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"NEW CONCEPTS OF HYDRAULICALLY OPERATED STEEL STRUCTURES"

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NEW CONCEPTS OF HYDRAULICALLY OPERATED STEEL STRUCTURES

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ABSTRACT

Traditionally, electrical or electro-mechanical drives have been used to operate steel structures like bridges, locks, gates or large valves. These drives, though reliable, are custom built and need constant maintenance. Also, transmission over large distances, stringent safety regulations and high demands on controls make Hydraulic drive and controls the obvious choice.

Properly designed electro-hydraulic systems provide an economical solution to complex needs. Advent of microprocessor has increased the scope of these drives tremendously.

This paper deals with the comparison of hydraulic drives with commonly used mechanical drives. Discussions involve use of environment friendly fluids, PLC based controls and high pressure hydraulic systems. New system design concepts will be discussed.

HISTORY

Most of us gathered here today have been involved with Civil construction projects like movable bridges, hydro-electric power plants, irrigation and navigational systems, flood control systems, etc., etc.

Most of these projects involve operation and control of bridges, gates, and valves.

Following are the requirements of a typical drive system.

A) Drive should be simple and reliable.
B) Low maintenance / easy to repair.
C) In case of power failure, still possible to operate (via emergency power or manually).
D) Compact.
E) Cost effective (considering the initial operational and maintenance costs).

These requirements can be achieved in any of the following ways:

1) Electrical drive.
2) Electro-mechanical drive.
3) Electro-hydraulic drive.

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ELECTRICAL DRIVE

Use of pure electrical drive for opening and closing, and control of bridges and gates, although it sounds simple, is not practical due to the required force (torque), location, controllability, physical size, and reliability, etc.

ELECTRO - MECHANICAL DRIVE

Typical electro-mechanical drive has electrical motor, reduction gear, chain / belt drive, gear box, and the crank system, etc.

See figure 1 for typical electro mechanical drive application.

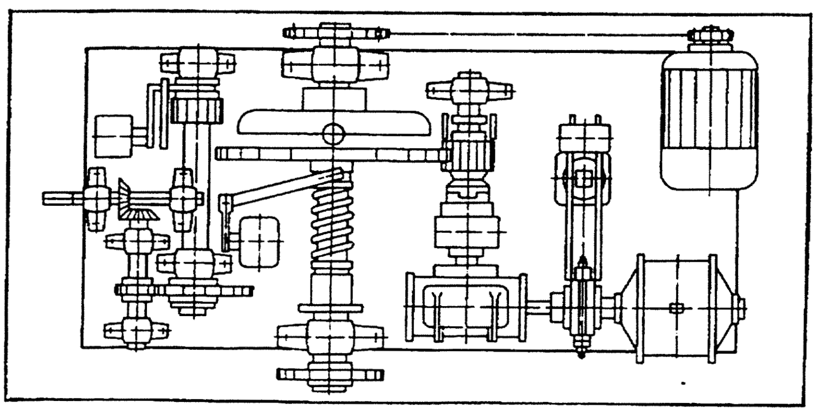

Figure 1: Typical Electro-mechanical Drive

ELECTRO - HYDRAULIC DRIVE

In these types of drives, electrical motor will typically be connected to a hydraulic pump. Oil is pumped through the control vales and via oil pipes to the hydraulic cylinder (or motor) which in turn operates the gates.
See Figure 2 for typical electro - hydraulic drive.

Figure 3 shows the mechanical and hydraulic drive for similar application.

