



Built for Purpose Straight Hole Drilling Motor

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Abstract

Applications and development of the positive displacement motor (PDM) has evolved over the last 50 years from a single generic design to highly specialized job-specific tools.

To optimize the performance of the PDM, well-specific configurations are required. However, motor "designs" are nearly the same in each application.

Focusing on conventional drilling applications, vertical and directional, the main variance in motor configuration is the use of a straight housing versus a bent housing. PDM Manufacturers design the motor, primarily to perform in a directional capacity. Yet with simple modifications, the motor is able to perform in both.

For vertical drilling, the operating parameters on a PDM are more extreme, compared to directional drilling. The average directional motor assembly is not designed to withstand the high weight on bit (WOB) demands of straight hole drilling. Nor does the average extended length power section offer the additional torque required by the new generation of aggressive PDC bits.

This paper will elaborate on the built-for-purpose straight hole drilling motor, along with its design benefits, performance advantages, and offer case histories to expound on its advances to the industry.

Introduction

Positive Displacement motors have long been a key component to drilling programs. One of the most beneficial realizations was the ability to drill in a directional capacity.

In 1962, the first directional drilling system containing a PDM was used offshore in California. This opened a wide spectrum of drilling capabilities and practical capabilities for field development, especially offshore.

As PDM technology improved, the spectrum was broadened. In short, extended reach lateral sections could be completed; operations in hotter wells, and shorter drilling curves are just a few achievements that new PDM technology provided.

Input from the operators helped to further increase PDMs into case specific configurations. RPM

considerations are made depending on bit selection. Elastomer technology and testing have helped to increase the life expectancy of the motor, especially with the integration of aggressive drilling fluids.

PDMs have a wide spectrum of configurations, but the basic "design" is still the same. A motor designed to perform first in a directional capacity and secondly in a vertical capacity is a dying opportunity. Straight hole drilling has evolved to a point where the PDM needs to be "designed" to fit the drilling environment, not merely configured to the well conditions.

Basic Well-Specific Motor Configurations

Many of our predecessors have explained the basics of Rene Moineau's *progressing* cavity pumps and outlined the basic components of a PDM. We presume, with much hope, this principal is understood.

Instead, we will spend time on well-specific PDM configuration and specific criteria that direct such a setup. These evaluations are critical in order to optimize PDM performance and maximize drilling efficiency. Let's look at a few points that motor companies and drilling engineers are required to evaluate prior to downhole operations.

The most obvious is motor size. Selection is based on various parameters including, hole size, retrievability concerns, annular returns, build rates, and casing programs.

Acknowledging that hole size and bit selection have been made, a suitable power section is selected. It is common knowledge that a high RPM power section is more suitable for Diamond impregnated drill bits, medium to low range RPM power sections are suitable for PDC bits, and low RPM models for tri-cone bits.

If high temperatures and/or aggressive drilling fluids are present, they pose a concern for elastomer swell. This involves configuring a power section to compensate for the expected swelling. Thermal expansion is relatively easy to calculate and obtain to provide the proper fit of the rotor and stator for each specific application.

Drilling media requires case specific evaluation. It is best that the synthetic or petroleum based fluids are

evaluated in the laboratory. Elastomer coupons can be exposed to a simulated drilling environment prior to actual field operations. Sometimes these drilling fluids do not affect the elastomer as expected. Petroleum based fluids may have a negligible effect, while some synthetics can be extremely destructive to a specific elastomer.

Air media requires its own set of parameters due to factors such as the compressibility of air-based media, along with lubricity issues. Typically, an extremely slow RPM power section and minor modifications are required to help reduce the likelihood of over-revving the motor if the tool face loses contact with the bottom of the hole.

Combine some of the above-mentioned well parameters, along with desired target locations (dictating stabilization, PDM lengths, and build rates), and it is evident that mud motors are very specific to an operator's individual well.

Non Well-Specific Motor configurations

There are typically two components that remain the same in all motor configurations; the bearing assemblies and transmissions. Both are designed to function in a directional capacity first. Essentially, there is a limited amount of space in the bearing assembly to handle WOB, radial load, and torque output, while still maintaining a short length to have an acceptable build rate.

