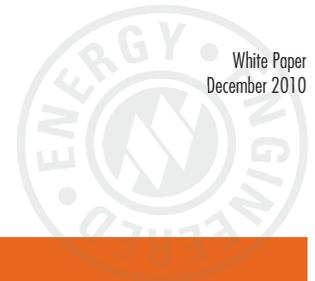


Mechanical Brakes and Modern Digital Controls Improve Safety, Reliability and Performance



Tom van Leeuwen
Facility, Product &
Development Manager

Aaron Kureck
Product & Development
Manager

Magnetek
Material Handling

INTRODUCTION

Overhead cranes and heavy moveable structures such as bridges, navigation locks and dam gates use a variety of electric controls and braking means to stop and hold loads, control deceleration, and provide accurate positioning.

This article discusses the evolution of modern spring-set industrial brakes in conjunction with modern digital controls, and how these work together to improve safety and extend equipment life, leading toward reliable and efficient operation.

EVOLUTION OF BRAKES

With the advent of the first electrically powered crane using individual motors in the early 1900s, the need for reliable braking means soon became apparent.

Hoists of early overhead cranes would typically include a crude (by today's standards) solenoid shoe brake. These brakes often did not use springs, but relied on the weight of the solenoid plunger to set the brake. They were designed to function either with a mechanical load brake or DC dynamic lowering controls providing two independent braking means. These brakes evolved into spring-set AC solenoid and DC magnet shoe brakes. Adjustable torque, spring-set, electro-hydraulically released thruster brakes were first introduced during the 1930s and provided smoother braking action for the loads handled with overhead cranes and heavy moveable structures.

Bridge brakes on early cranes and span-control brakes on heavy moveable structures were released and set by a foot pedal or hand lever directly connected by a mechanical linkage to a drum or band brake on the bridge drive. The eight 30,000-foot-pound brakes used to control the Congress Parkway Bridge in Chicago were still hand lever operated in 2010. These mechanical brakes were preferred over electric brakes because they allowed the crane operator to control coasting and load swing. However, they required frequent adjustment, and brake torque was limited by the amount of force that an operator could apply. This concept was later changed with the introduction

of foot-pedal-operated hydraulic brake systems.

Hydraulic systems were simpler for the crane designer, as only tubing had to be run to the brakes rather than a mechanical linkage. However, hydraulic systems can leak at connections, need bleeding to remove air from the system, and uneven tubing run lengths to multiple brakes can cause torque variations between brakes. Today, modern "brake-by-wire" packages with foot-pedal operated AC thruster brakes are preferred because they address these issues and provide operators with the same control of machine motion that they had with hydraulic brakes.

Trolleys on early cranes were typically not furnished with brakes and were allowed to coast to a stop or they were sometimes equipped with drag brakes that provided a limited amount of retarding torque at all times. Operators would frequently "plug", or reverse power applied to bridge and trolley motors, to develop a counter torque that slowed or even stopped the trolley or bridge in an effort to control load swing and position.

Newer brake designs include features such as automatic adjustment that compensate for lining wear and automatic equalization of shoe clearance that provides balanced braking and assures equal brake pad wear. These advances contribute to reduced maintenance costs and prolonged brake life.

Spring-set shoe brakes with AC solenoid release mechanisms have been phased out in favor of DC magnet brakes or AC thruster brakes. They provided very fast operation, but are no longer produced as they tended to require a lot of maintenance.

Until standardization of brake mounting dimensions occurred, each brake manufacturer had its own designs with different dimensions and electrical characteristics. As a result, brakes were not interchangeable between brands. Replacing these brakes today can be difficult, as many are not available or replacement is costly. Modern-design drop-in brakes are available that match mounting dimensions and torque of the original brakes – often at a cost less than that of a replacement coil or thruster. They can operate with existing brake wheels and avoid costly brake-support modifications.

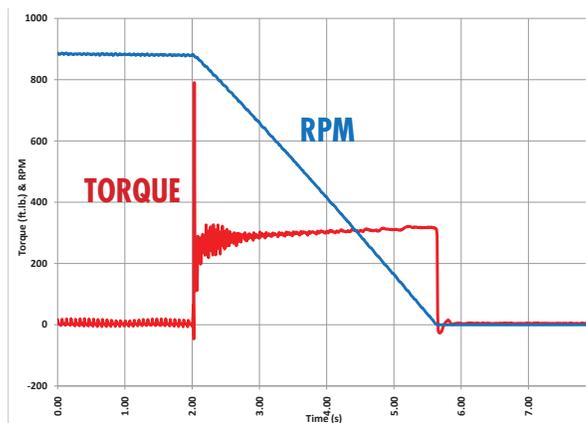
AC thruster brakes are being used today to replace aging DC drum brakes. Thruster brakes eliminate the need for AC-DC rectifier panels and have optional features such as stepless, externally adjustable time delays for both brake set and release, as well as external torque springs to permit maintenance personnel to “dial-in” just the right amount of stopping torque for traverse motions.

