HEAVY MOVABLE STRUCTURES, INC.
TWENTIETH BIENNIAL SYMPOSIUM

October 7-10, 2024

Gearless Direct Hydraulic Drive with Variable Speed - Features and Benefits for Heavy Movable Structure Applications

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Introduction

The industrial drives market has always placed a high demand on equipment reliability, productivity, efficiency and performance. In today's competitive market place these demands are of even more interest.

Electro - mechanical drives have in the past been the traditional drive in this industry when variable speed has been called for. Today the Hydraulic Direct Drive solution can in many cases be an alternative to the electro-mechanical drives. The hydraulic drives has proved to be a real alternative on applications where Load sharing is essential and in applications where high starting torque is needed and flexible productivity at various capacity needed without sacrificing efficiency using modular flexibility. Hydraulic drives are used in many applications with increased popularity and reduced maintenance. Hydraulic direct drives utilise standard components and are very easy to install on the driven machine shaft without the need of gear reducers or foundation.

Basic concept of Direct Hydraulic drive

A direct hydraulic drive system consists of (Fig. 1a & 1 b)

1. a LSHT (low speed high torque) hydraulic motor (Fig. 1c)
2. Power Unit with pump / fixed speed E-motor /Hydraulic Reservoir
3. and an Electronic control system (Spider)
4. Hoses and Piping

In most systems, the equipment except the hydraulic motor is located in a sound insulated cabinet. The hydraulic motor and the pump are connected to each other by flexible hoses and/or steel pipes.

Figure- 1a, Direct Hydraulic Drive system from Hagglunds Drives.

Benefits of Direct Hydraulic Drive System

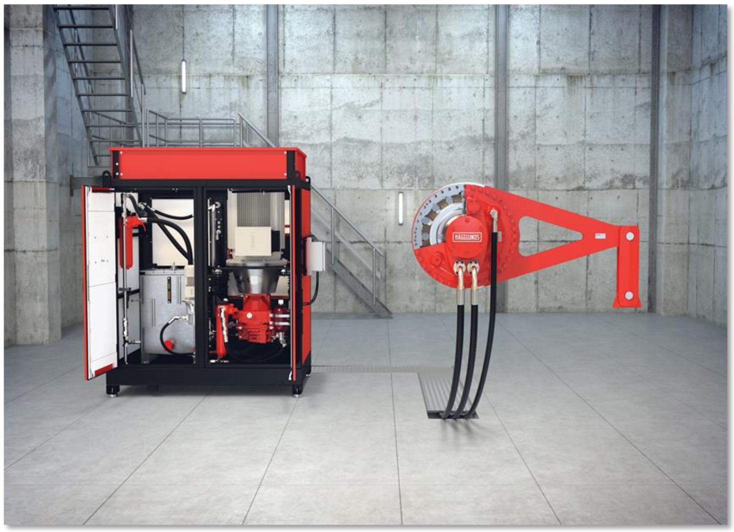


Figure- 1b, Direct Hydraulic Drive system from Hagglunds Drives.

The **Hydraulic Motor** (Fig 1c, 1d, 1e,1f) is a hydraulically balanced radial piston cam curve unit with a mechanical efficiency approaching that of a roller bearing resulting in outstanding torque efficiency (up to 98%). A torque arm is utilised to take out the reaction force whilst eliminating any other undesirable forces on motor bearings. Motor sizes available range from 2000 FT-LBf to 2,000,000 FT-LBf

