The Importance of Intelligent Drive Systems for Ultra-Long Face Conveyors

Caterpillar Global Mining

CAT®

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Introduction

Caterpillar, a leading worldwide supplier of longwall systems, was the inventor of the first armored face conveyor in the late 1930s. At that time, the chain conveyor was armored to protect its deck-plate from damages caused by blasting at the face, which was necessary to mine coal. This led to the product being known as a "Panzer." Since those early days, the longwall systems have evolved to meet the needs of its customers.

Today Caterpillar continues to develop longwall conveyor technology and set the industry standards. Longwalls keep getting longer and longer primarily to allow the operator more time to develop the entries for the next longwall panel. As the longwalls become longer, the challenges for face conveyors increase. Longer face conveyors have a greater mass of material to move, longer and heavier chain strands to move them and more powerful motors. Longer longwalls also mean greater stress and strain on all components of the face conveyor. A single failure can have catastrophic results, bringing production to a complete standstill until the problem is fixed. Since 1998, Caterpillar has provided outstanding service for longwall conveyors and mastered the challenges of faces longer than 400 m.

Important features include the fully automated tensionable tail drive and the line pan design, such as the innovative long-life Cat PF6 line pan. The chain is also a critical component, which is why Caterpillar has been involved in the design of chains and sprockets since 1990, although it does not manufacture its own chain.

The 42 x 146 mm and 48 x 144/160 mm flat-link chains have proven to be a great success in allowing longer faces. With the new Cat PowerChain, operators will be able to continue the trend for longer faces. This new chain design has already proven itself in high-capacity beam stage loader applications in the USA and Australia.

Picture 1: World's First Cat 430 m AFC Underground in Germany 1998

Picture 2: Long-Life Cat PF6 Line Pan

Face-End Drives

Cat drives are rated according to the maximum torque level that can be applied. In the 1980s and 1990s, 15 and 25 series drives (25.000 Nm of maximum torque) were commonly installed with 250 - 600 HP per drive. Today the new standard has risen to Class 65, which is capable of 2 x 1.200 kW or 2 x 1.900 HP per drive. Bigger drives are under development. Single-piece sprockets, which are exchangeable without disassembly of gearboxes, are common today with modern Bucyrus drive frames. The head gate drive frame is normally the cross-frame style, while the tail drive is tensionable with a stroke of up to 1 m.

The automatic tensioning is done reliably using a Cat PMC-R unit. The stroke of the tensioning cylinder is measured via a reed rod sensor; a pressure sensor also supplies its information to the control unit, which in turn operates the cylinder according to the actual load on the AFC using electrohydraulic valves.

Picture 3: Cat Cross Frame

Gearboxes

For more than 60 years, Caterpillar has developed, manufactured and tested its own gearboxes for underground coal mining machines. Today these gearboxes are primarily used for applications such as shearers and automated plow systems, armored face conveyors (AFC), entry conveyors or beam stage loaders (BSL) and crushers. Gearbox designs include ranging arms and haulage units, down drives, bevel-spur gearboxes, planetary gearboxes, CST gearboxes (only for face conveyors) and UEL overload protection gearboxes (mainly for plow systems).

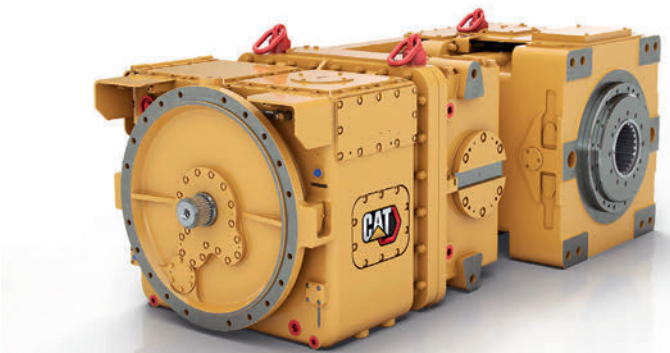
Caterpillar uses a high-power density design for compact dimensions, as well as high grade gears, which are usually case-hardened. All Cat gearboxes are characterized by high safety factors, higher availability and extended lifetime. High-quality housings made of ductile cast iron are used. The integrated water-cooling system is protected by yield valves. Heat exchangers are usually exchangeable without the disassembly of the gearbox. Special features such as an oil level sensor, temperature sensors, vibration sensors and oil sampling devices are being offered, depending on the type of gearbox.