In addition, the transmission assembly must be thin enough to account for bend angles and rotor eccentricity while operating at its maximum bend within the outer bent housing. Typically, the transmission is not required to see a lot of torque, nor the bearing assembly, in a directional mode.

However, when a directional assembly is placed in a vertical drilling environment, the entire motor is exposed to much higher operating parameters. For vertical wells, operations tend to be more extreme. The average directional motor assembly is not designed to withstand the high weight on bit demands, vibration, and extended exposure to rotation. Nor does the average extended length power section offer the additional torque required by the new generation of aggressive PDC bits.

Built for Purpose Straight Hole Drilling Motor (xPDM)

Since PDM configuration is a requirement to specific well parameters, why not configure a motor to a straight hole drilling environment? It is a question not being wholly answered by the industry. It was in a small part, by a couple of the large well-known service companies, but that typically comes with a dedication of the operator to take additional services. This requirement is not always desired, merely to utilize a built for purpose straight hole drilling motor (xPDM).

In order to truly configure a PDM to a vertical drilling environment; a few design features would be essential. Those design features must acknowledge the basic premise that straight hole drilling operations are focused more on reaching a target faster versus accuracy. The target is reached by higher WOB, higher flow rates, and/or higher differential PSI. Essentially, the motors are more often run at their maximum capacity to achieve total depth.

The following design requirements are asked of a built for purpose straight hole drilling motor.

- Increased Torque
- Higher WOB Capacity
- Higher Vibration & Shock Loading
- Durability
- Safety catch features
- Conveniences

Some independent PDM manufacturers have made fragmentary attempts to create a stronger motor for performance drilling. Some have made special bearing assemblies with higher WOB capacities; while other manufacturers have come out with higher torque and/or new equidistant power sections. However, these are merely perfunctory efforts. A true xPDM must match more than just one requisite of vertical drilling parameters.

Design Requirements and Benefits

The initial step was to obtain a power section that could provide a considerable increase in available torque on the market. A power section that gives a high torque output is merely a general direction. It must be suited to the bit applications required by the well. Additionally, the most advanced components must be utilized in order to achieve this extra power.

As for improvements to power sections, a number of advances have been developed and implemented over the past 5 years. Improved manufacturing processes, coupled with stringent quality control standards have resulted in rotors and stators that are held within tighter tolerances to the design specification. These improvements result in lower friction and more uniform loading across the length of the power section. Lowered friction and uniform load sharing help to increase the run life of the parts.

The introduction of higher performance elastomers and more stages in the power section allow for higher differential pressures to be used. There are several benefits from the added stages and higher performance elastomers. Initially, these improvements directly increase the torque capability of the power section. Secondly, the power section maintains more consistent

speeds at load and experiences fewer instances of stalling.

The combinations of these improvements and extensive dynamometer testing have expanded the limits of the power section. These enhancements have also reduced the likelihood of elastomer failure through mechanical, fatigue, and/or hysteretic failure modes.

The second requisite was additional WOB capacity and compensation for shock and vibration. There are two prominent designs of weight bearing components in a PDM. The most common is an anti-friction design, containing a rolling element, such as a ball or cylindrical roller, on mating races. The second design is a friction bearing. The friction design is composed of load bearing elements with contact points made of diamond, PDC, or tungsten inserts. The friction design works these hardened inserts against each other, but at a HP sacrifice.

For the xPDM, a revolutionary anti-friction design was implemented. This design, coupled with a conservative safety factor and redundant implementation facilitated the goal to reach current WOB requirements for vertical drilling. In addition, shock-absorbing components are included to minimize detrimental forces and promote the life of the bit and bearing assembly.

Durability is a two edged sword. A tool can be durable in one environment, but frail in another. So by designing a built for purpose straight hole motor (xPDM), durability becomes inherent. WOB capacity, external housings, and output components designed with a high safety factor. The power section is designed to function at a broad capacity while still providing plenty of power and rpm, thereby reducing internal loads. Body components must be designed equally strong to handle tool flex; reactive torque that affects motor back offs, and long term exposure to a rotation and vibration, that increases cyclical fatigue. With these considerations and basic engineering principles, the xPDM is born durable.

