HEAVY MOVABLE STRUCTURES, INC.
SIXTEENTH BIENNIAL SYMPOSIUM

September 19-22, 2016

HYDRAULIC DRIVES GET CONNECTED

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ABSTRACT

Bascule or draw bridges are today often driven by large hydraulic cylinders as a part of a hydraulic drive system. These cylinders can be designed to generate sufficient pushing and pulling force to position and hold the bridge leaf in any desired position. Although the concept of a hydraulic cylinder has not changed much over the past decades, the technology that is used has changed significantly.

Bridges can be installed in all kinds of environments, varying from inland to coastal, all with their own characteristics when it comes to corrosion. One of the most critical parts of the cylinder, the piston rod coating, can be adapted to satisfy the demands these environments require. The so called “Nexgen coating technology” has been especially developed for mild (fresh water) and harsh environments (salty or brackish water).

To monitor the position of the cylinders, and thus of the bridge, accurate position feedback is also required. There are various solutions for position monitoring available that provide limited information. During the numerous movements and long life time of the bridge and its drive system, it is very useful to keep record of the movements of the bridge. Today it is possible to integrate smart position monitoring with the sensor technology. Such provisions are common in automotive sensor technology. This gives the opportunity to generate and store extra information such as mileage (cylinder rod travel), number of movements, temperature, speed, operating time and accelerations over a period of bridge operation. This offers the possibility of remote condition monitoring of the cylinders and predicting/planning the correct maintenance activities. Modern technology allows us even to use our cell phones for this.

This paper will explain how to optimize the design of the equipment for the specific environment, integrate possibilities for condition monitoring and use the output for service activities needed which will maximize the efficiency and performance and eventually will result in a better stability in operation and less down time of the bridge. Another advantage is the possibility to predict Life Cycle costs which in the end will result in a lower Total Cost of Ownership (TCO) of the hydraulic system compared to costs of other solutions.

PROFILE OF AUTHOR

In his position as Sales Manager Large Hydraulic Cylinders for Civil Engineering, Hans Verschuuren is responsible for the sales of large hydraulic cylinders and providing technical support to global customers of Bosch Rexroth. After he completed his studies in Mechanical Engineering in 1995, he has been in his current position since 2007 in the civil engineering department of Bosch Rexroth Netherlands in Boxtel. During his career he has been involved in several hydro power & civil engineering projects, both technically and commercially.

Introduction

Traditional cylinder design

Traditionally a (large) hydraulic cylinder consists of a cylindrical barrel with closed end cap on one end and a cylinder head on the other. Inside the barrel a piston is connected to a piston rod which goes through the cylinder head and is attached to a counterpart (object, structure or machine) by means of a male or female clevis, often with an integrated spherical bearing. This subassembly, called the piston rod group, moves back and forth and gets its power from pressurized hydraulic fluid that flows through the connection ports on both end cap and cylinder head. Specially selected seals and bearing strips make sure that the hydraulic cylinder is free from leakage and is able to move fluently. It is also possible to have different mountings of the cylinder barrel like bottom clevis, trunnion, front, mid or bottom flange or feet to attach it to a steel or concrete structure. Depending on the requirements of the application and the environment, cylinder rod material may be structural steel, a high grade alloy or one of various types of stainless steel. Known piston rod coatings such as Chrome, Nickel Chrome or Ceramic (since the 1980’s) can be applied. Options like cushioning, manifold blocks and piping, drain plugs, ice scrapers and simple measuring systems are also available. The output of these measuring system can be used for determining the position of the piston rod compared to its original position.

Figure 1: Basic cylinder design

Maintenance or repair of the hydraulic system and its components will only be done on regular basis, as described in the O&M manual or after malfunction of the application caused by some kind of failure. This is always a bad timing and will in most cases be very time consuming and expensive to solve.