The task of the gear engineering center is development of standardized gearboxes and drive systems. It further acts as the support- and competence-center for gears, gearboxes and drive technology. It is responsible for the supervision of gearbox production, assembly and testing, as well as carrying out RCA's (Root Cause Analysis), design and value analysis exercises. State-of-the-art tools for calculations, draft and engineering design are used. FEM analysis for critical parts – such as planet carriers, ring gears and gear cases – is carried out routinely.

Caterpillar uses high standard machine, assembly and quality processes for their gearbox manufacturing. Regular inspections of all incoming material and checks prior to machining and assembly ensure top quality. Prior to shipping, 100% of all gearboxes manufactured must perform and pass load tests.

The Caterpillar longwall manufacturing hub in Luenen, Germany, has a state-of-the-art gearbox test facility where monitoring of temperatures, torque, power consumption, speeds, water flow rates, lifting force and external cooling are continuously performed.

Picture 4: Longwall Gearbox Test Facilities



Picture 5: Cat CST45 Gearbox

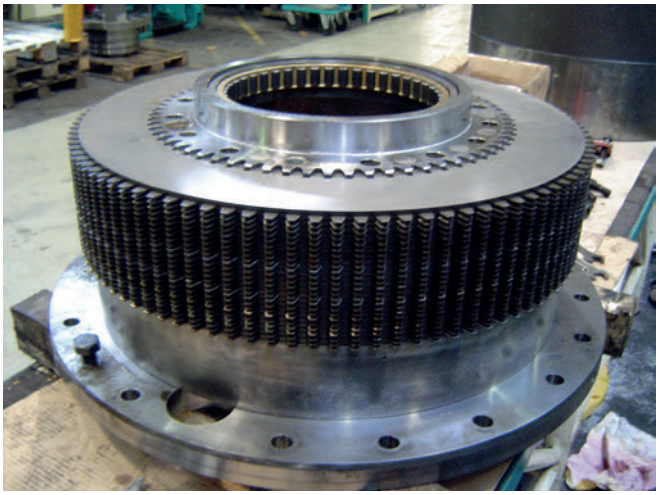
The Intelligent CST Drive System

The intelligent CST drive system is the result of a long-standing exclusive collaboration between Caterpillar and Baldor Electric Company and its predecessors starting as early as 1991. This development was specially made for AFC systems using the CST, a planetary gearbox and a sophisticated Cat control system. The Cat planetary gearbox includes an integrated multi-disc CST clutch by Baldor, proven in countless belt conveyor applications.

The CST consists of a wet reaction disc pack located at the output stage of a planetary gearbox. Varying the clutch pressure infinitely controls the torque transmitted to the output shaft.

The "supply" unit is part of the gearbox and is located at the motor side. This unit comprises a high-pressure pump for the clutch operation, high-volume cooling oil pump, heat exchanger, high-pressure filter, system hydraulic controls and a junction box for the connection of all sensors and actors of the drive control unit mounted outside the gearbox. To prevent overheating, a high flow of cooling oil is used during startup acceleration, normal operation and under overload conditions. The gearbox and the supply unit are permanently filled with oil for cooling, clutch operation and bearing lubrication; therefore, only one medium is required. The system works in a closed loop and is practically wear-free. The only external connections are the water lines for the heat exchanger and the cable to the external drive control unit.

Sensors measure input and output speed, clutch pressure, oil temperature, as well as other parameters. The main activator is the servo valve, which allows an infinite adjustment of the clutch pressure.



