Latest Developments in Longwall Mining Technology

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Abstract

Ever-higher requirements from mine operators have led to numerous significant developments in longwall mining technology over the past decades. Mining companies are looking for higher productivity, longer life, a higher degree of automation, full system solutions, increased safety and equipment suitable for extremely high or low seam applications. Being in the longwall business for more than 70 years, Caterpillar and its predecessors have invented state-of-the-art solutions over and over again to meet those challenging demands with the overall goal of minimizing operating costs.

This paper will provide an overview of the latest innovations in roof support technology, armored face conveyor systems, shearers and automated plow systems, as well as operational experiences from leading mines around the world.

Introduction

The modern longwall mining method was first developed in the early 1970s when the first shield supports were introduced. Since that time, all components of a longwall system have been considerably upgraded in areas such as installed power, conveyor chain speed and capacity, structural integrity, and—first and foremost—automation. This is a continuous process. Caterpillar and its predecessors have always been at the forefront of such developments, which were driven initially by the demands of the extremely arduous German deep mining conditions—among the most difficult in the world.

The longwall mining method is used today in the following main markets: China, USA, Australia and Eastern Europe. Further markets exist in countries such as Turkey, India and—to a smaller degree—Western Europe.

Low operating costs are crucial for survival in today's highly competitive hard coal market; and Cat longwall equipment is the preferred choice of customers all around the world for keeping costs low. Enhanced productivity comes from higher installed horsepower and higher machine speed, which are part of the essentials for increasing production rates. However, this alone is not enough, as systems with higher availability and reliability, quick and easy maintenance, and a minimum lifetime of at least a complete panel are also very important aspects. Increasing face width and panel length are also part of the equation, which not only increases the panel yield but also brings about a reduction in panel development requirements. When this is also taken into account, the driving force of the underground coal mining industry is understood. Caterpillar has successfully developed longwall systems that meet these requirements, with face lengths of up to 435m already in operation.

Roof Support Technology

Cat roof supports—also known as shields—operate in ranges from 0.6m to more than 7m. Caterpillar has a wealth of experience in both high- and low-seam applications, and is able to tailor roof support design to geological conditions and specific customer requirements. Most shields today are two-leg designs. Only gate-end shields sometimes have two additional legs to cover the longer canopy, which is necessary because of the widths of the high-capacity head and tail drives of the AFC. The typical shield width has increased from the original 1.5m to 1.75m, with 2m used for most higher seams. The advantages are obvious: there are fewer shields required for the same face length, which reduces the total number of components and therefore the cost. Furthermore, moving fewer shields takes less time. This reduces the overall cost to the operator and is playing an important role in improved production and productivity.

Another interesting feature that Caterpillar offers is a highly efficient dust suppression system for both shearers and plows. This water spray system includes a moving "water curtain." High-pressure water is sprayed through nozzles mounted in the shearer running track. The number of nozzles can be set to a programmable number of shields. The system is activated and controlled by the extremely reliable and very flexible Cat PMC-R roof support control system. The spray zone moves with the mining machine back and forth through the longwall, and is considerably more effective than the standard dust-control systems built into shearers. This system has helped many mines around the world to greatly reduce dust and to stay well within the respective approved limits.

Cat longwall dust suppression system

Roof Support Technology

Since 2006, Caterpillar has specialized in designing and supplying special shields for the longwall top coal caving method (LTCC), where extremely thick seams are being mined. This method utilizes a second AFC behind the shields to take the coal on top of the longwall outside of the face. Several such systems have been supplied and successfully installed in Australia at the Austar, Narrabri, Broadmeadows and North Goonyella Mines.

Caterpillar has also specialized in designing and manufacturing plow shields for medium and thin seams for many decades. The latest of these low-seam plow shields was supplied to DSK Ibbenbüren Mine in 2013 as part of a full longwall system—including the new Cat GH800B Gleithobel plow system. This picture shows the maximum-dimension walkway created using custom design—especially of the canopy and the relay bar—in close cooperation with the customer.

This system, like all Cat roof supports, is characterized by thorough design, inlcuding FEA analysis, superior welding quality proven by successful structural testing, and extended underground life allowing for minimum longwall operating costs.

Cat LTCC roof support with front and back AFC

Cat roof supports specifically designed for low-seam operation

Armored Face Conveyor Systems

One area where Caterpillar offers superior technology to minimize operating costs is the AFC drive system. Expecting the demand for more and more horsepower as early as 1991, Caterpillar predecessor Westfalia Lünen began the development of the integrated CST (Controlled Start Transmission) drive system in a joint venture with Dodge Reliance CST (now ABB Baldor) and released it to the market in 1994. Well more than 500 units have been sold in many countries including the USA, Australia, Germany, China, Poland, the Czech Republic, Kazakhstan and Russia. The planetary gearbox with an integrated, infinitely controllable clutch is currently available from 500 kW to 1.800 kW installed power.