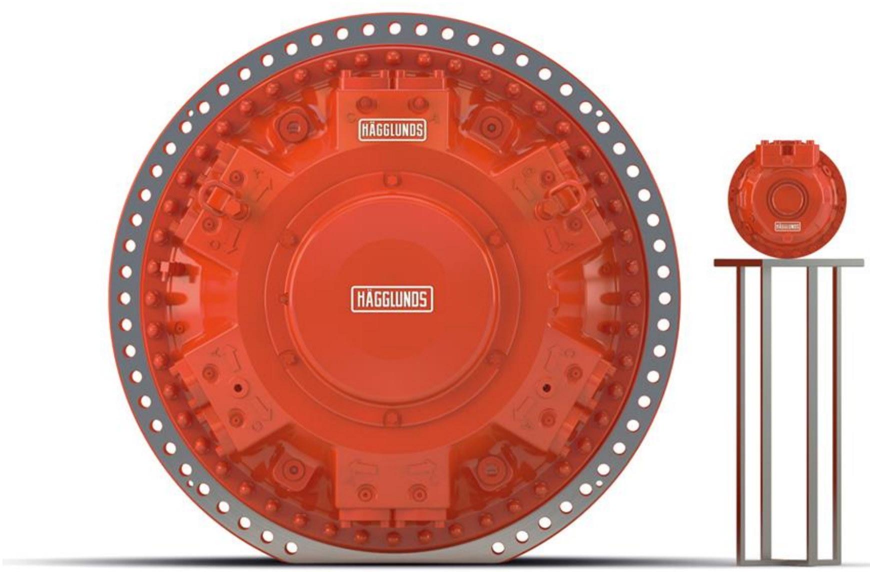


Figure- 1c, LSHT Low Speed High Torque Radial piston Motor size range available today.

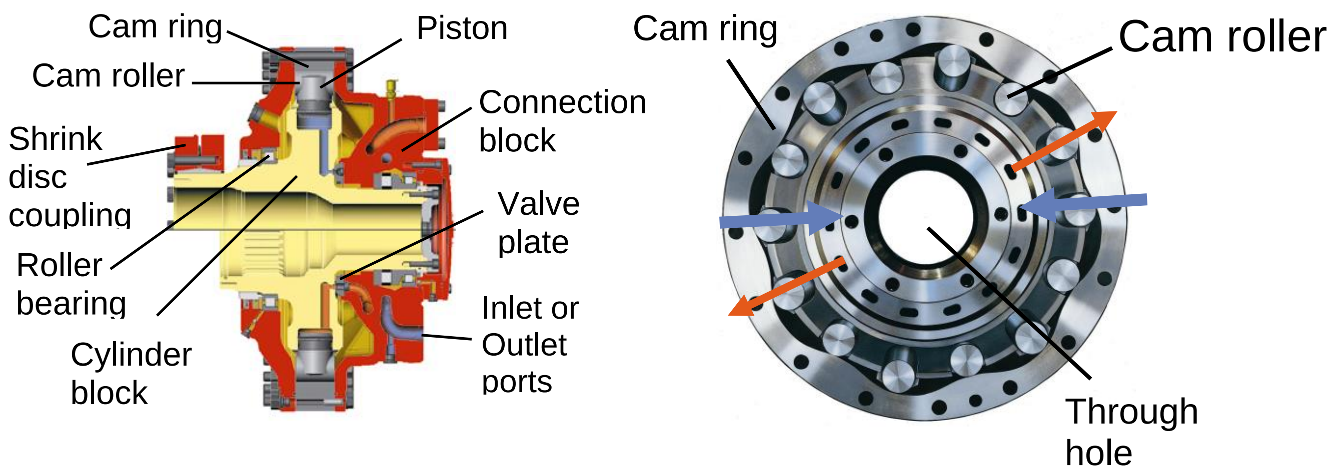
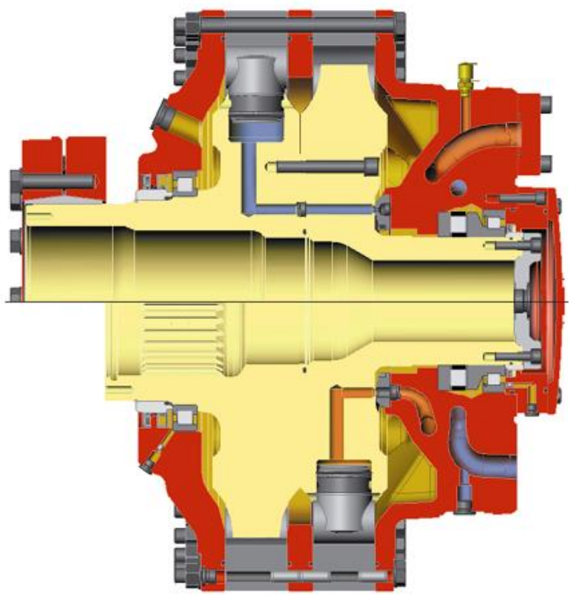


Figure 1e, Low Speed High Torque Hydraulic motor from Hägglunds Drives Inc.

