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Top-Drive Drilling Systems: Hydraulic vs. Electric

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ABSTRACT

Since 1982 over 300 Top Drive systems have been installed worldwide, on virtually every type of drilling rig. An ongoing debate centres on the prime mover for rotating the drill pipe. Should it be "electric" or "hydraulic"?

The purpose of this paper will be to provide a detailed comparison of both systems, outlining the advantages and disadvantages of both. Details of the designs, installation requirements, efficiencies, actual field performance and relative cost comparisons to install and operate will be presented.

The results presented will show the relative merits of each system and technically compare the overall operational aspects of each system as reflected in the current drilling environment we are experiencing today. The data presented will provide the potential user with the necessary information to evaluate an application and select a system.

INTRODUCTION

Top Drive drilling systems have become the predominant method for drilling most offshore wells in the 1990's. With their continued development from the power swivels of early days to the full fledged drilling systems available today, we have witnessed a number of improvements.

The significant feature that separates the systems of today from early power swivels is the use of a torque wrench to allow stands to be broken out at any point in the derrick.

Continued development of these Over head Drilling Systems now provide the user with an integral swivel, saving weight and valuable system length, a variety of built in torque wrench devices that allow pipe to be easily broken out during back reaming operations, remote operated safety valves, greatly adding to operational flexibility and safety and now a variety of gear ratios, dual speed transmissions and even multiple motor capability is offered. With four major manufacturers offering these over head drilling systems, a choice is available in the source of the prime mover to rotate the pipe, both electric and hydraulic driven systems are available. The purpose of this paper is to present both systems, evaluate their advantages and disadvantages and provide the user with a comparative update of the equipment on the market today.

POWER RATINGS OF HYDRAULIC MOTORS
VERSUS ELECTRIC MOTORS

The question of the proper size of hydraulic motor to replace an electric motor arises frequently, this is often a confusing and misleading problem, as electric motors are not rated on the same basis as hydraulic motors, and the difference between the two methods of rating must be taken into account in making the selection.

Electric motors will develop as high as 250% over their rating for short periods at least, and many cases have been known where 120 to 150% were carried continuously. The rating of electric motors is there for every conservative. Also electric motors have a large reservoir, in the power lines, from which to draw energy.

On the other hand, hydraulic motors are limited by the force available from the power unit. This is so much and no more. In other words, it is not a case of flexibility in the source of power as with the electric motor. There is no excess energy to draw from.

Electric motor starting torques are as high as 500% of normal while most hydraulic motors have starting torques of about 80% of normal running torque. This means that the pressure required for running must be multiplied by 125% when calculating power unit requirements.

The practice of rating hydraulic motors is not so conservative, as these motors are rated at the maximum that a motor in perfect condition can develop in the laboratory.

Furthermore the power developed by a hydraulic motor decreases with higher fluid temperatures and lower viscosity. Hydraulic motor power curves, to be comparable, must therefore be made at certain standard temperatures and viscosity.

As every piece of equipment should be operated with a certain factor of safety, an allowance of 25% should be made to allow for losses due to starting torque conditions. The result is as follows, taking as an example an electric motor and a hydraulic motor, each rated at 10 horsepower.

The electric motor can be expected to deliver up to 50% in excess of its rating, or 15 horsepower, while the hydraulic motor should not be expected to deliver, continuously, over 80% of its rating, which gives a net of 8 horsepower.

This means that according to the present practice of power ratings, a hydraulic motor should be selected with about twice the rating of the electric motor which it is to replace.

This should, in no way, be considered as reflecting adversely on the hydraulic motor. It is simply a condition brought about by two entirely different methods of rating the power of these units.

EQUIPMENT OVERVIEW

Currently available on the market today is a variety of both electric and hydraulic powered overhead drilling systems. In general principle we will limit our discussions to manufacturers who have actually designed and supplied equipment to date.

In the hydraulic equipment side, both single and multiple hydraulic motor versions of equipment are available.

The basic design features an integrated swivel, single gear ratio transmission driven by either a large single variable displacement axial piston type motor or four smaller motors of similar design.

This design feature is what separates the approach taken by the two designers. In the case of a single hydraulic motor, the entire flow and pressure from the hydraulic power unit is directed through the single motor to produce the desired torque or speed characteristics. Since speed is a function of the flow rate, the flow must be increased or decreased to provide the required drilling speed. As additional torque is required the pressure must be subsequently increased to provide the additional force.

The hydraulic power unit to drive this equipment is composed of a main hydraulic unit for drillstring rotation and a secondary power system for auxiliary functions.

The main power unit can be driven by a 872 kW (1170HP) DC motor driving a single, variable volume pump. This system is capable of 350 bar (5000 psi) maximum working pressure and a maximum flow rate of 1600 L/min (400 GPM). These two parameters would not occur simultaneously and are limited by the INPUT horsepower available.