Customers have always appreciated features like integrated no-load motor startup, soft-start, heavy load startup, accurate load-sharing between several drives and excellent, rapid overload protection in case of hard jamming of the chain. These features help reduce downtime and increase productivity for Caterpillar customers. The CST drive system is the only available system where full break-down torque (BDT) is applied at all drives from all motors at the same time. This is known as synchronized heavy-load startup. Essentially, the CST allows a staggered motor startup at any sequence, as the AFC startup sequence is completely independent. Normally, the tail drive is engaged first to pull away any slack chain, then all drives apply increasing torque simultaneously. This way, all drives reach full BDT at the same time if this is required by the AFC. This is achieved through the intelligent and extremely fast real-time PMC-D Cat drive control system. This means the BDT for the motors of a CST drive system will always be less than with any other drive system. Furthermore, as the CST couplings are only engaged when all motors are at full speed, there is an additional amount of kinetic energy that is used to start the AFC.

One slight disadvantage of the CST has always been the ability to operate at lower speeds. This is due to the fact that the cooling oil pumps and the high-pressure pump for clutch operation are driven by the main motor. If the main motor is slowed down, the cooling oil flow will be reduced exponentially and the CST would overheat under load. A revised version of the CST gearbox released in 2012 now offers a built-in electrical pump motor which is independent of the main AFC motor and thus allows infinitely lower AFC speed.

The first of these innovative drive systems has been in successful operation at Bogdanka Mine in Poland since 2012. It is part of a complete Cat plow system that includes a Cat variable frequency drive (VFD) to operate and control the speed of the face conveyor and the plow motors.

Traditional Cat CST gearbox (from 500 to 1.800 kW installed power)

Upgraded version of the CST gearbox with integrated pump motor

Cat VFD system underground

Shearers

Caterpillar has upgraded its range of longwall shearers over the last few years with the clear goal of further increasing reliability and availability while utilizing a new, common electronic platform to build on the leading automation capabilities. The proven concept of a one-piece mainframe (can be designed as a three-piece mainframe for customers with transportation limitations) has been maintained. While this offers maximum protection to all major shearer components, another advantage is that downtime due to difficult geological conditions is minimized, as other shearers in such arduous conditions are more frequently damaged.

The first next-generation Cat EL3000 shearer went to work in 2012 in Australia's Narrabri mine as part of a complete Cat LTCC system. Several more shearers of the same size are now in operation—primarily in Australia. Mines are also using the smaller EL1000 and EL2000 machines. All use common, newly developed control hardware and software, allowing more automation features while making maintenance and fault-finding easier than ever before.

New Cat EL3000 shearer during final testing at Caterpillar in Lünen

Automated Plow Systems

Cat plow systems have been in operation since the early 1940s. This proven technology is now fully automated, with systems installed in numerous faces not only in Germany but also in the USA, China, Kazakhstan, the Ukraine, Czech Republic, Mexico and Poland. Since the mid 1990s, Cat plow systems have had enough installed power to cut up to 2 x 400 kW at a plow speed of up to 3 m/s. They can now mine seams of any hardness. The longest face currently cut by a Cat plow is 400 m wide, and the maximum seam height currently using a plow system is 2.3 m. Inclinations of 50° or more present no problem for Cat plow systems. Building on the successes of automated plows from the mid 1990s, Caterpillar has developed the next-generation Cat GH1600, with double cutting horsepower (2 x 800 kW) and a 42 mm chain.

This system commenced production at DSK's Prosper-Haniel mine in Germany in September 2003 on a panel width of 400 m in extremely hard coal. It has repeatedly demonstrated that high production figures can be achieved from very hard coal. The current world record for low-seam longwall faces was set at Cleveland Cliffs Pinnacle Mine in the USA, using a complete Cat GH1600 plow system. In August 2012, the plow longwall produced 29,500 tons per day from a seam less than 1.5 m thick. This came only months after Bogdanka Mine in Poland had set the previous record at 24,400 t/d in February of the same year. Bogdanka now operates two complete Cat plow longwalls; another system is being delivered in 2014 while a fourth one was ordered and will be delivered in early 2015.

The latest plow model is a redesign of the standard GH800, built on experience gained from the GH1600 plow system—especially with regards to the cast plow guide. The new GH800B also uses a one-piece casting for the plow guide, allowing for a very low guide height and thus easy loading of the coal onto the face conveyor. The first system of this type has finished its first very successful panel at RAG Deutsche Steinkohle's Ibbenbüren Mine in spring of 2014 in a seam around 80 cm thick.

High-horsepower Cat GH1600 Gleithobel plow system (max. 2 x 800 kW)

New Cat GH800B Gleithobel plow at Ibbenbüren mine

Summary

Caterpillar has been a supplier of leading-edge technology for underground longwall mining for many years. The recent innovations featured in this paper—the innovative dust suppression system, the LTCC system solutions for extremely thick seams, the low-seam plow roof supports with a maximum travelway, a new innovative VFD system for face conveyors and plow systems, and the new and improved shearers and plows—demonstrate the Caterpillar commitment to remain at the forefront of technology.

The application of state-of-the-art technology based on the needs of customers and extensive testing prior to application will minimize overall operating costs. Productivity will increase through increased production, availability, reliability and lifetime. This will keep Caterpillar customers competitive in the long run.

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