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NEW CORE HEAD BIT DESIGN FOR INCREASING RECOVERY IN SANDSTONE

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Abstract

Onshore operations performed under high-risk and high-cost conditions present challenges, particularly in delicate operations, such as core cutting and recovery. Achieving zero non-productive time (NPT) as a result of well-planned tripping and obtaining a higher core recovery percentage while maintaining the quality of cores are difficult tasks. This paper describes the successes of an extended lip core head bit design used in nine wells in all blocks of the Orinoco oil belt.

The expertise and knowledge used during the coring operations of the Orinoco belt in Venezuela focused on selecting the core head and core barrel length and exercising proper control of drilling parameters. In addition, accurate and timely decisions optimized coring time by reducing tripping and producing core samples while maintaining hole integrity. The use of the extended lip core head minimized the turbulence caused by the contact of the fluids with the formation and helped to ensure the highest recovery rates historically obtained in the Orinoco heavy oil belt.

The extended lip core head has produced more than 4,055 ft of core samples with greater than 87% recovery in nine wells over the last two years. This outcome represents an increase in recovery of more than 20% in the zone of interest (unconsolidated sandstones) above the overall recovery in the area. The extended lip design has minimized the effects of turbulence caused by fluids during cutting and reduced washout of the formation before getting the sample into the inner tube of the coring assembly. This, in conjunction with proper drilling parameters, has resulted in better core recovery percentages.

This paper discusses the core head design features that help improve recovery in unconsolidated sandstones, which includes a continuous process of gathering and processing information related to previous core head design development, drilling parameters, dull grading conditions, and core sample integrity. In addition, this paper describes the performance results and upcoming modifications to the core head design to improve the recovery percentage in the lithology of the Orinoco belt.

Introduction

The Orinoco oil belt is known for its large deposits of extra heavy oil. It is located in the Orinoco River basin, with an extension of 55,314 km^2 that includes the states of Monagas, Anzoategui, Delta Amacuro, and Guarico. It consists of four exploration and production areas: Boyacá, Junín, Ayacucho, and Carabobo.

The zone of interest is primarily characterized by the presence of shale and sandstone that are very fine grained and very poorly cemented. While coring in this type of unconsolidated formation, the job becomes very complex because of the low recovery percentage obtained. This procedure includes cutting, saving, and removing the core samples from the hole, while maintaining the best integrity conditions possible. The processes associated with recovering the sample at the surface require managing difficult procedures, expertise, proper core head design, and the selection of mud properties and cutting parameters.

The customer concerns focused on the quality of the samples because the quality of the testing data obtained in the laboratory depends on the quality of the samples recovered. The primary factors influencing core quality are related to fluid erosion and invasion while the sample is being cut. This fluid invasion and/or erosion can be caused by the core head geometry and associated with the profile, cutting structure, hydraulics, and jet orientation, affecting the core sample integrity. The difficulty of capturing and maintaining the sandstone in the inner tube of the coring tool assembly during tripping out until it arrives at the surface arises from the possibility that the sandstone will crumble and fall because of the lack of a seal provided by a stronger formation type, or in the worst case, failure of the catch system and the low consistency of the sample. Despite these known challenges, the customer expectations included obtaining quality samples with a high percentage of formation recovery.

Companies that provide these services are aware of the challenges and continuously seek techniques to improve recovery in the area. Consequently, the factors previously described are subject to continuous changes to help improve recovery. In this particular case, several factors were considered for changes, including the length of the core barrel and the core head design. These changes provided good results in nine wells tested in this field.

Development

Core Barrel Length Changes

The core barrel is part of the bottomhole assembly (BHA) and is designed to contain the inner tube. The inner tube, used to store the coring samples, can be composed of aluminum, fiberglass, or steel, depending on the manufacturer and application. They are commonly designed to be 30 ft long.

While tripping in, a column of fluid is created in the BHA until a lock system prevents the flow into the inner tube; it is then deviated to the annulus between the core barrel and the aluminum tube when the coring point is reached. After the fluid flows into the tube stops, it continues flowing through the annulus to cool and lubricate the core head and to clean the hole. A fluid column remains inside the tube to be displaced by the core as the core enters the tube.

While the core is being cut and transferred into the inner tube, formation must overcome the axial forces generated by the column of fluid above. When the formation is unconsolidated, the entry process is complex because the formation might not be sufficiently strong to push the column of fluid away and provide entry for the core sample into the tube.

A primary problem related to this scenario occurs when the core becomes compacted until a sufficient force to overcome the weight of the fluid column above is achieved; this acts as a restriction and results in the deformation of the sample. During this process, fluid contacting the formation erodes it, creating a poor quality sample.

To help minimize the effect of the fluid column weight over the sample while getting the sample into the inner tube, the core barrel length was reduced to 15 ft, enabling the core to enter the tube with less effort and less possible deformation.

