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Applying Technology and Maintenance Practices to Maximize Uptime

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Introduction

As operational costs continue to increase for public works systems, the importance of reducing unplanned downtime is growing. Unexpected failures can knock systems out of commission for weeks and cost millions in repairs and user costs. An inoperative movable structure can result in delayed shipments, expensive re-routing, and various other negative impacts.

Movable structures such as bridges, sector gates, and locks face unique challenges over the course of their operational lifetimes. Exposure to harsh environments such as marine elements and weather can wreak havoc on equipment if it is not maintained properly. Equipment size requirements, fluid leakage, and emergency-stop (e-stop) conditions have also presented challenges.

New technologies, along with improved maintenance, can help address these challenges and prevent downtime in hydraulically actuated bridges. In bridges actuated by hydraulic cylinders, the cylinders have been improved to address common challenges faced by owner/operators. Unique sealing systems in the cylinders help prevent leakage, and laser-cladded weld overlays protect the cylinder's piston rods from corrosion. Advanced cushioning systems have helped minimize e-stop impacts of movable structural components. Low-speed, high-torque hydraulic motors have provided increased efficiencies and further minimized fluid leakage. Proper maintenance, regular inspections, and appropriate employee training provide additional measures to help operators and owners maximize uptime for the machinery that operates each movable structure.

This paper will highlight these technology and maintenance advances, as well as the best practices in machine set up and services that can help heavy movable structure owners and operators improve productivity and reduce maintenance costs by keeping equipment running.

Methods of Moving Heavy Structures

The types of movable structures considered for this paper include bridges, as shown in Figure 1; sector gates for marine applications; and other civil engineering applications. Two primary methods have been used to move these structures: electro-mechanical methods and hydraulic methods.

Figure 1: Bascule bridge.

Electro-mechanical movement of heavy structures has been accomplished through various techniques, primarily gear- and motor-driven systems. Electro-mechanical methods can be accompanied by various challenges such as:

- Size of equipment (weight and space/length)
- Alignment
- Couplings
- Torque density
- Corrosion of the drive line

Hydraulic movement of heavy structures can be achieved through the use of hydraulic cylinders (linear acutators) and motors (rotational actuators). Challenges associated with hydraulic movement include leakage of hydraulic fluid, corrosion of components, and e-stops of prime movers.

Fluid leakage can occur when a hydraulic system allows fluid to escape the system. Leaks can occur at fittings, hoses, pumps, valves, cylinders, and various combinations of components. Failures can often be attributable the presence of dirt in the system. Besides high fluid consumption, the economic effects of hydraulic system leakage include inefficient machinery operation, environmental damage, safety and accident liability, premature machine component failure, poor manufacturing quality, and increased capital costs.

Corrosion can transpire when hydraulic components are exposed to water and other environmental elements, as shown in Figure 2. Bridges over waterways are inherently exposed to water, which can lead to corrosion of steel components. In cold regions, salt and other de-icing chemicals can bring additional corrosive conditions. Structures in saltwater environments also face accelerated corrosion. Land-based structures may operate in less corrosive conditions, but still encounter dust, dirt, and other elements.