The auxiliary power is supplied by twin pumps driven from a common shaft 45 kW (60 HP) AC motor. This arrangement provides an HP circuit of 210 bar (3000psi) at 40 Umin (11 GPM) and an LP circuit of 110 bar (1500 psi) at 120 L/min (30 GPM). There is additionally a pump feeding circuit. The overall capacity of the reservoir on the hydraulic unit is 1500 Litres (400 GPM) and weighs 8500 kg (19,000 lbs) without oil.

In the case of the multi motor design four axial piston bent axis hydraulic motors are utilized to rotate the drive shaft. This design approach allows the use of smaller motors that ~reconnected in parallel to achieve the desired torque speed characteristics.

The circuit design uses four (500 cm³/rev) fixed displacement motors connected in parallel. It is for this reason that a sequence control system is required to provide multiple flow paths connecting from two, to all four motors to the source of hydraulic power. This is accomplished using four pilot operated direction control valves.

A consideration for hydraulic motors to prevent cavitation is to supercharge the outlet with a positive pressure of 1.4 bar (20 psi). This is accomplished through the use of a separate supercharge pump loop. The net effect of this pressure is to reduce the overall delta pressure available to the motor system to 330 bar (4700 psi), while protecting the pumps from cavitation. The hydraulic unit utilized to power this system is composed of a main power and control power systems. The main power unit is driven by four 230 kW AC motors driving variable displacement axial piston pumps. The replenishment/filtration circuit is comprised of two 10 kW AC motors driving fixed displacement gear pumps. Only one pump is required for normal operation. The auxiliary system is a 55 kW AC motor with a variable volume pump. This pump system supplies hydraulic power to the auxiliary (non drive) related systems.

The system provides for oil filtration to 12 micron absolute on the pressure side and 6 micron absolute on the return side. A water to oil heat exchanger is provided for cooling purposes.

The electric driven machines offer much diversity as well. A number of manufacturers of hydraulic machines additionally offer electric versions but two manufacturers have clearly made their position, to only offer DC electric machines.

The power source for these electric machines revolves around the industry proven series or shunt wound dc drilling motor. The early electric Top Drives were based on the railway traction motor and later the 740 kW (1000 HP) drilling motor. The present systems use the newly introduced high torque motor capable of 872 kW (1170 HP) on a continuous basis. This motor has become the standard offering by most manufacturers.

The designs of the electric top drives fall into basic categories; single and two speed mechanical transmissions and single or dual motor drives.

The basic design features of the electric driven top drive are similar to the hydraulic ones. They feature an integral swivel design and gear reduction with ratios varying from 5.33 to 1 to 6.83 to 1. The two speed models available feature a low gear and high gear ratio to provide both high torque and high speed options. This feature provides a flexible torque output while lowering the required input power.

In the case of the dual motor machine, two, high torque shunt wound motors drive a single 5.33 to 1 ratio gearbox. This design provides the maximum torque and speed available of any machine today with the redundancy of two separate motor systems.

The principal of operation of the electric top drives is to utilize the SCR for supply of DC power to the drilling motor and auxiliary AC and control circuitry for the ancillary functions. These systems require air or hydraulic power as well to operate.

The power supply for these machines is the rig SCR system. These systems are typically capable of 750 volts dc and 1600amps which is more than adequate for the 1240 amp continuous current rating of the high torque motor. An additional, normally 20 HP AC blower motor is utilized for cooling and a small AC powered lubrication pump as well, on some models. Control circuitry is supplied to conventional solenoid valves for system functions.

There are a number of differences between these machines that are inherent in the design. By virtue of the hydraulic motor being explosion proof the hydraulic Top Drive does not require any purge systems as is the case of the electric powered machine. It's cooling fluid is hydraulic oil, which require heat exchangers to be relocated from the unit itself to the hydraulic unit or other equipment room. The electric machines currently in use, all use air as their cooling

medium, and where regulations dictate, utilize onboard water to air heat exchangers. A remote mounted air system is gaining popularity as well, due to its simplicity. This system draws air from outside the hazardous area and blows the air through a flexible hose attached to the Top Drive.

EFFICIENCY

As we evaluate the two methods of rotating the drill pipe one must consider the basic efficiency of the electric prime mover against the hydraulic motor. The basic hydraulic energy transfer system is composed of the following components as represented below.

AC INPUT-AC MOTORS-HYD PUMPS-LINES-HYD MOTORS-GEARBOX-DRILL STRING

The electrical energy transfer system is composed of the following components as represented below.

