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"BRIDGE DRIVE SYSTEMS INCORPORATING HYDRAULIC MOTORS AND GEAR REDUCERS"

by JAMES F. ALISON, III
Steward Machine Company, Inc.

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Introduction

In recent years designers of movable bridge drive systems have made numerous departures from the time-proven designs of the past. Modern hydraulic and electronic systems for the most part have brought about this change. As a result of this evolution several new options are now implemented in bridge drive systems. Most of the changes have come about in an effort to increase reliability, decrease installation costs, decrease maintenance costs, and provide a smoother application of power or "soft start." Movable bridge designs are governed by many factors. Therefore, the choice of drive system must be made on an individual basis. No one drive system is the best choice for all applications. This paper intends to explore the optimum component arrangements of hydraulic motor-based drive systems only.

Component Layout

The major components of a hydraulic motor bridge drive system are power unit, motor, brakes, reducer, drive pinions and racks. The optimum hydraulic motor drive system layout consists of low-speed high-torque motors shaft mounted directly to an enclosed parallel shaft gear reducer, hydraulic machinery brakes mounted to either the reducer or the motor, or both, floating shafts with gear couplings connecting the reducer output shafts and pinion shafts, and traditional rack and pinion arrangements with bearings supporting the pinion shafts. Figure 1 shows a plan view of a typical bascule bridge hydraulic motor drive system for one leaf. Similar drive layouts for vertical lift bridges are shown in Figures 2 and 3. In all hydraulic motor drive systems it is desirable to directly mount the motor and brakes to the reducer housing. The low-speed high-torque hydraulic motor produces enough torque to drive the bridge without the high reduction ratios required with electric drives. Some degree of gear reduction is desirable to minimize the size and cost of the motors and brakes. In single reducer applications where load sharing is required, the reducer should have a differential to ensure equal torque to both pinions. If desired, redundant motors can be employed by mounting one on each side of the input shaft. In the event one motor fails, the other motor can be used to operate the bridge by varying the hydraulic system pressure and flow rate. Redundancy can also be built into the power units by using dual pumps and drive motors or by using a separate power unit for each motor.