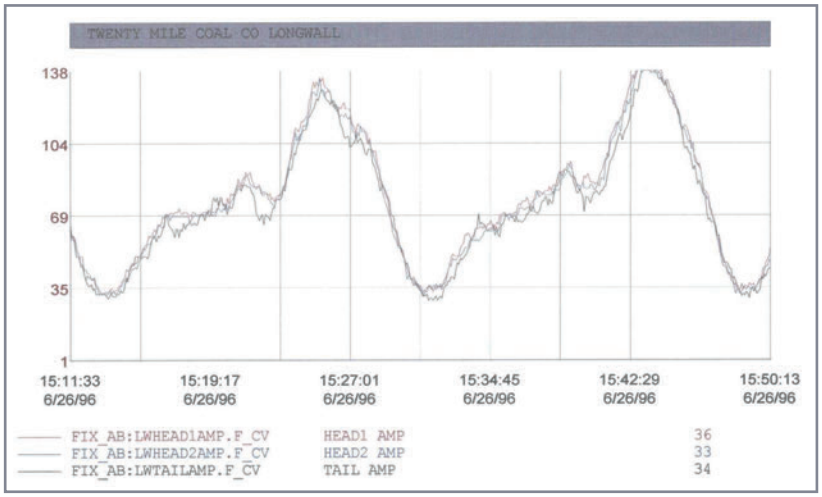
Picture 6: CST Clutch Pack

The system was developed, extensively tested and optimized between 1992 and 1994 at the Caterpillar facility in Luenen and also at the DMT (Deutsche Montan Technologie) institute in Essen, Germany, an independent research center for the coal mining industry. Rather than using a gearbox test rig, the system was successfully trialed on an actual chain conveyor with a length of approximately 80 m. The control algorithms were fine-tuned during these tests.

During the motor start, each clutch first operates at 100% slip, allowing a no-load start-up of the asynchronous motors. Individual motor start is staggered using time delays based upon the mine's requirements. This is extremely important to minimize voltage drop. After the last motor has reached its nominal speed, torque is applied first to the tail drive sprocket to pull away any existing slack chain and to avoid a possible chain breakage in the cross frame. Then, within milliseconds, torque is applied to the head drive sprocket by gradually reducing the slip at all of the drives simultaneously. Clutch pressure is increased until the required breakaway torque is reached. Because the drive control units are connected to a master-slave network, it is guaranteed that all drives will operate with the same start-up characteristics at all times. The full breakdown torque of all motors can be utilized at the same instant if needed. This allows starting of long face conveyors, even if they are fully loaded and carrying material that has an increased friction factor due to long downtime.

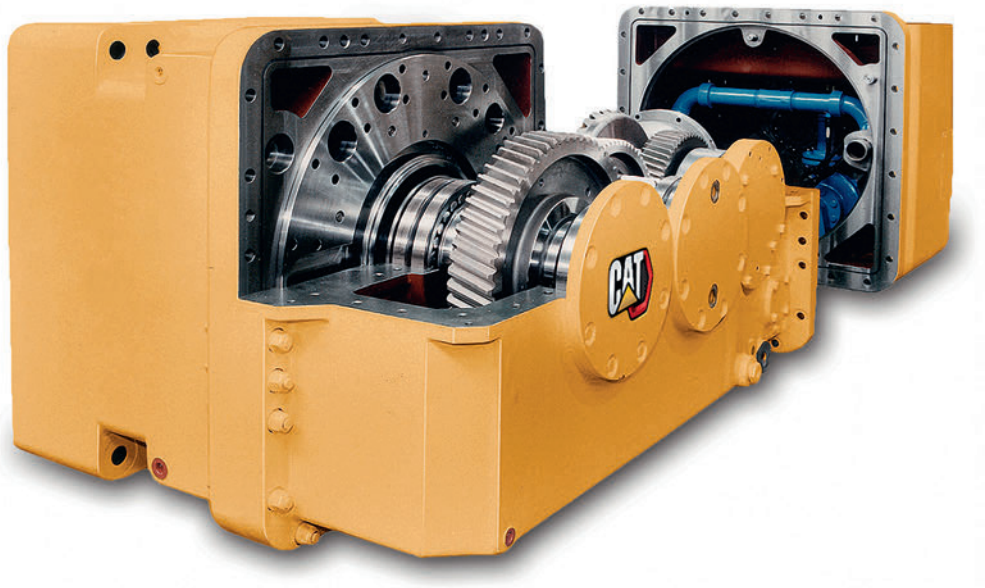
This is also important for soft treatment of the chain and for maintaining the integrity of the sprockets. This unique feature allows the use of motors with a breakdown torque factor of only 2.5 because all motors are synchronized to provide the same torque at all times up to the point of breakdown torque. All of these features create a superior CST drive system that will allow the start of the AFC in conditions where other drive systems simply will not.