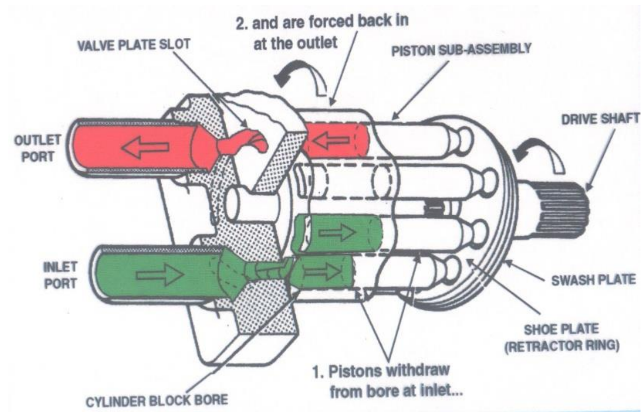


Modular Simple design

- Many sizes available, torque range from 2000 FT-LBf to 2000,000 FT-LBf. per motor.
- up to 3000 HP
- From 0 to 400 rpm
- Displacement;
- from 500 cc to 500, 000 CC / REV

Figure 1f Multiple Cam Rings motor (2 cam rings shown, up to 8 cam ring motors available)

The pump displacement is controlled by an electric signal



The pump flow is controlled by the angle of the swash plate

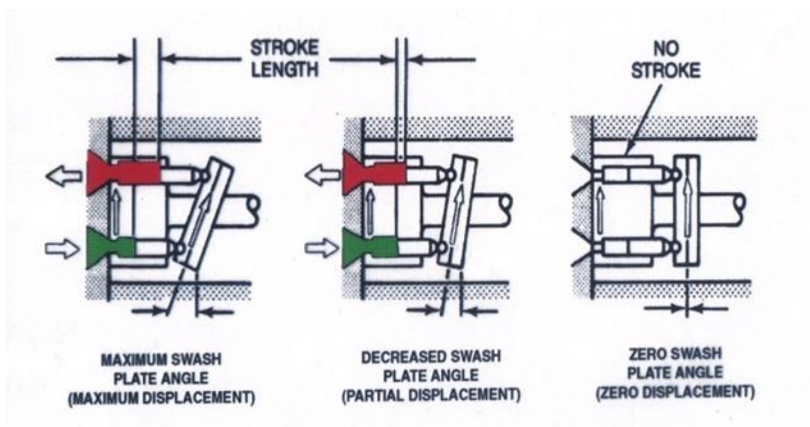


Figure- 2a, Variable Displacement Axial Piston Pump.

All main pumps are Axial Piston Pumps (see Fig. 2a) with Variable Displacement and constant direction of rotation at a maximum flow rate of each pump. Pumps are sized to application taking into account required flow rate as well as rotational speed of the electric motor.

The output flow of the pump is determined by the eccentric displacement of a swash plate. The displacement of the swash plate will be positioned by means of a piston inside the pump with electrically controlled solenoid located on the pump.

The three main features of the pump include pressure compensation, constant power control and flow control. Pressure compensation is defined as a maximum pressure limitation, when the hydraulic system pressure exceeds the pressure compensation set point the pump will reduce the flow to a level in which it can maintain the set point pressure. Constant Power Control is factory set to match the connected electric motor horsepower at max system pressure, when the flow/pressure combination reaches the power control set point the pump will reduce the flow to maintain a safe power draw on the electric motor. Flow Control is activated when below the parabolic power curve. Recommended compensator pressure setting: 350 bar (or 10-20 bar below cross-over valve setting)

The typical Hydraulic Power Unit is designed as a closed loop hydraulic system for continuous high integrity drive applications. The unit consists of a standard AC induction electric motor and a hydraulic pump. The electric motor starts up in an unloaded condition and runs at constant speed, driving the pump. The pump is a variable displacement unit, the displacement of which determines the flow and therefore the final speed of the drive.

Things to consider for Hydraulic system:

1. Setting of charge pressure
2. Hot oil return flow
3. Drain of motor and pump case
4. Filter of drain and return flow
5. Cooler in return line
6. Level and temperature sensors
7. Accumulators connected to pump
8. Speed encoder
9. Accumulator connected to high pressure line of movable roller side
10. Hose for hydraulic balancing

The pumps are driven by a fixed speed AC electric motors and provides output flow from either port A or B (bidirectional and symmetric). Oil goes from pump outlet to motor inlet forcing the motor to rotate and returns to pump inlet port. 20-25% of the oil comes from the closed system for conditioning. The conditioned oil is reintroduced to the closed loop again by a boost pump.