Nexgen cylinder design

Cylinder coatings

From miter gates to metal casters, from oil rigs to bridge equipment, large hydraulic cylinders (LHCs) are integral components in the functioning of the equipment in mechanically demanding and corrosive environments. The expected operational lifespan of LHCs varies based on their application, ranging from a few years to up to sometimes 50 years in civil applications. The design of this equipment and the materials utilized in these large-scale hydraulic systems are engineered to provide reliable performance throughout their expected lifecycle in the specific environmental conditions. On LHCs, maintaining the integrity of the cylinder rod which is exposed to environmental conditions in operation is essential for maintaining the long-term

operating life of the system. The rod surface also needs an appropriate coating to provide the correct, and durable, base for the cylinder's tribological system which exists between the cylinder head and the piston rod. It additionally needs sufficient mechanical properties and corrosion resistance.
There has been an evolution in the technologies used to create and apply these cylinder rod coatings. One of these technologies is High Velocity Oxygen Fuel (HVOF) spraying.
The HVOF sprayed metallic/metal matrix coating evolved from earlier generation plasma sprayed ceramic coatings. This evolution was driven by a desire to improve the corrosion resistance of rod coatings, particularly for applications where the piston rod is operated in harsher environments and is kept extended outside the cylinder for longer periods of time. Although the plasma sprayed ceramic coatings demonstrated effective rod protection, this is typically dependent on the quality of the plasma spraying process. If the plasma spraying process is not properly controlled, quality suffers, leading to early corrosion problems and excessive hydraulic fluid leakage due to damage to the sealing system. Also a low frequency of movement in combination with insufficient maintenance can influence the lifetime of the coating.

The HVOF process

HVOF spraying is a process in which a powdered substance is sprayed onto the surface of the piston rod. The particles are heated by a burning gas mixture of a fuel (e.g. hydrogen, methane) and oxygen. Subsequently, the particles are accelerated to supersonic speeds before they hit the substrate material. During this collision the partially molten particles undergo plastic deformation and rapidly solidify to form the typical 'stacked pancake' buildup of the layer. The HVOF gun is specifically designed for obtaining these high particle speeds.
The properties of the current generation of HVOF coatings are the result of thorough research and development. Two of such properties are coating porosity and oxidation level. Due to the buildup of the coating, there is always a certain amount of porosity and oxidation present in the final coating. On the one hand, porosity can accelerate corrosion; however, the porosity on the surface also acts as small oil pockets, which ensures a good tribological surface. A certain degree of oxidation adds to the hardness, flexibility, and wear resistance of the coating. However, if oxidation levels are too high, this can have a negative influence on the corrosion resistance. Controlling and balancing these properties through quality processes and HVOF process refinements have been the focus of coating development efforts.

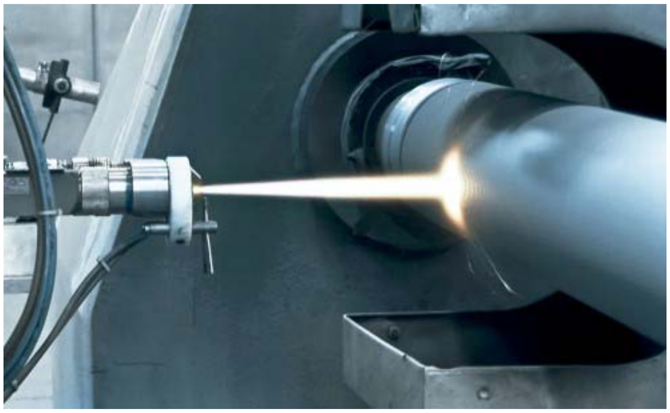

Figure 2: HVOF spraying process

Other points of attention when spraying HVOF are:
• Grit blasting technique and blasting materials for improvement of coating adhesion and preventing unnecessary oxidation.

• The chemical composition of the powder, the size of the powder particles and the production method of the powder.
• Better control of HVOF combustion characteristics such as gas flow and pressure, flame speed and distance and the design of the spraying gun.

Nexgen cylinder coating

From the beginning of 2017 a new development in first class piston rod surface technology from Bosch Rexroth will be available using laser cladding welding technology. With a powerful 20kW laser it is possible to apply a stainless steel coating in various compositions of the metal base powder and in different layer thicknesses. The composition and thickness will be adjusted to the demands of the application and environment, which means that there will be a solution for all applications, from high performance to less demanding applications.
The efficiency and speed of the process will make it even possible to eventually replace the traditional Cr and Ni/Cr coatings. This is shown in Figure 3, where costs of all common rod coatings are shown and compared to the laser cladded coatings. Besides development of cost, environmental demands will disqualify the production process of chrome coatings in the near future. The optimization of the process and the development of the in-house coating center have been done together with the renowned German research organization Fraunhofer Institute in Stuttgart.