TYPES OF FRICTION BRAKES

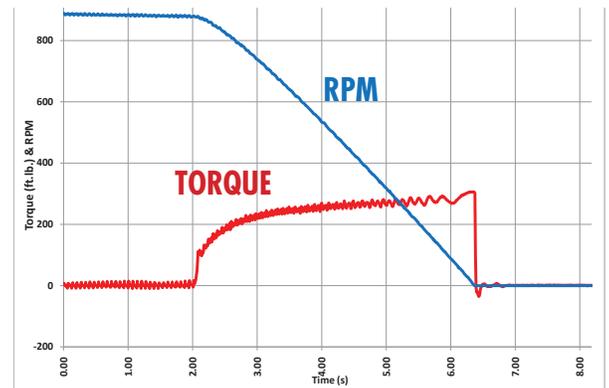
The rugged design and construction of shoe or drum brakes makes them the brake of choice for critical applications such as steel mill cranes and heavy moveable structures. They provide a retarding torque to the drive train by applying friction to a rotating drum through contoured shoes. Shoe brakes are spring-set and electrically released by a DC clapper magnet or AC Thruster. Spring-set, electrically released brakes are referred to as “fail-safe” because they automatically set if the actuator fails or power is cut.

The caliper disc brake consists of a plate disc connected to the drive train that provides retarding torque through friction pads, which grip both sides of the disc with a clamping action. Because of the large disc area these brakes dissipate heat easily and have a high thermal capacity. Preferred applications include container crane hoists, where the sintered metal linings can withstand extreme disc temperatures. Caliper disc brakes are normally spring-set and released by AC thrusters. Single caliper disc brakes apply substantial shaft and motor or gearbox loads that require careful analysis to ensure safety.

Thruster brakes (either shoe or caliper disc) give a smooth application of the brake by means of a torque spring. The inherent cushioning effect of the internal hydraulic fluid makes the thruster brake ideal for high-cycle or jogging applications as mechanical shock to the drive train and resultant component wear is virtually eliminated.



DC Magnet Brake Torque Curve



AC Thruster Brake Torque Curve

TYPES OF MOTOR CONTROLS

Many older cranes and heavy moveable structures utilize contactors to reverse motors and provide speed change, and rely on friction brakes for stopping. Depending upon the duty cycle, contactor tips and other moveable parts may have to be replaced frequently. Modern AC variable frequency and digital DC controls eliminate these mechanical parts as well as the need for inefficient mechanical load brakes and high inertia eddy current load brakes.

The following types of controls continue to be used on overhead cranes, hoists, and heavy moveable structures:

AC CONTACTOR CONTROL

Single and two-speed AC magnetic controls are the most basic type of crane controls and are still used on light and moderate duty cranes and hoists. However, the latest generation of low-cost, compact variable frequency drives (VFD) is competitive with contactor controls and has become the control of choice for the vast majority of applications.

Three-step and five-step control, using wound-rotor motors and secondary resistors, found on early cranes has already been replaced by variable frequency and flux vector controls using low-cost squirrel cage motors. Not only have variable frequency controls proved to be less costly, they also provide enhanced performance and improved duty cycles over multi-step contactor control. The high cost and poor availability of wound-rotor motors and eddy current load brakes has also hastened the demise of wound-rotor controls.

AC STATIC STEPLESS

AC static stepless controls were the forerunner of modern crane control. They use wound-rotor motors, solid-state components, and stepless induction master switches to provide infinitely variable speed and torque control. With AC static stepless control, creep speeds of 10:1 are possible. It is called “stepless” because it varies the motor

speed by changing the inductance of a wound rotor without the use of speed step magnetic contactors and resistors. The rate that the crane accelerates or decelerates is completely under the operator's control – only limited by available torque and how quickly the operator moves the master switch. Plugging control is integral on most traverse systems.

However, AC static stepless controls have drawbacks. They are expensive and use many components such as saturable reactors, transformers, and/or thyristors. The poor output waveform and fixed secondary resistor result in poor efficiency at reduced speed, which may produce excessive motor heating, especially during prolonged low speed operation. Bridge-and-trolley systems have a tendency to accelerate to full speed when lightly loaded and accurate speed regulation can be a problem. In addition, systems with saturable reactors require a large amount of space and add considerable weight to a crane.

DC CONTACTOR CONTROL

DC magnetic controls are primarily used with DC-series wound motors. Historically, these have been used in steel mills and other severe duty applications. They have the advantage of providing normal speed under rated load and higher speeds (over-speeding) under no-load or light load conditions. While high production can be achieved with this type of control, it does not allow for accurate positioning of loads. This type also tends to be maintenance intensive due to the many moving and wearing parts that must operate under severe duty and in harsh environments.

DIGITAL DC MOTOR CONTROL

Digital DC controls (DDC) employ semiconductor technology, which provides better control of motor speed and torque than contactor control. DDC controls are microprocessor based, solid-state, four-quadrant DC-to-DC controls designed for series, shunt, and compound wound motors and are a compact replacement for traditional contactor control. In addition, energy savings can be significant as DDC drives recover energy from the load and return it to the DC power supply.