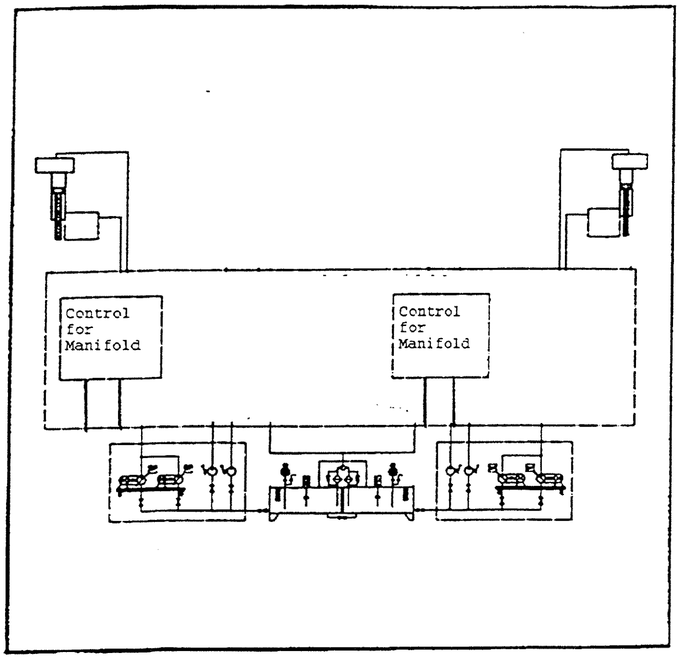

Figure 2 - Electro hydraulic Drive

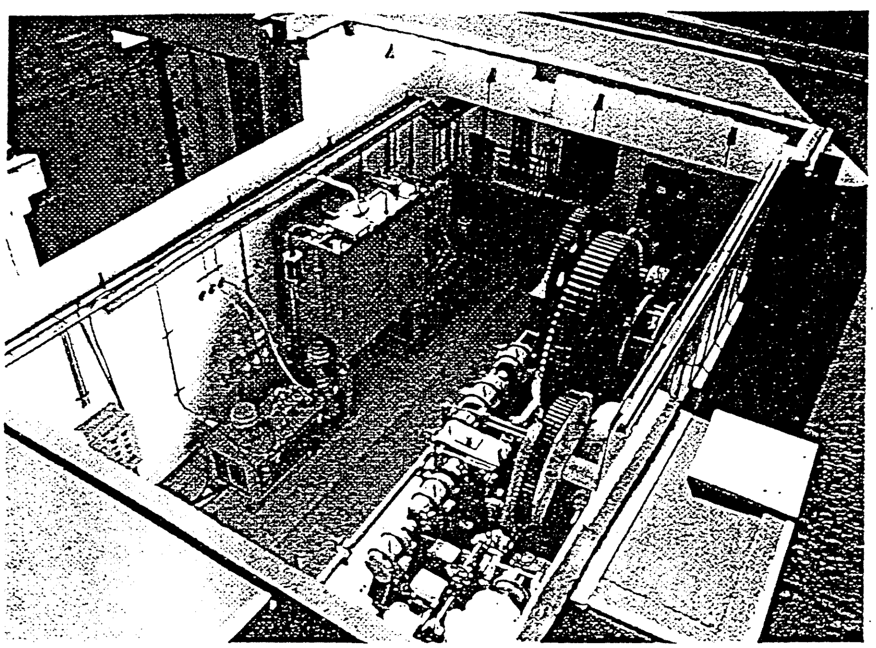

Figure 3 - Electro mechanical vs. Electro hydraulic drive

COMPARISON OF MECHANICAL AND HYDRAULIC DRIVES

MECHANICAL	HYDRAULIC
I. Power Transmission	
• Articulated chains, gear racks, worm gears, or leaf segments, used as lifting elements, are driven by an electrical motor.	• Hydraulic cylinder (or motors) used as a lifting element and are driven by pressurized oil, which is supplied by a hydraulic power unit
• Transmission element is a multistage gearbox working on a pinion - or rope drum	• Transmission element is hydraulic oil, which, in comparison to the mechanical transmission element is not subject to wear.
II. Components	
• Major structural components such as lifting elements, gearboxes, frames, etc. are custom designed and specially built.	• Hydraulic drives consist of components, which are produced in large quantities. Spare parts are therefore, available as an off the shelf product.
• Spare parts are therefore difficult to obtain, have long delivery times and because of their uniqueness, are extremely expensive.	• Only some parts of a hydraulic cylinder which are related to the stroke are custom made. All other parts of cylinder and system are standard industrial components.
III. Physical Layout	
• Lifting components and drive elements have to be close.	• Because the power transmission is achieved by pressurized oil, there is almost no limitation in distance between the lifting and drive elements.
No flexibility in the position of the mechanical elements.	
Deviations in the line of force and power transmission over great	This allows for possible savings in underground structures.

IV. Maintenance

- The lifting components require constant maintenance and lubrication.
- These lubricants may cause environmental pollution
- Wear on the lifting components influences the safety factors.