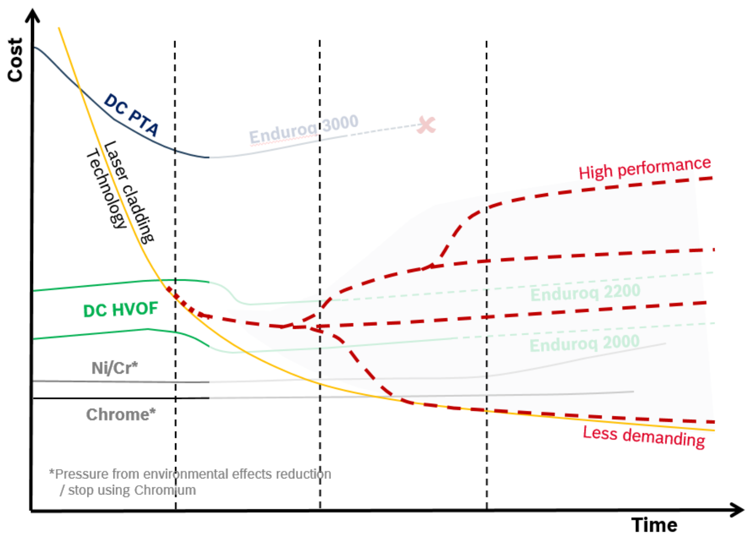

Figure 3: Cost development of various rod coatings

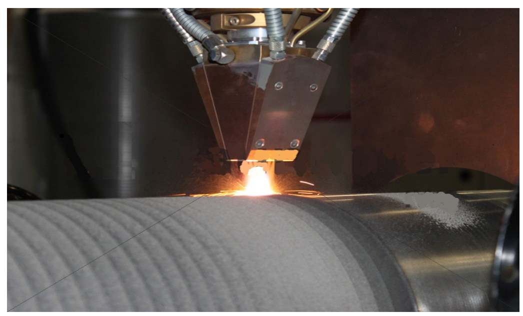

Figure 4: Laser cladding process

CIMS measuring system

Developing reliable and durable cylinder coatings has been a key technology challenge for LHC manufacturers. While various methods have been developed, both the HVOF process and laser cladding provide several advantages such as high corrosion resistance and high wear resistance.

Another big advantage these coatings offer is the possibility to integrate a measuring system into the cylinder. This so called CIMS (Cylinder Integrated Measuring System) is a contactless sensor that was developed in the 1980's and has had several upgrades to the electronics and the housing. Originally it was only designed to perform as any other measuring device and give feedback as to the position of the cylinder with high accuracy and independent of the stroke length.

The principle of CIMS technology is that the piston rod is encoded (incremental) with a trapezium-like profile in the ferromagnetic steel rod which is then covered with the HVOF or laser cladded coating; the combination of CIMS with the laser cladded surface has even been patented by Bosch Rexroth.

After applying the coating the rod is honed to the final dimension and roughness. This means that the coating thickness needs to be higher than the depth of the groove of the trapezium-like profile and the needed thickness to maintain other properties of the coating. When the sensor moves over the piston rod, a magnetic field will be generated because of the presence of a permanent magnet in the sensor. By placing Hall-effect sensors between the magnet and the rod at a defined distance, the sensors generate signals that can be converted into an analogue or digital position signal.