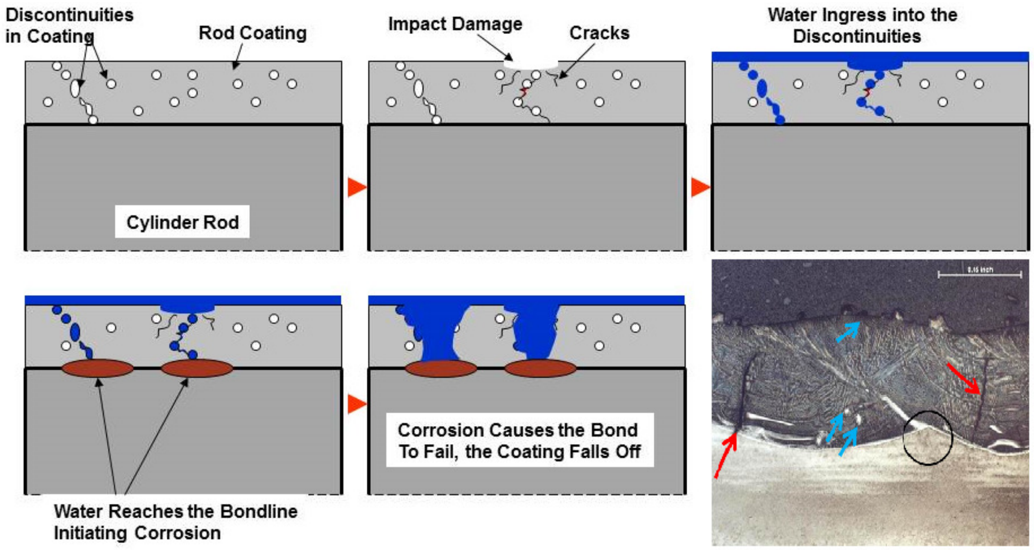

Figure 2: Illustration of how coatings fail on cylinder rods. Cross-sectional view of rod coating indicates large cracks (red arrows), porosity (blue arrows), and corrosion in deeply penetrated bond line (black circle).

E-stop problems occur when a movable structural component fails to decelerate and slams into another component. For example, a bridge span being lowered into position strikes a bridge abutment with excessive force, rather than being lowered gently onto the abutment. Various cushioning systems have been employed, but many cushioning options have proven inadequate to properly stop a runaway moving structure and have resulted in significant structural damage.

New Technologies Offer Solutions

New technologies have significantly addressed many of the challenges of hydraulic systems. Leakage of hydraulic fluid has been greatly reduced through high-efficiency, integral-brake motors, as shown in Figure 3.

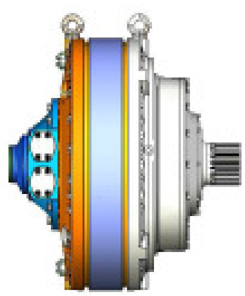

Figure 3: Exterior view of integral-brake motor.

Integral-brake motors feature an enclosed, wet-disc, brake design, with the brake on drive side of the load, directly connected to the pinion, as shown in Figure 4. With the brake located within the motor housing, rather than in an external assembly, the likelihood of fluid leakage is greatly reduced. This arrangement also reduces the potential for corrosion of the braking system and other components, as the components are not exposed to water and other environmental elements. Primary static integral braking technology on the drive side of the load helps lock the bridge to prevent wind from actuating the bridge unnecessarily.

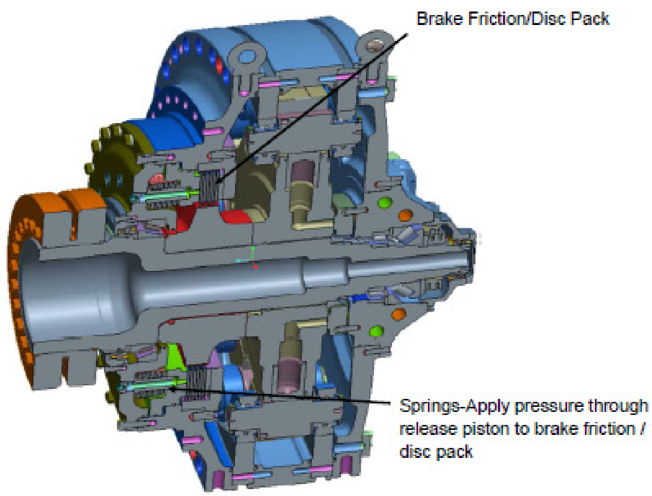

Figure 4: Cutaway view of integral-brake motor.