The speed of the drive is controlled by the oil flow from the hydraulic pump. The hydraulic motors are mounted directly to the HPGR shafts and its counter reaction force is managed by a torque arm.

To prevent cavitation an accumulator on low pressure side (7) is required. The accumulator is located in the drive unit close to the main pump.

Parallel mounted coolers are mandatory when more than one cooler (5) is required to fulfill the cooling. If they instead are connected in series there is a risk of failure due to pressure spikes in the return flow.

To cope with the excessive pressure spikes created in the system due to uneven material flow, accumulator (9) connected to the High pressure side of the movable roller is required. This accumulator provides the required damping and that the system is prevented from going into an unstable oscillation mode. This accumulator also helps by reducing the natural frequency of the closed loop hydraulic system to a level which is far from the oscillation frequency of the load due to uneven material flow.

To ensure that the torque is shared equally between the rollers, pressure balancing connection is required between the two hydraulic motors.

Accumulator on the High pressure side of the floating roller is mandatory to prevent uncontrolled natural frequency oscillations. The volume of the accumulator is dependent on piping volume and pre-charge pressure. As a rule of thumb, the pre-charge pressure shall be the half of the nominal load pressure. The pre-charge pressure shall never be greater than the nominal load pressure. The following table could be used as a guideline for selecting the minimum required accumulator volume in litres.

VI. THE CONTROL SYSTEM FOR HYDRAULIC POWER UNIT

The control system is a complete configurable controller developed to fulfill the control and monitoring demands of a hydraulic system.

The typical control system includes functions such as;

- Pump drivers
- Customer signal interface
- Local mode front panel with control buttons and indication display
- Monitoring of hydraulic system
- Speed regulators
- Pressure regulators
- Power limitation
- Drive logging

All functions are embedded in an IP65 Stainless steel enclosure with a temperature range of -40 to +50°C. The configuration of the system functionality is easily set from the local control panel or from a user-friendly software in a laptop connected via serial link to the motherboard.

The electrical signal interface to the factory system can be connected via discrete cabling with separate digital/analog cables for each function or via serial Fieldbus connection.

Harsh Environment

- Hydraulic motor withstands both very dusty applications as well as salty environments
- Hydraulic motor can be completely submerged under water
- Corrosion protection according to marine

Low Weight

- Easy to handle and maintain
- Reduced stress on the application
- Lighter construction
- No gears or gearbox is needed
- Reduced overall weight of the application

Single or Multiple Drive

- Single or multiple drive possibility
- Excellent load sharing
- 100 % balanced drives
- Reduced torsion/stress on the application
- High level of redundancy

Shock Load Protection

- Low moment of inertia and fast reacting hydraulic system protects application from shock loads
- Low additional stresses in the shaft and bearings from shock

Direct Hydraulic Drive for Radial Gates / Lift Bridges benefits;

- Excellent control of moving structures using closed loop direct drive
- Good retrofit possibilitiesc incl. torque arms, brakes and sensors
- Torques up to 2,800,000 Nm / Variable speed up to 400 rpm
- Low speed from 0.003 RPM
- Enclosed Disc Brake available
- High mechanical efficiency / Very compact drive / high power density

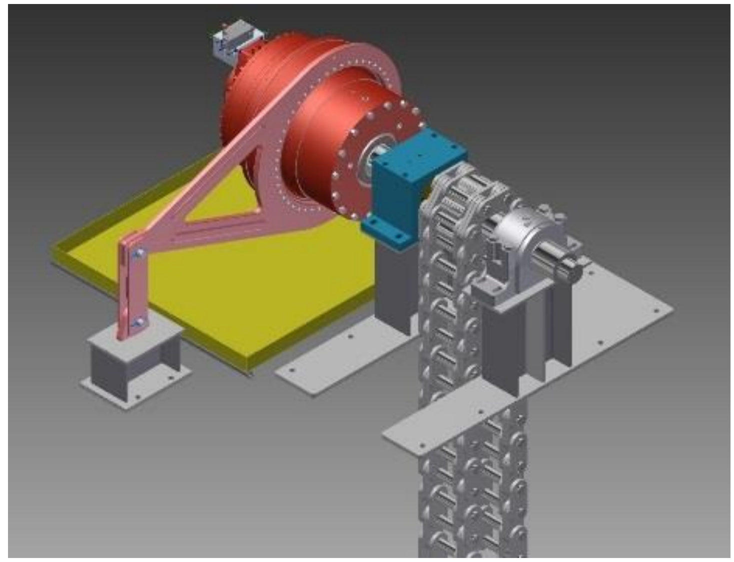


Figure- 2b, LSHT Low Speed High Torque Motor + Brake, Torque Arm arrangement concept for HMS.