AC has become the power source of choice, especially for new installations in paper mills, steel mills, bulk materials handling, shipyards, and many other areas. However, DC motors are efficient, robust and long lasting, providing acceptable performance for demanding applications. Digital Static Drives (DSD) are microprocessor-based digital logic controllers that deliver precise, repeatable AC-in/DC-out control of DC shunt-wound bridge, trolley, and hoist motors while significantly reducing operating and maintenance costs. This control has the performance characteristics

and many of the same advanced features of AC variable frequency control. It can be an economical drop-in replacement for those machines already equipped with shunt-wound DC motors.

AC VARIABLE FREQUENCY CONTROL

AC variable frequency drives reduce the characteristic high starting currents of AC induction motors, 300 – 400% inrush, to less than 150 – 200% (depending upon the drive selected). This minimizes shock applied to both the load and the equipment, ensuring smooth movement of loads and prolonged equipment life.

VFDs provide controlled programmable acceleration and deceleration, permitting a softer stop and start. With electronically controlled deceleration provided by the VFD, friction brakes normally perform the function of holding, not stopping the load, which greatly reduces brake wear and results in longer brake life. The longer brake life pays dividends when the power fails or an E-stop is required because the brake will be able to perform its function and bring the motion to a controlled stop.

Most single-speed squirrel-cage motors can be controlled by VFDs, including conical-rotor motors used by many European hoist manufacturers. Multiple speed control modes (two, three, and five step or infinitely variable speed) allow customization to suit the needs of specific applications or the desires of individual operators. A wider range of selectable speed choices (up to 1000:1) are available to the user compared to the fixed speed ratios provided by typical two-speed motors (2:1, 3:1 or 4:1) or micro-drives (10:1).

Modern VFDs can include safety features that reduce the possibility of lifting an overload, monitor brake function, minimize or eliminate load swing, prevent overheating of the motor, and provide safeguards to limit unauthorized or unsafe modification of drive programming.

DIGITAL CONTROLS AUGMENT FRICTION BRAKES

Modern variable frequency drives include safety and performance features that work in conjunction with friction brakes to enhance the safety and performance of overhead cranes and heavy moveable structures. They include:

- **Load Check™** – reduces the possibility of lifting an overload. When an overload is detected, this feature prevents further lifting but permits safe lowering of the load.
- **Load Float™** – allows loads to be held in position at zero speed without setting the brake. This feature permits accurate positioning of loads and reduces wear and tear on the brake's operating mechanism.



- **Sway Control** – minimizes load swing, reducing the potential for injuries and equipment damage.
- **Roll Back Detection, Torque Proving at Start and Brake Check at Stop** – monitors brake functionality at start and stop. This feature prevents the brake from releasing until sufficient motor torque has developed at the start of motion and checks that the brake has sufficient torque to hold the load at stop.
- **Snapped Shaft Detection** – this feature can detect that something has failed in the drive train by comparing the outputs of encoders mounted on the low speed and high speed shafts.
- **Reverse Plug Simulation™** – allows the controls to simulate a more aggressive acceleration and deceleration by using alternate acceleration and deceleration times while plugging.

PERIODIC EVALUATION IS ESSENTIAL

While the combination of sophisticated digital controls and modern mechanical brakes can bring enhanced performance, safety, and reliability to cranes and heavy moveable structures, it is essential that the control scheme be well conceived before implementation. Once the plan for the control system has been finalized, implementation should be carried out according to the plan, with appropriate testing of the safety features and proper setup of all mechanical and electrical elements of the system. From time to time, control systems should be evaluated to determine whether an update would provide performance or safety benefits.

An example of an underperforming control system was presented when a crane owner contacted one of the authors regarding a hoist brake drum that had turned blue. It was found that the crane operator had picked up a load perhaps 50% over the crane's rated capacity. The control was able to sustain the overload for 60 or 90 seconds, but then shut off its outputs to protect the drive and motor. The brake was sized for 125 – 150% of the full-load torque in accordance

with industry standards, and although the brake was unable to hold the overload, it still had sufficient torque to slow the load on its way to the floor. The wheel turned blue because of oxidation due to overheating. Most of the potential energy of the load was absorbed by the brake wheel. The problem could have been prevented if the drive used on the hoist had included a load check feature that was enabled by proper programming. Had the crane control system been evaluated to determine if current features needed to be upgraded, the load check feature could have been implemented and the unsafe lift would have been prevented.

CONCLUSION

Full featured AC and DC digital drives are the preferred method for control of cranes and heavy moveable structures, when used with "failsafe" mechanical braking systems. Combined, they form an effective electro-mechanical motion control system.

AC variable frequency and digital DC drives with features such as load float, load check, torque proving/brake check, snapped shaft detection, sway control and reverse plugging simulation can improve equipment performance and safety if properly implemented.

Spring-set friction brakes with features such as automatic adjustment, which compensates for lining wear, and automatic equalization, which provides balanced braking and equal brake pad wear, go a long way in reducing maintenance costs and prolonging equipment life.

Equipment owners should have electrical control and braking systems periodically evaluated to make sure that the many features that are available are fully implemented and that all control and braking systems are properly programmed and adjusted.

The combination of properly applied mechanical brakes and modern digital controls will assure that overhead cranes and heavy moveable structures will provide many years of safe, reliable operation.