There are always the "what if's" in downhole tool operations. Most PDM Manufacturers incorporate features to reduce the likelihood of fishing operations. Integration of these features has evolved from a marketing advantage by those who incorporated these designs, to a mandate by operators who will refuse to allow a PDM in a well without such components. There are two basic catch mechanisms.

The first feature is the rotor catch. In the event of an external connection failure below the top of the motor, a rotor catch is a device that will prevent the bottom portion of the motor from being left in the hole.

The second catch mechanism is a "bit box catch". In the event of an output shaft failure, this will prevent the

remaining portion of the output shaft and bit from being left in the hole.

Reverting back to the first safety mechanism, there are two common designs. The first type catches on the stator elastomer. Though this can be reliable, situations can arise where an over pull on the BHA may be required. This can cause the rotor catch to exceed the holding properties of the elastomer; resulting in stripping out the elastomer and unfortunately leaving a fish in the hole.

The other design option of a rotor catch is a metal-to-metal design. This typically is used in a catch mode inside the top sub. However, they tend to restrict circulation. Restricted circulation poses a serious hazard if a well takes a kick while the catch is engaged. However, a slight modification of the metal-to-metal design was introduced to allow circulation. At press time, we have been fortunate enough to not field-test this design.

The last issue of conveniences touches on handling features and BHA benefits. Our proprietary xPDM is standardized to a length of 31' to promote additional timesavings and handling benefits to the operator during surface operations. Secondly, there is an option for float valve placement in the top sub. This allows the operator to reduce an extra component in the BHA, and another potential for failure.

Operational Results

Field tests in multiple areas have shown significant increases in ROP and a general correlation to improved bit life.

There are several PDC manufacturers that have highly aggressive bits on the market. PDC bit cutter technology has contributed greatly to the advancements in performance drilling technology. Field results show that bit runs with the self-sharpening, thermo stable, cutters produce ROP increases over 30% and can drill intervals that were not typically PDC drillable. New PDC cutters are considerably more abrasion resistant in the lab than other commercially available PDC materials, resulting in significant economic benefits.

As this cutter wears, the highly wear resistant, thermo stable layer forms a distinct lip. This lip dramatically increases contact stress at the rock interface, providing higher ROP over other PDC cutters. Significant improvements can be achieved in highly abrasive environments that reduce the life of conventional PDC bits. The new generation cutters are ideally suited for drilling demanding formations such as sandstone and interbedded sand/ shale sequences. The wear resistant, diamond lip design also allows the cutter to stay sharper and drill farther in less abrasive formations, such as

limestone and chalk.

Until now, the true potential of the bits have not been recognized. The extra torque available in an xPDM allows these aggressive bits to penetrate the formation as they were designed to do. The aggressive cutting action by the bit and reduced stalling in the xPDM, points directly to an increase in ROP and bit life.

East Texas

Several wells drilled in Freestone County, TX by the same operator point a direct advantage of the xPDM over the conventional PDM. These case histories were drilled in the Mimms Creek Field. Drilling was performed in the Buda shale; 8-3/4" hole section over 3700' intervals. The case histories utilized two different rigs, and each with PDC bits. Side-by-side comparisons indicate that the xPDM has significantly and consistently outperformed the conventional extended length PDM.

Figure 1, represents two different PDM manufacturers that supply an xPDM-type motor versus two PDM manufacturers with conventional extended PDMs. The Built for Purpose Motors increase ROP by an average of 70%.

Permian Basin

The Nash Draw field in Southeast New Mexico provides another example of the xPDM performance advantages. In a field previously drilled with roller cone bits, evolutions in drilling solutions have shown the benefits of xPDM and aggressive PDC design.

A collaborative effort in which an operator in New Mexico and a PDC bit manufacturer embarked on an independent study to reduce the time spent with the current drilling program. The result was a "total drilling hours versus depth" curve utilizing conventional extended PDMs. The intention was to reduce rotating hours by including a well-specific aggressive PDC. In depth formation evaluation and compressive rock strength analysis revealed that this field was PDC drillable. The proposed time reduction was a 15% margin.