Applications for HMS

Malpaso Dam Roller Gate Upgrade with Hydraulic Drive

The Malpaso Dam, see (Fig. 3a, 3b, 3c & 3d) officially Nezahualcóyotl Dam, was started in construction in 1958 as the first of several major dams in the highlands of Chiapas. To date, it has a capacity of around 10 million cubic meters and a maximum water surface of 380 square kilometers, being the second largest reservoir in the country. The 138-meter-high dam serves two functions: First, it protects the lowlands of the state of Tabasco from annual floods. This task is more important than ever due to climate change, because by the El Niño weather phenomenon, more heavy rainfall than ever occurs. On the other hand, there are six Francis turbines which produce 1080 MW electric power and thus contribute to a sustainable energy supply in the region.

The operator, the Federal Electricity Commission (FEC), regularly invests in the maintenance of the construction. Here are the safety, reliability and availability of all technical equipment always most important. The technical facilities of the dam built in 1958 are partly still original parts. This includes the hoist drives for the spillway gates. Mechanical equipment in Civil Engineering construction is usually designed for a minimum lifetime of 35 years (DIN 19704-2, 2014), however many installations have already exceeded their usual service life and need to be considered for retrofit and modernizations actions.

Figure- 3a, Malpaso Dam, Mexico. Radial Gate (Roller chain Gate)

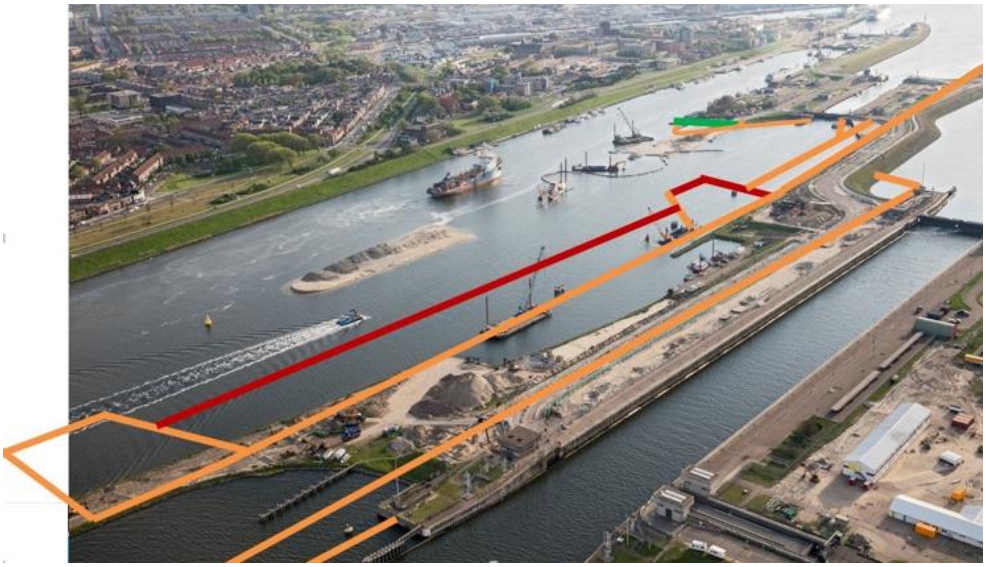
Figure- 3b, Malpaso Dam before retrofit (Existing E/M drive Original)

Figure- 3c, Malpaso Dam after Hydraulic Drive upgrade.

- Hydraulic power unit including weatherproof enclosure
- Local Control Panel with touch screen and remote control option
- Pre-manufactured pipework to reduce installation time

Figure- 3d, Malpaso Dam after Hydraulic Drive upgrade, New HPU redundant System.