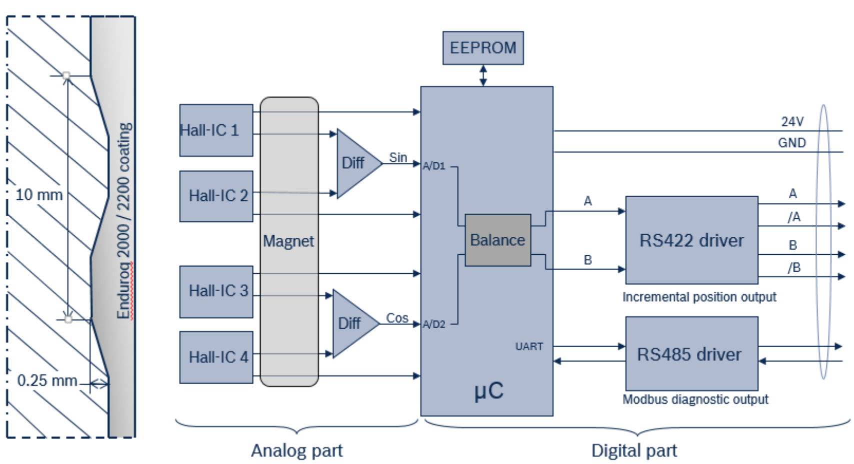

Figure 5: CIMS working principle

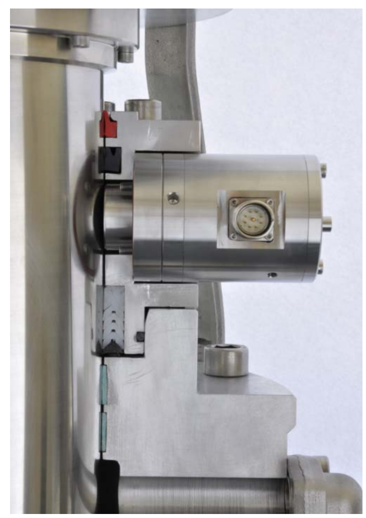

Figure 6: CIMS in cylinder head (cross section)

Cylinder intelligence; CIMSmart

Until 2015 the functionality of CIMS remained the same. However, due to a growing demand in mainly the offshore market, the sensor was upgraded in close cooperation with the Bosch Engineering Group that is also responsible for all Bosch automotive sensors. An additional condition monitoring functionality was added to it, which is important for any application that has requirements on uptime. For application condition monitoring to be successful, it is important to know relevant failure mechanisms of the product in detail and to store typical process data and process incidents. The sensor has the principle requirements for application monitoring on board. It continuously measures position and temperature, is fitted with a processing unit, has a data storage possibility up to 5 years and has an interface to access collected data. Two of the implemented properties derived from position signals are mileage (cylinder rod travel) and number of strokes. They both could be an indicator for a specific wear mechanism. Depending on the number of strokes and combined with the speed the piston rod is moving, it can give an indication on the lubrication status of the seals during movement and thus give an indication for preventive maintenance.