The introduction of the xPDM afforded additional timesavings to the operator by upwards of 86%. This xPDM curve was obtained by a four well performance average, during which a field record was set. Based on

previous offsets with roller cone bits, a 270% reduction was realized.

Conclusions

PDMs perform most effectively when configured to specific well parameters. The xPDM addresses the case specific configuration for straight hole drilling. By creating the built for purpose straight hole drilling motor, multiple advantages are attained. Increased output torque and weight on bit capacity, answer the drilling demands of the straight hole market, which have long been neglected. The combination of improvements in PDM design and materials, helped forge the capabilities and integrity of the xPDM. While design features, such as standardized length and catch mechanisms, provide additional insurance and equipment handling benefits to the operator. The well specific xPDM, coupled with more durable and aggressive bit designs dramatically improve ROP; while maintaining excellent run life over conventional PDMs.

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Nomenclature

Define symbols used in the text here unless they are explained in the body of the text.

BHA = bottom hole assembly

ROP =drilling rate of penetration

Rpm =revolutions per minute

TD = total depth

WOB = weight on bit

HP = Horsepower

xPDM = Built for Purpose Straight hole Motor

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Figure 1: P-Rate Comparison
xPDM vs. PDM
(Freestone County, TX)

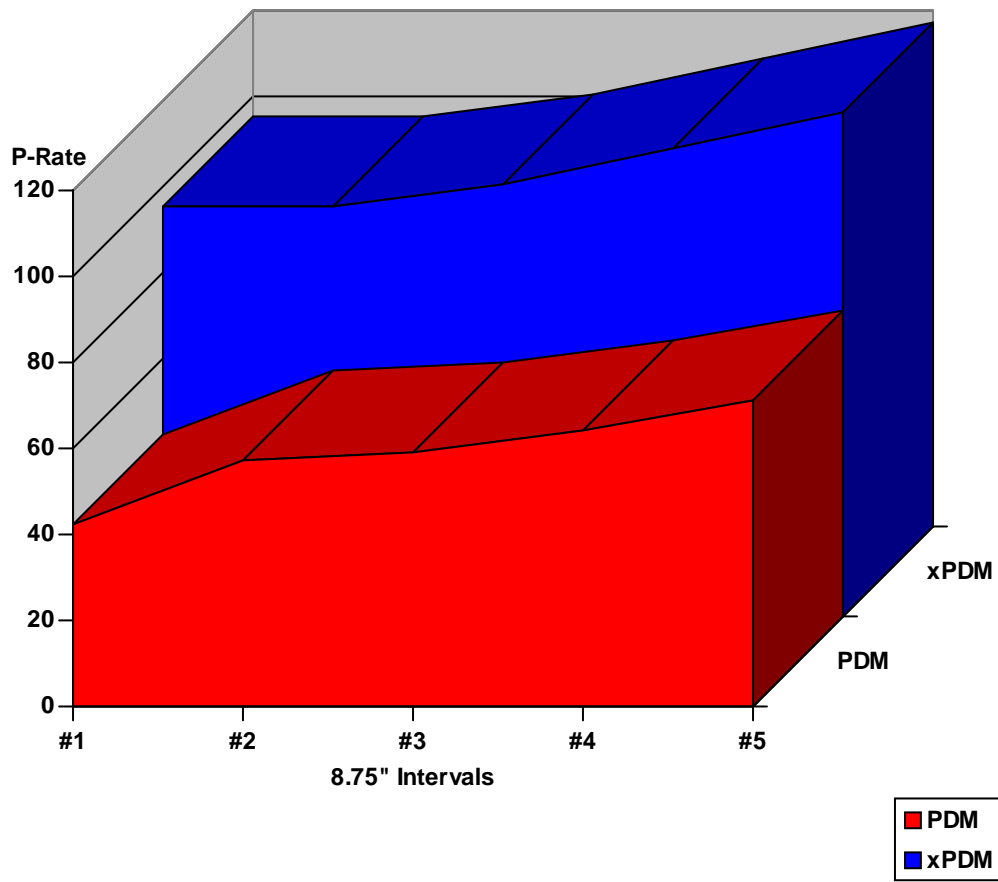


Fig2: Time Savings of xPDM in Poker Lake Well