New Sealock project Ijmuiden, Amsterdam, NL



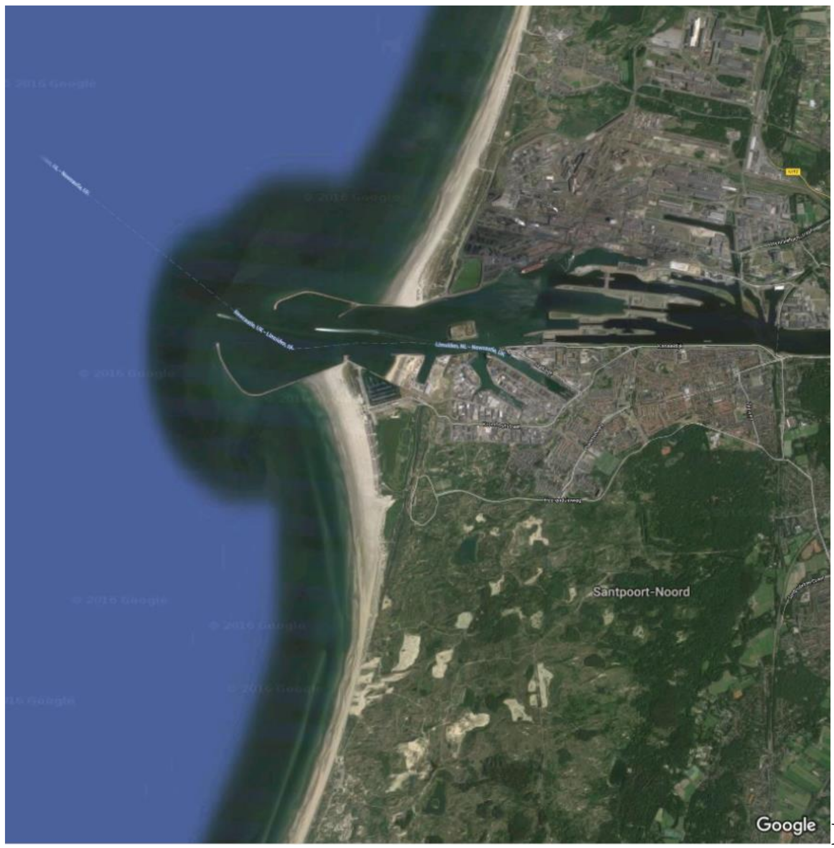
Figure; 4a; New lock planned 2014-2019 Left of existing old lock

Figure; 4b; New lock added to allow larger ships and retire 2 old locks-In operation from 2022

The existing North Lock will reach the end of technical lifetime in 2029. The lock has become too small for the new larger ships 70 m wide compared to 50 m wide before. New ships are 500m long compared to 400m long, 18m deep compared to 15 m deep. A new large sea lock allows larger ships safely and smoothly pass through the canal between Amsterdam and the North Sea.
New lock is built in between two existing locks.

Some backgrounds;

Weight of one sliding door 2400 Tons
Dimension of one sliding door 72 m x 24m x 11m
Damming from both sides, Locking cycles 24 hours / day
Opening / Closing time 4.5 minutes
Road traffic; vehicles with axle loads upto 13 Tons
Planned Maintenance 72 Hrs / Year
Unplanned Maintenance 18 Hrs / Year