The running slip is typically 0.2 % and the constant gliding friction allows the clutch to operate virtually wear-free. Accurate load sharing between the AFC drives is accomplished by constantly measuring the power consumption or current usage at all drives and adjusting the slip accordingly. A maximum running slip of approximately 0.6 % is sufficient for most operations, even when the chain is heavily worn out leading to uneven pitch, which is the major reason for different power consumption between the drives. That means the drive system efficiency is more than 99% at all times. This allows the operator to fully utilize the installed horsepower for the face conveyor to peak efficiency at all times, thus minimizing the risk of stalling in overload conditions and avoiding overheating of any of the motors, which eliminates the potential for downtime. Furthermore, it allows access to short-term power reserves for higher loads. The CST's durable design also maximizes the total operating time or useful life of the chain and the sprockets.



Picture 7: Accurate load sharing between three CST drives underground

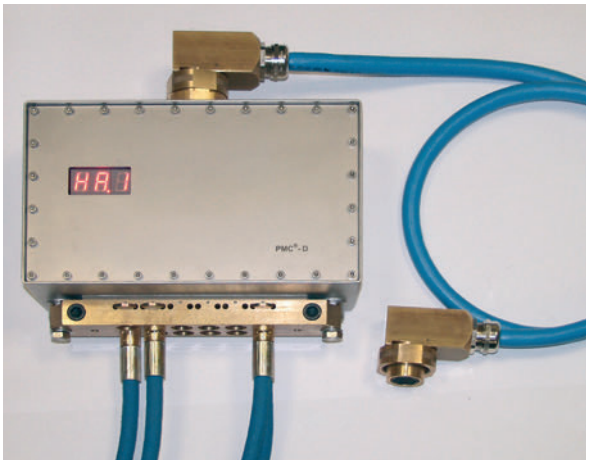
Excellent overload protection is achieved by constant measurement of input and output speed of each gearbox. The system immediately senses any oncoming chain jam and de-clutches all gearboxes at the same time. As the clutch is applied to the low speed high torque output shaft of the gearbox, the high masses of inertia, not only of the motor, but also of the gearbox, are immediately separated from the sprockets before a dangerous peak chain force is reached. The CST is the only intelligent drive system on the market today that can guarantee integrated safe overload protection for a high-performance face conveyor, thus giving optimum protection for all components of the drive train, especially the chain. Overload protection will become even more important in the future with the continually increasing installed horsepower.



Picture 11: CST Drive Systems Size 45 with max. 800 kW at 50 Hz (1,250 hp at 60 Hz)

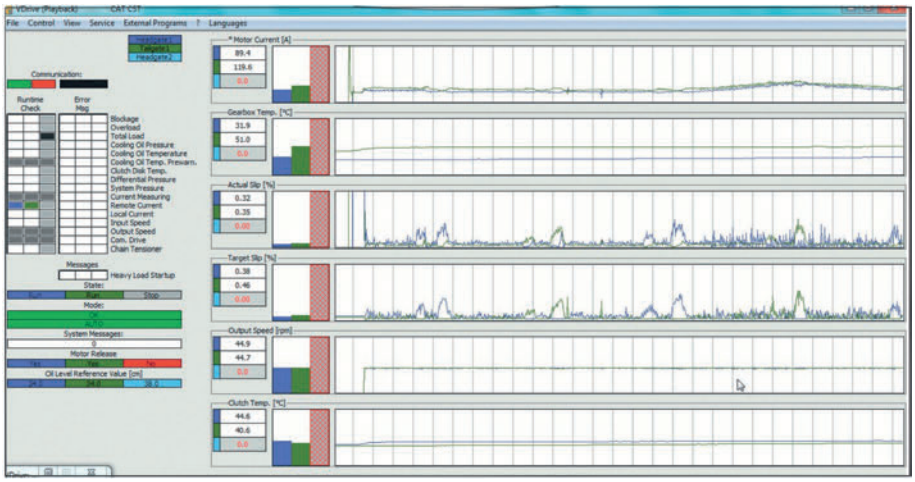
The Cat CST drive system was specifically developed for the operation of chain conveyors, unlike other systems available today that came from belt conveyor applications. The operating characteristics of chain and belt conveyor machines are completely different in terms of system length, stiffness and loading characteristics. Because the Cat design is based on chain conveyors, it allows for superior programming

