but the contour and the bottom are being drilled in the "Total mode". The pull of the round is about 90 %. Two rounds per day, 25 days per month gives a production of 200-220 meters/month. If the contour is free from protruding rock the automatic drilling is applied also for the contour holes.

The wears of drilling tools are equal to the MTRC tunnels described above except for the bit life that is about 500 meters. Here again is concluded that the Can-rig is treating the drilling tools well.

One man operates the three-boom rig and when the "Total" mode is utilised the booms have no down time not even for shorter rounds. The time for the drilling operation including mob and demob is in the range of 2-2,5 hrs and the penetration rate for the 48-mm spherical button-bits 2,5 meters/minutes. The drill pattern and the travelling routes for the booms are shown for both ng< below. In cases where only one rig has been placed in front of the tunnel face the drilling of the rounds takes 3,5 to 4 hrs.

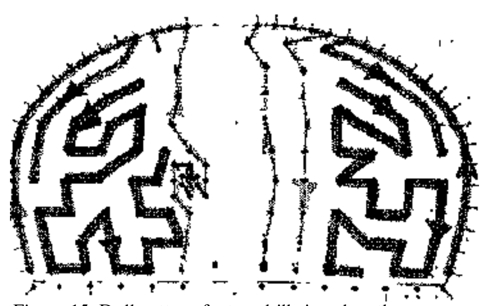

Figure 15 Dnll pattern for two drill rigs when they are working in parallel The path for each boom is shown in colours. Please noie that there is a overlap of about 1,5 meters in the centre

Considering firstly the length of the round secondly the length of the rounds with respect to partly poorer rock-quality, over-break cannot match the result from the MTRC tunnels. Without any splitting on rock-classes the results from 450 meters of tunnel is shown in the histogram below. Here as well as in the MTRC-project the drilling of the contour starts 10 cm outside the theoretical line and the bottom is meant to be 30-cm outside the theoretical line.

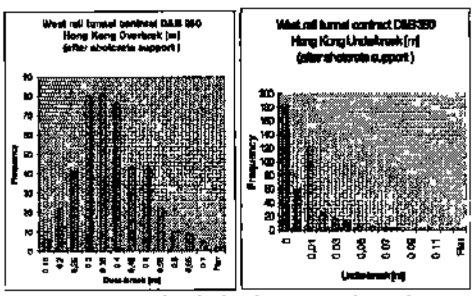

Figure 16. Over- and under-break at West rail tunnel contract D&B 350 chaînage 1556 to 1997, for overbreak 0,15 m isthe first mark on the x-axis and the first bar in the underbreak histogram covers all zero registrations.

What is surprisingly encouraging is that underbreak is found only in half the surveyed sections and where found only smaller quantities is registered. As the deviation is depending on the length of the hole with a power of more than one (I) possibly 1,5 -2 a 5,5 meter long would deviate 50 % more than for a 4 m long hole. ConsequenUy the underbreak ought to be more embarrassing than in the MTRC case as shown above.

Information the on the rock quality over the reach 1556 to 1999 has been provided by the contractor and it can be concluded that almost all excavation is done in rock having a Q-value higher than 10. That means that the rock quality can be considered as good speaking in general terms. Overbreak caused by geology should not have been dominating in this

6 FINAL WORDS

For a machine supplier it is very important to have good relations with skilled customers, as they to some extent become partners in the development work of new equipment. It is the believe in Atlas Copco that the new generation of rigs will a profitable tool when chasing costs in the tunnel construction. It has not been convincingly shown that overbreak is drastically improved. There are however many prerequisites that have to be fulfilled in order to achieve low overbreak result.The other improvements like better drill steel economy, savings on operator cost higher utilisation etc. have been easier to verify. This is also the reason for the well reception of the new generation.