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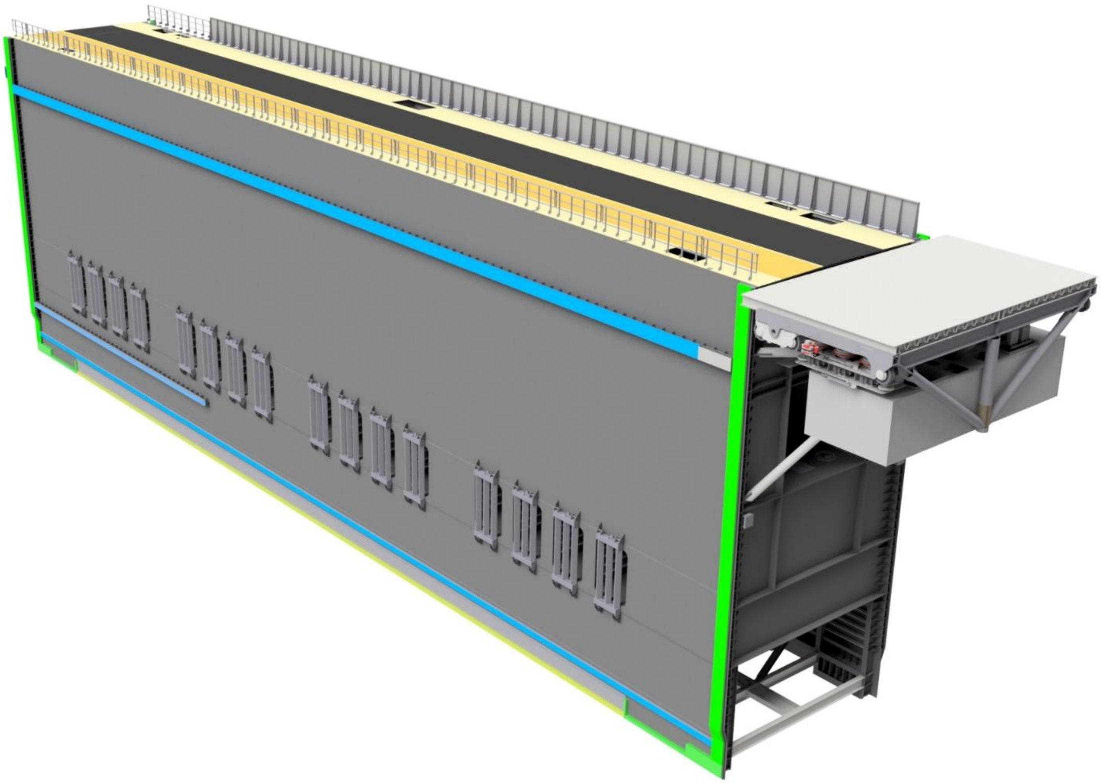
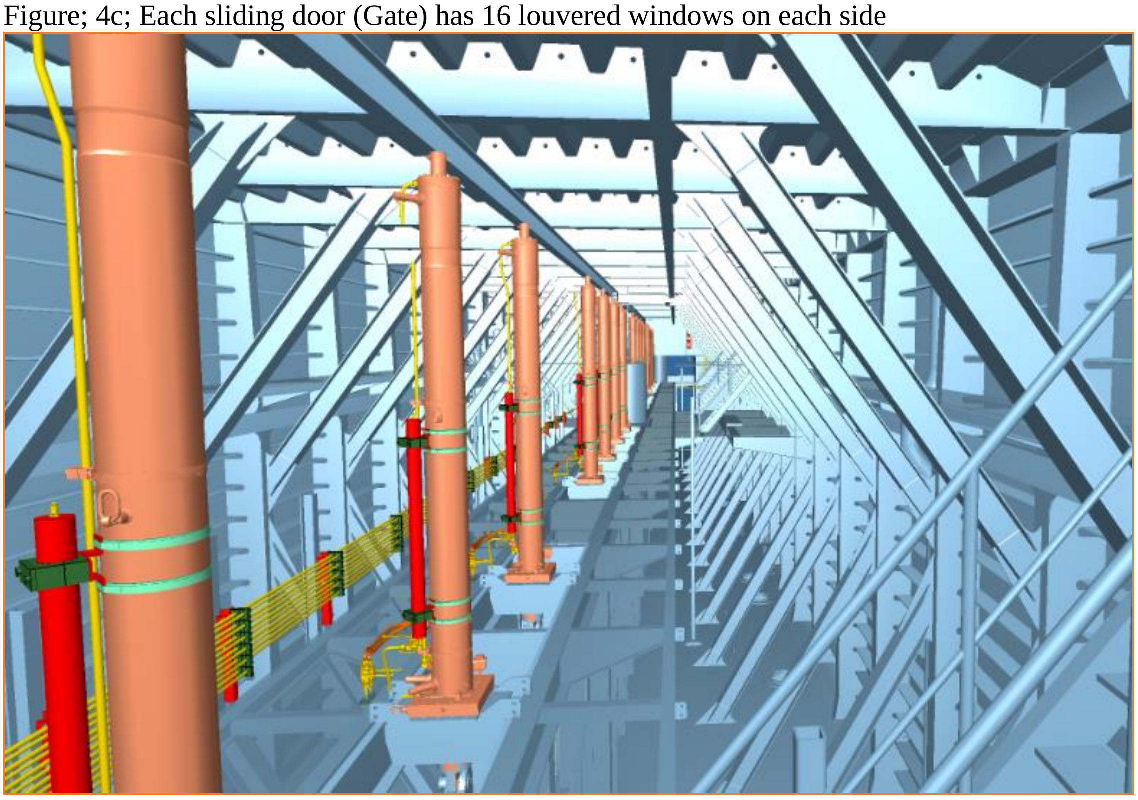
Figure; 4b; New lock with Direct Hydraulic Drive completed 2022