AC INPUT-SCR-CABLE-DC MOTOR-GEARBOX-DRILLSTRING

On the surface as we compare the systems, we can only identify one additional component in the hydraulic system which would lead to an overall reduced efficiency. But, the results are related to the form of the energy and the number of times energy changes its form. As we analyse the hydraulic system we see electric al energy changing to rotating shaft energy, converting to fluid energy, frictional energy in the transmission lines, back to rotating shaft energy and through the gearbox to the drill string. This results in three form change sand a significant loss of input horsepower in the form of heat throughout the system. The overall system efficiency based on a four motor and pump system can be calculated as follows:

$$1.00 \times (.97) \times (.88) \times (.95) \times (.885) \times (.98) = .70$$

In the case of the electrical system we maintain the form of electrical energy up to the DC motor, although changed to DC , where it converts to rotating shaft energy and likewise through the gearbox. The overall efficiency of this system can be calculated as follows:

$$1.00 \times (.99) \times (.99) \times (.95) \times (.98) = .91$$

The net result of these comparisons show the electrical system is much more efficient, by nearly 21 %. This efficiency when considered as an annualized energy cost would amount to a significant additional fuel expend it u re to generate the additional electricity required.

Table 2 provides a comparison of typical torque speed curves for both electrical and hydraulic systems. These curves reflect the fundamental efficiency advantage the electric drive has. With 872 kW power input, they are a under each electric curve is greater than the corresponding area for the hydraulic machine with 920 kW input. The case of the single hydraulic motor system when plotted is significantly less than the multiple motor system. This is noted in Table 1 by comparing performance values.

INSTALLATION

The requirements to install either a hydraulic or electrical Top Drive are quite similar in that both systems require the same basic components.

Both systems require guide rails and electrical control cabling to operate the equipment. Both systems likewise require fluid piping. Where the electric systems use low pressure small diameter piping, to supply air, water for cooling on some systems or hydraulic accessory power, the hydraulic machine requires large diameter, nominal 97 mm high pressure piping, for its main supply. The electric top drive uses dc cabling to replace this piping.

The current users of these systems indicate that the installation of piping is time consuming and costly when compared to cabling and that the flushing requirements of the new hydraulic systems cannot be over emphasized. Both systems typically utilize hydraulic power units. In the case of the hydraulic driven machine the unit is quite large in size, one system

measuring 4170x2670x2230 (mm) and weighing over 11,000 kg. This can present a deck space problem on retrofit applications or on small platforms. In the case of the electric driven machines only a small hydraulic unit is required for auxiliary functions, if an existing source of hydraulics is not already available. This might typically measure 1200 x 968 x 1650 (mm) and weigh 1700 kg. Some models will be offered that require no hydraulics at all, using pneumatic power to operate auxiliary functions.

RELIABILITY

The question of reliability of dc electric motors and the ability of our industry to maintain and repair them is well documented.

The key to reliability of the hydraulic system is cleanliness. For a high pressure hydraulic pump to survive it must live in an environment of oil that is clean, clean, clean! Just how clean? It should have dirt particles in it no larger than 10 microns and a concentration of no more than 11 in a 100 millilitre sample. This is defined as a class 3 environment.

Contrary to common belief the oil that comes out of a new drum is not clean enough for a high pressure system to operate on. Proper filtration of all circuits is another key to reliability. A properly designed hydraulic system should contain filters that are sized properly and located in a position to protect vital components from contamination.

A properly designed hydraulic system should include the best available filtration in both high pressure and return systems as well as a reservoir that will maintain a clean oil system when established.

ADVANTAGES/DISADVANTAGES

The hydraulic system offers the advantage of reduced weight of the actual Top Drive itself. Although this weight savings in the derrick is offset by hydraulic power unit weight and reduced variable deck loading.

By design it is inherently explosion proof, but adds the risk of a pollution hazard due to its high volume and high pressure requirements.

It is capable of stalling for very long periods which may give it an operational advantage during jarring or stuck pipe situations. It is felt that the installation of large hydraulic standpipes is costly and more time consuming than installation of DC cable.

The smaller size and weight of a hydraulic motor would facilitate and easier change out, in the event of a motor failure. The multiple pump/motor design would offer an additional degree of flexibility as well.

The use of a common reservoir, which would become contaminated if a high pressure pump failed is, a serious drawback to the system. Continued use without complete filtration would cause a premature failure of the other pumps.

Common use of a complete hydraulic package would allow the central hydraulic unit to support other equipment resulting in savings.

The electric machines offer greater model options, more horsepower, a wider experience base and a significant efficiency advantage.

The cleanliness of the power form minimizes the chance of a major oil spill and lends itself toward the zero discharge requirements of new contracts. It requires overall, less total space on the drilling rig and maximizes valuable deck space and loading. Installation of electric machines are inherently easier due to the experience base of a typical rig crew (electricians & mechanics). Few rigs have experienced hydraulic personnel.

Due to its inherent design it requires an onboard cooling system to meet explosion proof requirements. This adds to the complexity and hampers maintenance.