- In the hydraulic drive system the energy carrier, oil, acts as a lubricant / corrosion protector.
- Maintenance normally would limited to visual inspection.
- It is common to use environmental friendly hydraulic fluids.

V. Operating Features

- Smooth starting and deceleration is difficult to achieve, is inaccurate and can only be achieved at great costs.
- Overload protection is not accurate (slipping clutch).

- Speed control as well as smooth starting and deceleration is easy to obtain because of the very simple, standard components (Proportional valves, variable pumps).
- In contradiction to mechanical drives, overload protection / safety valves can be adjusted easily and accurately.

VI. Special Features

a) Synchronization:

- Synchronization can be done but is more involved and due to more external parts is susceptible to damage, etc.

- Can be achieved rather easily by proportional hydraulic system and cylinder position feedback (CIMS).

b) Underwater

- Typical mechanical system cannot be used under water.

- Cylinders can be partially or completely under water and even the drive station can be submerged. The system, however, must be designed accordingly. This has been done in the past.

Finally, following are the major components of the two drive systems:

MECHANICAL	HYDRAULIC
Electrical motor	Hydraulic power unit
Coupling	Inter-connecting piping
Gear box	Hydraulic cylinder
Winch	
Cable / Chain	

Above mentioned features have been known and used for decades in deciding whether to use an electro-mechanical or an electro-hydraulic drive.

Following recent developments have opened an altogether new horizon of opportunities for electro - hydraulic drives for bridges:

* High Pressure:

Hydraulically driven bridges in the United States today operate per the AASHTO specification. In most cases, normal operating pressure is 1,000 psi and peak pressure is 2,000 psi.

Most commercially available hydraulic components are rated for 3,000 to 5,000 psi continuous operating pressure. Thus, if higher operating pressures of approximately 2,500 to 3,000 psi is used for bridges, it still will use standard, of the shelf components. Obviously, higher pressure means smaller size cylinder and motor which means smaller pumps, valves, oil tanks and interconnecting piping. Complete system becomes more compact and one does not compromise the safety.

Most proportional and servo valves offer better and more stable control at 3,000 to 5,000psi.

Regarding reliability of high pressure system, most aerospace hydraulics operate at 3,000 psi and in V-22 and LHX programs, operating pressure is 5,000 psi. Thus, the higher pressures of 3,000 psi do not compromise safety or reliability.

Recent trends, even in the US Army Corps of Engineers, are to go up to 2,000 psi to 3,000 psi systems for locks and dams.

* New System Design Concepts

Various improvements can be made at system design stage to make complete unit simple, reliable, easy to operate and maintain.

Use of custom designed valve manifolds avoids leakage paths and makes commissioning and trouble shooting much easier. Also, the use of manifold on the hydraulic cylinder offers a much safer system in case of hose burst etc.

Use of MIL type cylinders instead of customarily used tie rod cylinders offer a technically much superior solution. Side loads, type of bearings, seals, etc. can be specifically selected to meet application needs, thus avoiding expensive frequent cylinder maintenance. Use of Ceramax coated piston rods and CIMS synchronization systems make hydraulics more user friendly.

Use of variable volume pumps over fixed volume gear pumps offer much higher efficiencies, larger control options and easy to adapt electrical / electronic controls.

* Environmental Friendly Fluids

Over the years, most commonly used hydraulic fluids were petroleum based oils. If these oils leak into the environment, it would create major problems. In the last decade or so, use of environmentally safe fluids have become more common. With more testing and development of safer fluids, we are sure they will be used more and more in the years to come.

Rexroth has very successfully used Mobil EAL 224H fluid for the US 90 bridges over the intercoastal way also called McCormick Bridge and the SR 105 bridge over the Sisters Creek for the Florida Dept. of Transportation.

* Electronic Controls

Advent of micro processor, PLC, PC and their integration into the electro - hydraulic drives have made electro - hydraulic drives much more attractive.

One can conveniently program the acceleration / deceleration rates, dwell times, store the data for recordkeeping and maintenance etc. changes if required, can be made in the field and rather quickly.

Thus, we at Mannesmann Rexroth believe electro - hydraulic drives would become almost standard for the future. Mechanical drives may only be used for very small loads.