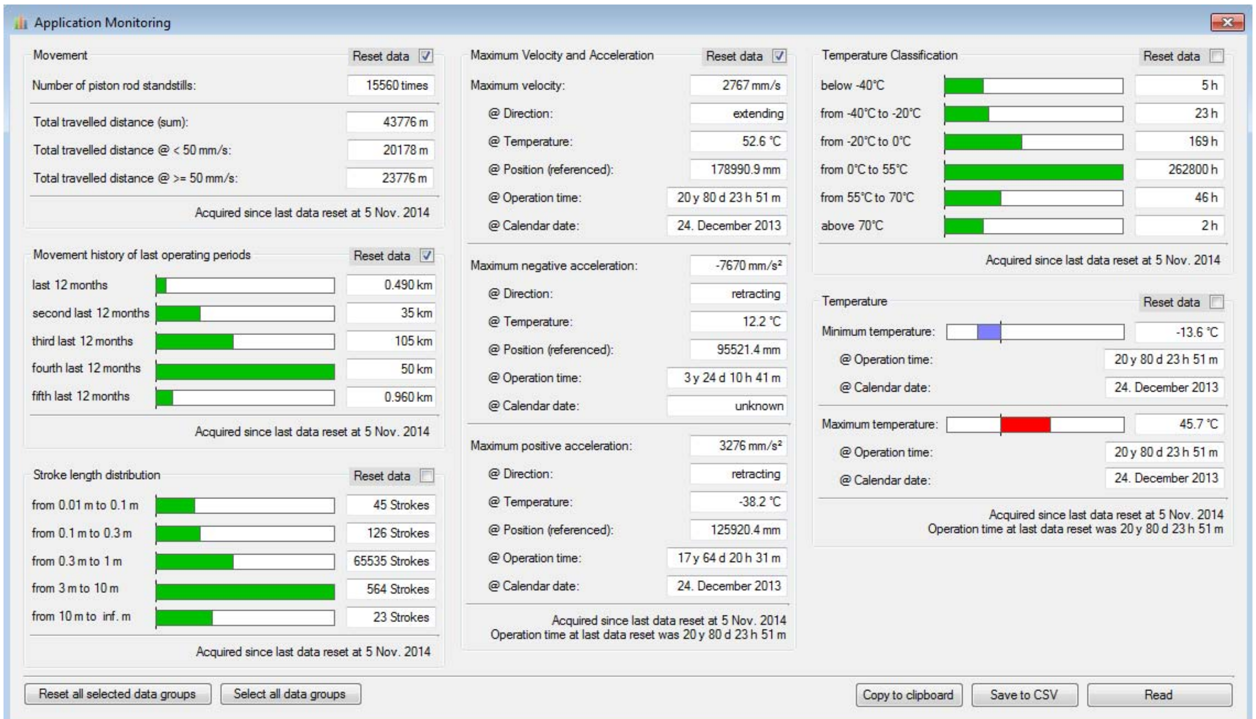

Figure 7: CIMSmart application monitoring User Interface

Conclusions and future outlook

Having the Nexgen Cylinder Design makes it possible to monitor the equipment, have condition-based maintenance, prevent failure, improve safety and plan future maintenance. Further developments by adding sensors (for e.g. hydraulic pressure, temperature, oil condition, but also accelerometers) will, when put at the right position inside the cylinder, increase the possibilities even more to monitor both the application and the condition of the cylinder. Eventually this will lead to more uptime and costs reduction, resulting in a lower Total Cost of Ownership (TCO) of the hydraulic system.

Together with an Online Diagnostics Network (ODiN), realistic condition monitoring is possible with large volumes of data that can be continually collected in real time. By using and analyzing the data, a health index can be created for each individual application. The great advantage of using ODiN is that failure models calculated using data mining are much more accurate than models that are created by hand. Thanks to ODiN's secure online connection, it is possible to read out the data and thus the status of the application from anywhere in the world.

This way of communication, data collection and analyzing fit perfectly in the basic thought of the upcoming Industry 4.0, where (in the future) machines can predict failures and trigger maintenance processes autonomously or self-organized logistics which react to unexpected changes in performance.

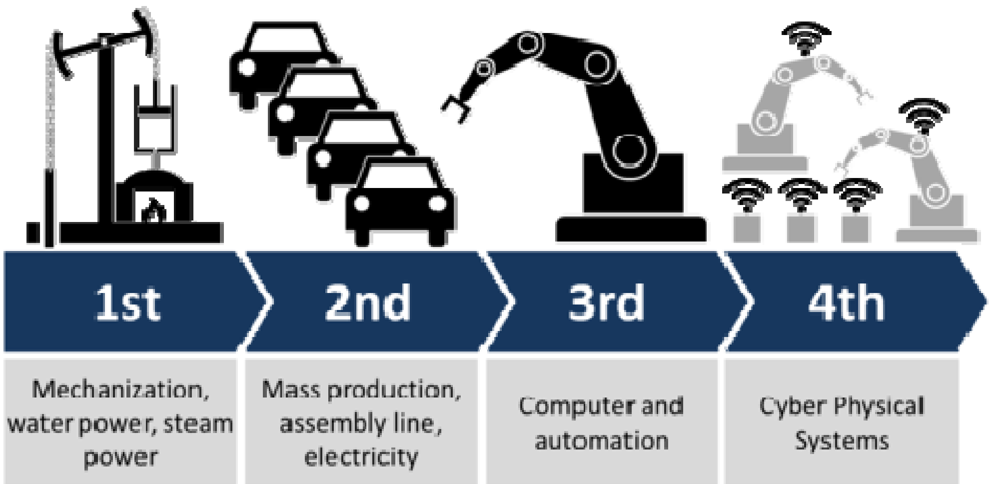

Figure 8: The four industrial revolutions

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