Core Head Bit Design Changes

To help increase the recovery percentage in the area, changes to the core head design were considered. Core heads are selected on the basis of the type of formation to be cored. Following the principles of polycrystalline diamond compact (PDC) bits, core head selection considers the cutting structure, number of blades, size of cutters, gauge pads, and hydraulics that provide the best match to the formation strength. For example, softer formations require a smaller number of blades and larger cutter diameter to ensure appropriate drilling/coring efficiency. Factors, including vibration modes in hard formations and bit balling tendencies in plastic formations, should be considered during the selection of design features and hydraulics to avoid producing poor quality cores (Zambrana, 2008).

The core heads typically used in the Orinoco oil belt consist of five- to nine-blade designs with 19, 16, or 13 mm cutter sizes, based on the lithology to be encountered. Typical lithology of the area consists of sandstone and shale with very low cementation and very low compressive strength (**Fig. 1**). The presence of siltstone and coal is expected in layers that are thicker than 15 ft; consequently, one additional blade and a smaller cutter size is used to avoid major damage to the cutting structure (**Fig. 2**).

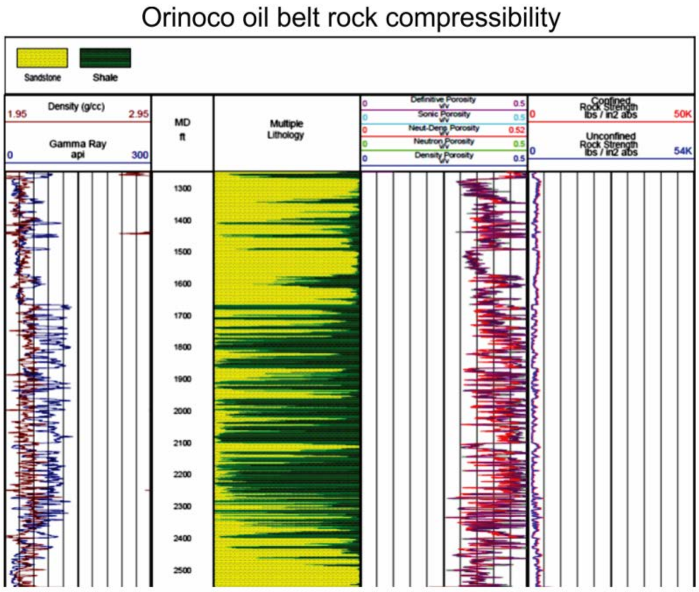

Fig. 1—Typical lithology of the area.

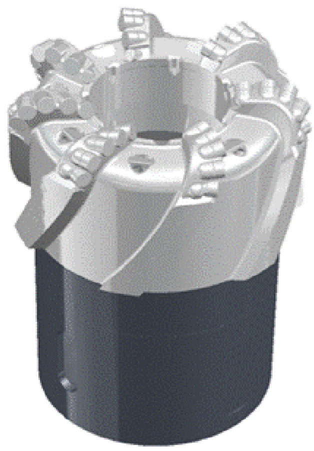

Fig. 2—Core head normally used in the Orinoco oil belt coring jobs.

Conversely, soft formations are best drilled with high flow rates and high hydraulic horsepower per square inch (HHSI). In this case, larger-diameter cutters with a low back rake orientation to provide aggressive cutting structures and the use of large-face volumes to help cleaning by facilitating rapid transportation of cuttings are desired (Zambrana, 2008).

When hydraulics is calculated, an erosion problem often occurs in the presence of unconsolidated sandstones. The erosion is caused by the fluid speed and the turbulence created by the impact of the fluid with the formation around the cutting zone. This impact creates a fluid filtrate invasion and subsequent erosion of the core.

To help minimize this effect, the core head design was modified to ensure that the turbulent fluid pattern created in the bottom of the hole did not directly affect the integrity of the core. Instead, it ensured continuous cleaning of the hole and cooling of the cutting structure. This new core head design consists of a lip (**Fig. 3**) extending out at the level of the inner diameter.

Fig. 3—New extended lip core head.

This extension helps ensure that the unconsolidated sandstone core is protected from the turbulence created by the fluid impact force, preventing it from affecting the core integrity by invasion and erosion. During coring, the impact of the fluids around the extended lip is more forceful near the ports exit and becomes weaker near the cone of the core head, avoiding erosion and damage.

An appropriate extended lip length ensures that the impact force is such that its contact with the cutting structure acting in the bottom hole does not dissipate before it makes contact with the last cutting structure, maintaining its primary objective of cooling, lubricating, and minimizing the effects of fluid filtrate invasion and erosion.

Because of the small number of cutters located on the extended lip, the cutting structure becomes more exposed when encountering a harder layer of formation, causing potential premature damage. Lessons learned and recommendations adopted from field experience include the need to closely follow the well log correlation profiles to ensure that the formation to be cored is 100% soft sandstone (or any soft lithology) or that it does not include important, interbedded harder layers.