The efficiency of modern integral-brake motors can also increase their effectiveness in movable structures. With a volumetric efficiency of 99.5 percent, the case fluid flow in these motors is steadier than with conventional motors, which are typically rated at 97 percent or less volumetric efficiency. The steadier flow minimizes pressure spikes, which also helps reduce the likelihood of fluid leakage.

Corrosion problems on hydraulic cylinder piston rods have been greatly reduced through coating of key components with new technologies such as laser cladding [1]. This technique provides a metallic coating with a strong metallurgical bond between the coating layer and a substrate material, such as carbon steel in the case of cylinder rods. Using precise, state-of-the-art lasers such as the high power diode laser (HPDL) as a controllable heat source, metallic powder is injected into the system by nozzles. Energy from the laser beam produces a shallow, molten cladding pool. Filler material powder is injected into the beam and the pool. As the laser beam passes through the area, the cladding pool solidifies rapidly, leaving the desired build-up of cladding material with minimal dilution of the base material. The result is a protective coating including the following characteristics:

- Optimized corrosion, wear, scratch, and impact resistance
- Optimized ductility and strength
- Resistance to bending
- Consistent coating depth
- Strong adhesion due to the metallurgical bond
- Hardness throughout depth and length without cracking
- Optimized surface characteristics designed for longer seal life
- Certified production welds tested both destructively and non-destructively before and after the weld to verify superior quality
- Field repairability

E-stop cushioning problems in hydraulic-cylinder-actuated bridges can be addressed through more advanced cushioning systems developed in recent years [2]. A multi-stage cushioning design that provides progressively adjustable deceleration can help avoid high-impact collisions of structural components. The progressive design expands on standard cushioning options using longer cushion spears and multiple needle valves arranged in a manner that gradually reduces the number of available needle valves in the return fluid flow path, allowing adjustable deceleration to fit a particular application.

Key factors to be considered when designing progressive cushioning systems include:

- Length of the cushion spear
- Calculating the load to be decelerated
- Sizing needle valves for optimum flow control

The Importance of Proper Maintenance

Hydraulic systems require proper maintenance and operating conditions for optimal performance. In particular, maintaining a clean environment and providing contamination control can improve system performance, increase component life, increase uptime and reduce repair requirements.

A systemic approach to contamination control can help establish system objectives and best practices to avoid contamination-related failures. This approach strives to clean the fluid sufficiently to eliminate contamination as a factor in the failure of system components. The first step in this approach is to set a target cleanliness level that accounts for the specific needs of the system. Once the target has been set, filters can be selected and positioned in the system so the target can be achieved. After the machine is in operation, system operators can monitor performance and confirm that the target cleanliness level is being maintained. This can be accomplished by sending a fluid sample to a particle-counting laboratory that provides cleanliness code data to established standards. Proper selection and placement of contamination control devices in a system can eliminate the vast majority of hydraulic system failures [3].

Integral-brake motors can reduce maintenance and repair costs due to their sealed environment. With the internal friction discs submerged in the operating fluid, external corrosive environments have no impact on the friction material and surfaces. This leads to longer friction life, and more reliable brake-holding torque throughout the life of the product, resulting in lower repair costs than those associated with external band style friction brakes.

Shaft-mounted, torque-arm-restrained brake motors can also reduce alignment concerns common to electro-mechanical solutions, reducing installation time during commissioning and routine maintenance activities. This mounting arrangement eliminates the need for redundant external bearings common with electro-mechanical drives.

Because the integral wet parking brake is self-adjusting for wear, no additional adjustments are required for the life of the installation. The 350-bar pressure rating, coupled with the extremely low inertia of the integral brake motor, helps meet the most demanding applications, including e-stops, and extends operating life, while reducing unplanned downtime common with electro-mechanical drives with high inertia.

Conclusion

The various challenges encountered in moving heavy structures can be addressed by modern technology and maintenance practices. Improvements in reliability and serviceability of hydraulic systems can address concerns of infrastructure designers and make hydraulic systems a viable alternative in movement of heavy structures.

References

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