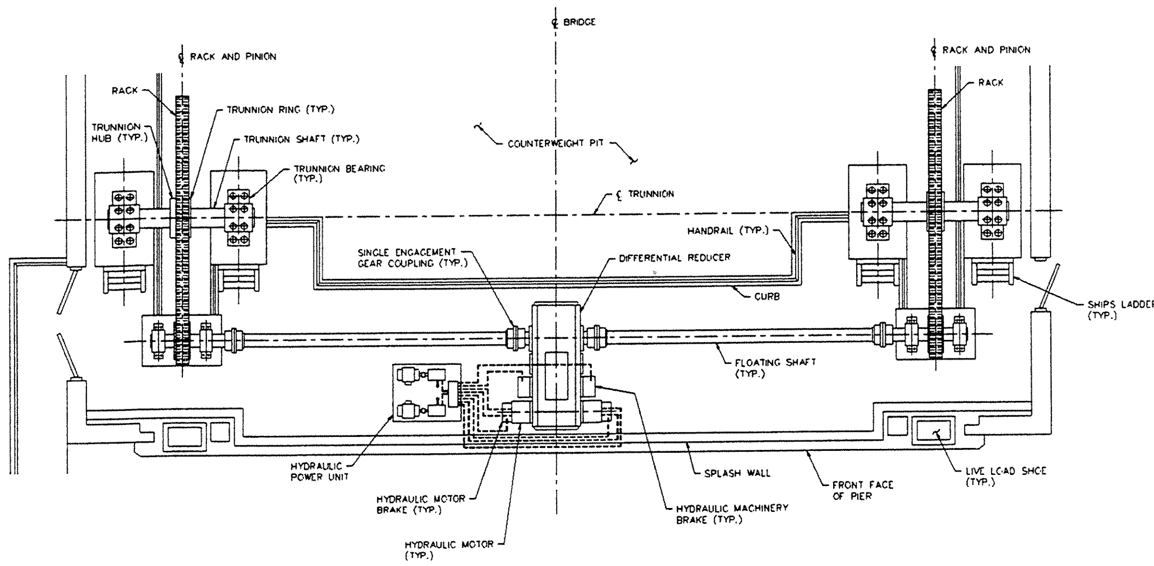

FIGURE 1. BASCULE BRIDGE

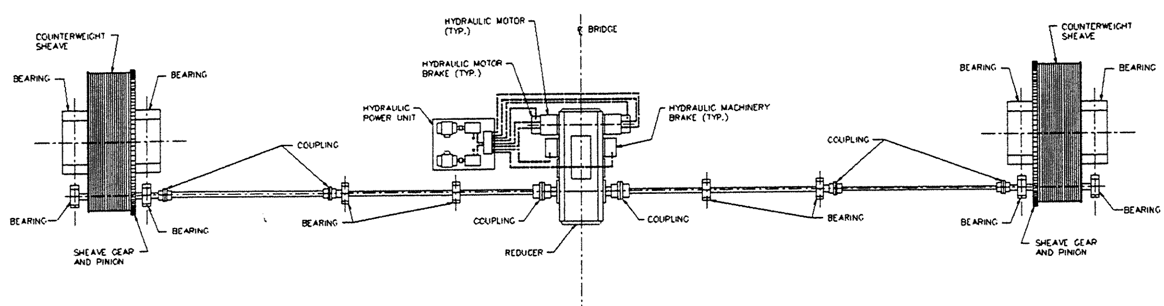

FIGURE 2. VERTICAL LIFT BRIDGE - TOWER DRIVE

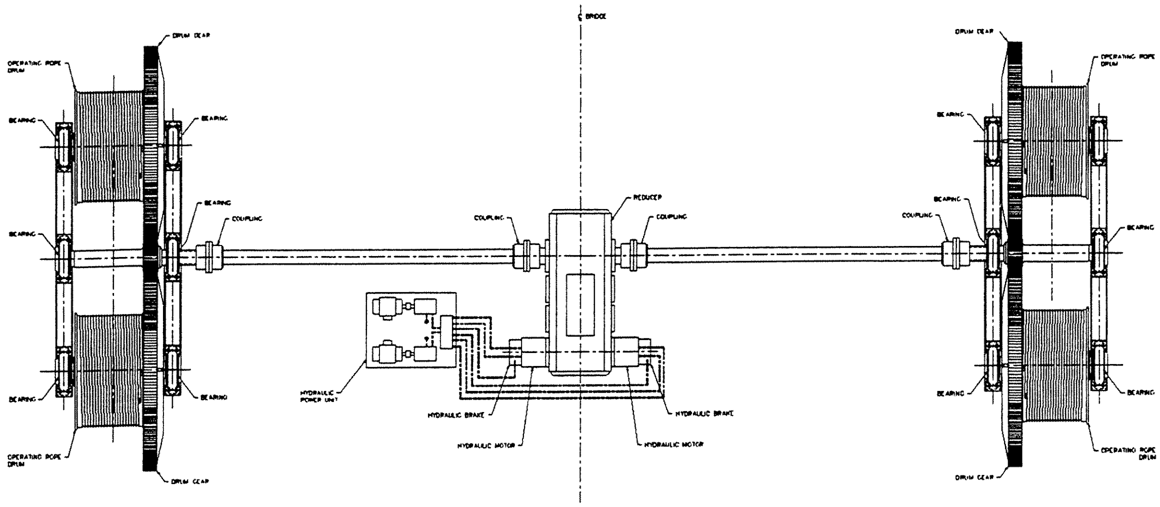

FIGURE 3. VERTICAL LIFT BRIDGE - SPAN DRIVE

The goal of this design is to make the drive as compact as possible and easier to install and maintain. Make every effort to keep the motor and brakes in "stock" form. The reducer will be custom built for the application and is easily changed to match the "stock" form of the motor. Design the system to reduce field alignment and installation as much as possible. Let the drive components be assembled and aligned in the shop by the reducer manufacturer; this reduces fieldwork and shifts system integration responsibility to the reducer manufacturer. The drive system can be checked and tested as a unit in the shop before shipment to ensure that everything is working properly.

With this basic layout the designer will still have to make some decisions about component sizing and the degree of redundancy required. To a large extent, these will be based on installed costs rather than mechanical capability. A cost comparison between motor and reducer will have to be made to determine the optimum motor size and reducer ratio for the particular application. Generally, the cost of a reducer is governed by the output torque required and the number of reductions. In most cases the ratios will be in the range of 10:1 to 50:1. A double reduction reducer is required to obtain ratios in this range. Typical main drive pinions operate at approximately 2 RPM. Therefore, a hydraulic motor operating at 50 RPM would require a 25:1 reducer ratio. A single reduction reducer would be limited to a ratio around 7:1 and require a much larger hydraulic motor. Generally, the cost comparison for this component layout will favor smaller motors and larger reducers. This is good because a large reducer provides plenty of space for mounting the motor and brake. Also a double reduction reducer has an intermediate shaft for brake mounting.

Redundancy can be handled in a variety of ways. Even the most basic system should have two motors. One of the main advantages is that if one motor fails, it can be taken out of service easily, and the bridge can operate on only one motor. The differential reducer will still operate both main drive pinions with one motor out of service. Hydraulic power units may have dual pumps and electric motors for an extra measure of reliability. If contamination of the fluid occurs, it is possible that with a common fluid source both motors or pumps could fail. Individual power units and reservoirs for each motor may be required to decrease the likelihood of a total hydraulic system shutdown. A dual reducer system like the one on the Welch Causeway Bridge offers the ultimate in redundant hydraulic motor drive systems. As shown in Figure 4, each main drive pinion is driven by separate motor-reducer units. The shaft between the reducers is for emergency use only and is not installed during normal bridge operation. Load sharing is performed by the hydraulic system in this case. If a motor fails, the bridge can be operated by one motor through one reducer to one main pinion or to both pinions if the emergency shaft is installed. If a reducer fails, then the bridge can be operated by the other motor-reducer unit through one main pinion.