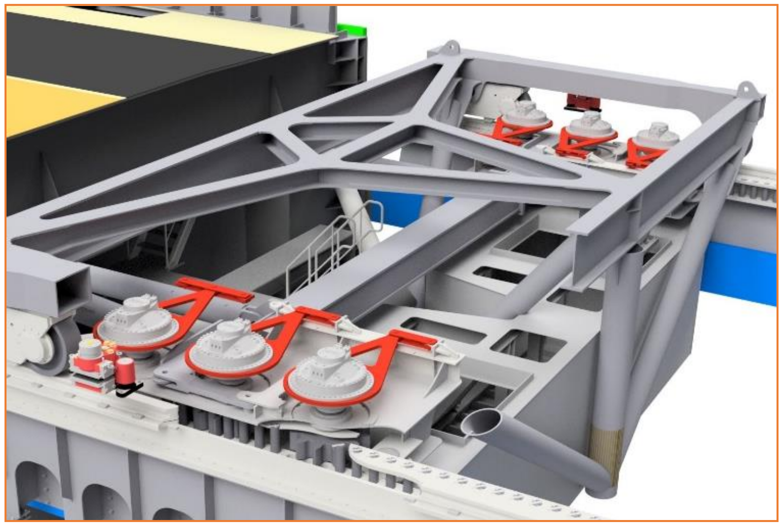
Figure; 4c; Each sliding door (Gate) has 16 louvered windows on each side



Figure; 4d; Balancing the load using 48 Hydraulic Cylinders with HPU for each sliding gat

Hydraulic Scope of Supply;

- 12 Hägglunds CB 560, incl.:
- torque arm
- absolute encoder
- flushing set
- harsh environment kit
- special painting
- 4 HPU's,:
- V = 1700 L
- P = 3 x 110 kW,
- Q = 3 x 323 l/min
- p = 180 bar
- ss interconnecting piping
- amplifiers pumps
- hydr. oil / commissioning
- hardware monitoring



Maintenance - Direct Hydraulic drives are getting more and more user friendly and more and more applications are utilizing the features and benefits of DHD in increasing the growing demand of productivity. The experience from many of these applications have allowed DHD professionals to optimize new and improved ways to provide long-term reliability and reduced maintenance. DHD does require some skills and training, which is well within the capacity of a typical process plants.

Size of Equipments - DHD uses modular multiple Electric motors / Pumps and Hydraulic motors, these items are standardized readily available produced in reasonable volume compared to a large electric motor and Gear reducer used for VFAC drives. Even larger Hydraulic motors are made from many common parts from several different motor sizes.

Environmental Aspects - DHD does require handling Hydraulic fluid, which is an environmental hazard. The design of DHD is such that it is a sealed system and uses mostly o-ring type fittings and connections, which are made for industrial quality and for the process industrial. Mostly routine commonsense type maintenance practice is needed. Also oil companies are coming up with environmentally friendly high performance synthetic oils.

Conclusion

The number of direct hydraulic drives in the industrial drive market is increasing steadily. In applications where variable speed is needed, high starting torque is required, power sharing is essential or where shock loads occur frequently, hydraulic direct drives should seriously be considered. The closed loop hydraulic system has also proven to be insensitive for harsh environments which mean a low maintenance cost for the drive.

Direct Hydraulic drives have made Technological advancements and are getting more user friendly with increasing training efforts by industries. Hägglunds Drives, Sweden has delivered Over 150000 LSHT Hydraulic motors have been installed over past 65 years and demand is steadily increasing.

Besides Civil Engineering these types of drives are used in other process industries like Mining & Materials Handling, Pulp and Paper, Chemical, Rubber and Plastics, Recycling and Steel. All these industries want to have the highest possible reliability and a low life cycle cost. These demands can be fulfilled by using a Hydraulic Gearless Drive (DHD).

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