of the CST drive system. The CST does not need any external water management system or water to be spilled onto the longwall floor. The overall water requirements are very low, with the CST using only about 25 liters per minute for its heat exchanger. The 0.2 % running slip – compared to 3 to 7% for other systems – means that the CST has much higher efficiency, which significantly reduces the mine's power bill.



Picture 8: PMC-D control system

Picture 9: PMC-V visualization unit



Picture 10: Visualization of CST date using V Drive software

The intelligent CST drive system offers benefits that are especially important for ultra-long face conveyor systems:

No-load motor start-up

- Allows freely programmable staggered motor start to avoid voltage drops

Synchronized AFC start-up

- Torque can be applied by all drives simultaneously independent from staggered motor start-up
- Soft-start of the conveyor with an adjustable speed ramp
- Synchronized AFC-start allows maximum total torque at all times and motors with less breakdown torque (BDT)

Accurate load sharing

- Maximum power utilization
- No overheating of AFC motors
- Minimum operational energy costs

Excellent overload protection

- Rapid overload protection by de-clutching before the actual overload occurs (no slip-stick effect)
- Minimum chain-breakages, minimum production losses
- Maximum life of all drive train components in case of chain jams

Minimum slip during operation

- Minimum power losses, minimum heat generation
- Maximum efficiency
- Low operating costs

CST clutch is mounted on the gearbox' low-speed side

- Optimum overload protection, shut-off at the sprocket
- Very accurate control of the slow-running clutch

Flexibility of operation

- Parameters for start-up, load sharing and overload protection are freely adjustable by the operator
- Implemented health monitoring features.

The first CST drive system was sold to Twentymile mine in the USA in 1994 and started operation in 1995. Since then, more than 400 CST gearboxes have been shipped from the Caterpillar plant in Luenen, Germany, to customers worldwide, including the USA, Australia, Germany, Poland, China, Russia, Kazakhstan and the Czech Republic. Not only have Cat CST drive systems been utilized on Cat face conveyors, but also to successfully upgrade third party face conveyors with a previously used inadequate drive system, particularly within the CIS region.

Currently the largest size allows 1.200 kW (1,950 hp at 60 Hz) per gearbox to be installed. Larger versions are under development for future requirements.

Summary

As the inventor of the armored chain conveyor, Caterpillar has consistently invested in research and development for all components of the face conveyor system. They are the leading expert for long faces with high-carrying capacity. In 1997, they supplied the world's first 430 m wide face with 3.2 MW installed power. Since then, several other long faces have successfully operated using the Cat CST industry-leading technology.

The Cat CST drive system features a soft-start and synchronized heavy-load start-up to smoothly start long, fully loaded conveyors, which helps extend the life of all drive train components. In addition, accurate load sharing allows the system to fully utilize the installed power of the face conveyor, which becomes more important as the face increases in length.

Process data logging by the Cat PMC-D using the V-Drive Software provides remote monitoring of the longwall face conveyor. Vibration monitoring of AFC drives is also possible with a Cat online monitoring system that is already proven in underground applications and supports preventive maintenance programs.

Several long to ultra-long face Cat conveyor systems have set production records in the USA, Australia, China and Germany and have established a benchmark for face width and productivity, which other operations worldwide strive to reach.

Picture 12: Compatibility Test for a Complete 400 m Long Cat Longwall

The Importance of Intelligent Drive Systems for Ultra-Long Face Conveyors

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