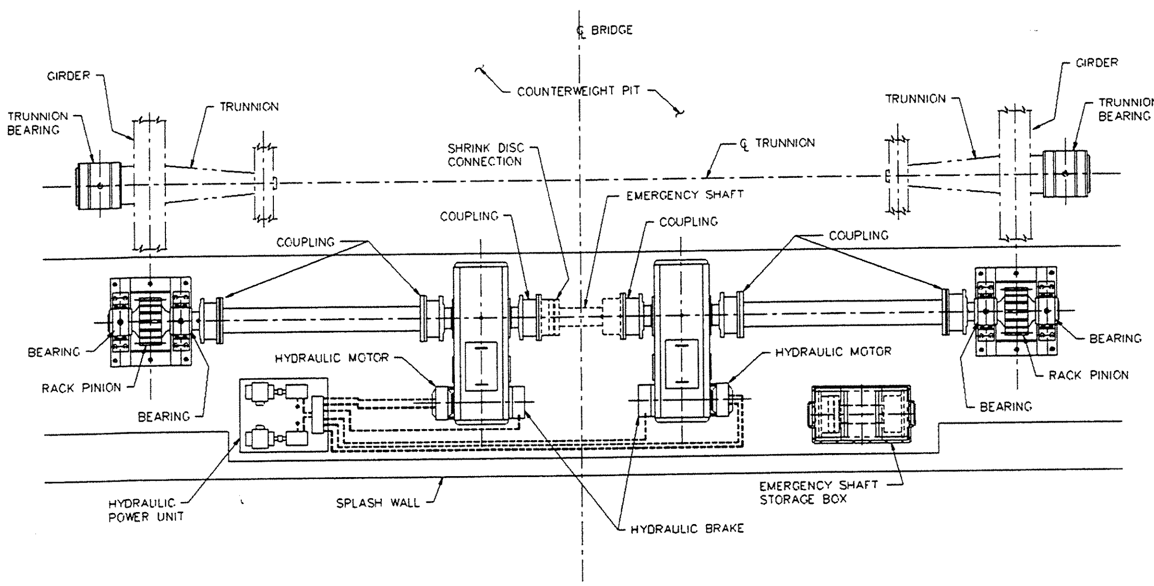

FIGURE 4. WELCH CAUSEWAY BRIDGE

Advantages

Hydraulic motors and reducers offer several advantages over other bridge drive systems. Hydraulic motors provide higher torque at slower speeds and require less gear reduction; therefore eliminating secondary reducers or open gearing other than the racks and pinions. The compact design of hydraulic motors and brakes allows direct mounting to the reducer housing or shaft mounted with torque lugs mounted on the housing. This arrangement can be assembled in the shop and tested before shipment. Motors have an advantage on existing bridge retrofit installations because they do not require major foundation modifications. Field installation of a hydraulic motor system consists of mounting the reducer and coupling the output shafts to the floating shafts. Alignment of the reducer, floating shafts, and pinions does not have to be perfect due to the use of gear type flex couplings on both ends of the floating shafts. Hydraulic systems by nature feature "soft start" qualities that are very beneficial in reducing shock loads to the drive system. Abuse of the drive system by rough operation and lack of maintenance causes many reliability problems in bridge drive systems.

Maintenance Aspects

Proper maintenance of bridge drive machinery is critical to its life and reliability. Many reliability problems are caused by poor maintenance. Hydraulic motors do not require any periodic maintenance. The gear reducer is splash lubricated and requires an oil change once a year. Enclosed splash lubricated gear reducers have proven to be very durable even when not properly maintained. There are many reducers still operating after over 50 years of service. The rack and pinion must be protected from corrosion and excessive wear with some type of open gear dressing. The dressing should be easy to maintain since the pinions rotate at low speed and don't throw off the lube during operation. The main pinion shaft bearings and couplings will require grease periodically. Again, the low speed of the shaft makes the components more tolerant of occasional neglect. Maintenance of the hydraulic power unit is the critical factor in hydraulic system reliability. The hydraulic fluid filters must be changed regularly. It is inevitable that sooner or later the hydraulic fluid will get contaminated and cause damage to a motor. When this happens the shaft mounted motors with shrink disk couplings can be removed easily for service with simple hand tools. After the contaminated fluid is purged, a spare motor can be installed to operate the bridge. If the bridge has two motors, it could operate on one motor. A single differential reducer will still provide equal torque distribution with only one motor driving the bridge.

Summary

The main points to keep in mind when designing a hydraulic motor drive system are the motor's compact size, high torque, and accessibility for maintenance. The drive layout should take full advantage of these features to maximize return on the considerable investment in motors. The following simple guidelines for selection and layout will ensure proper application of hydraulic motor drive systems:

1. Select a stock motor.
2. Size the reducer to match motor and bridge requirements.
3. Avoid any open gearing or secondary reducers.
4. Shaft mount the motor to the input shaft with a shrink disk coupling and torque lugs mounted to the reducer housing.
5. Locate the brakes on the reducer shafts, mounted to the reducer housing.
6. Require the reducer manufacturer to mount and check all components in the shop before shipment.