Core Head Design Improvement Opportunities

To improve the current core head design, allow aggressiveness, and provide durability when cutting harder formations, the primary blades should be extended to the corresponding cutter at the top of the extended lip. This change needs to be accompanied by the appropriate hydraulic arrangement to ensure that no erosion, balling, or poor cooling occurs during the operation.

Orinoco Oil Belt Operating Coring Recommendations

Better core recovery percentages in the Orinoco oil belt have been achieved in conjunction with proper drilling parameters and the application of best practices obtained from lessons learned, including the following:

- Good lithology correlation is necessary. A precise interpretation of geological information from offset wells provides information about the formation type to be cut, making it possible to select the proper core head to be used for the next job. In this case, an extended lip core head was recommended when homogeneous sandstones were expected; a standard core head was recommended when interbedded formations were encountered.
- The core length should be limited to no more than 10 to 15 ft. When the BHA is designed to cut more than 15 ft of core, the increment of the weight of the fluid column over the core attempting to enter the inner tube leads to low recovery percentages.
- Good communication is required between the geologist, engineer, and coring operators to ensure adequate core head selection and parameters are used.
- Low flow pumps are required. A minimum flow rate is necessary to core sandstone and avoid erosion; consequently, the pumps should allow flow ranges of 40 to 200 gal/min.

- Good rig conditions are important. Accurate readings for weight-on-bit (WOB), torque, revolutions per minute (rpm), and gal/min are necessary while coring to obtain good-quality core samples and avoid erosion, washouts, and turbulence.

Field Results

The extended lip core head design was tested in nine wells in the area; the primary challenge was to recover more than 75% of core, at the best quality possible, within the zone of interest. Usually, core intervals are approximately 600 to 800 ft in the 8 1/2 in. section to obtain a core of 6 3/4 in. through a highly interbedded formation of unconsolidated sandstones and shales at the top of the lithology column and unconsolidated oil-impregnated sandstones at the bottom. The presence of coal and limestone is expected. **Fig. 4** shows the BHA used in these wells.

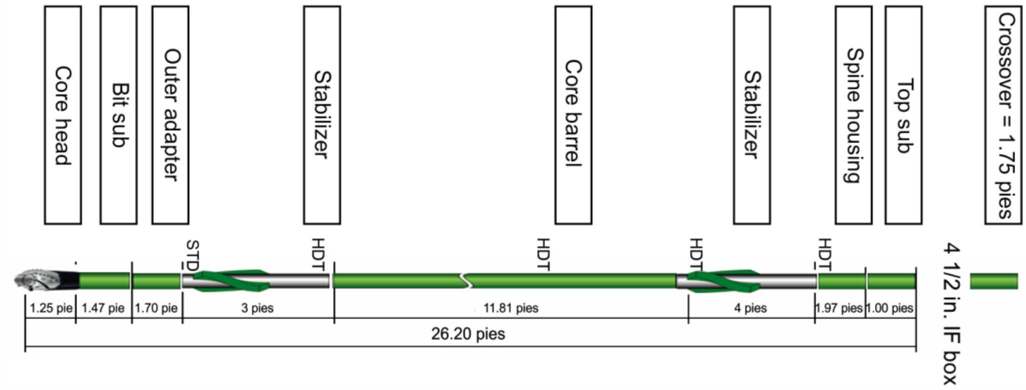

Fig. 4—BHA arrangement used.

The first well was cored, and many lessons were learned in the process. The job was planned for coring 600 ft, with an initial BHA core barrel length of 30 ft. The primary challenge of this job was to achieve more than 75% recovery with lithology data from a far offset of 5 km in a geological synclinal structure. Despite failures of the core catcher mechanism and insufficient control of the flow rates from the pumps, 587 ft of the formation was cut with a recovery of 75.78%, but the expectations were not exceeded. First, 395 ft was cored using a standard core head, providing 74.3% recovery through shale and interbedded sandstones. Unfortunately, there was no accurate formation tops data; consequently, intervals of sandstone greater than 40 ft thick could not be identified to allow appropriate selection of the core head type. From the log data, a body of sandstone greater than 62 ft thick was expected; consequently, the extended lip core head was used. Small layers of limestone and coal were encountered, but the predominant dull grading condition observed indicated broken cutters in the extended lip and shoulder areas of the core head. Despite this, the cutting process resulted in 86.1% recovery, which represented an increased recovery of more than 15.8% compared to that obtained with the first core head (**Fig. 5**).

After this well was completed, the next wells were all worked with a 15 ft BHA configuration and with a primary recommendation: a twin well to provide accurate data to help identify the next formation type to be cored and, consequently, select the appropriate core head.

Fig. 5—Standard core head used in shales and interbedded formations.

Next, eight wells were cored, alternating the core heads in accordance with the formation type and obtaining good results when the sandstone was cored (**Fig. 6**). Based on the dull grading conditions observed and to continuously improve results, several small changes were made to the core heads to increase durability, providing the ability to drill aggressively in more than one environment (**Fig. 7**).

Fig. 6—Extended lip core head design.

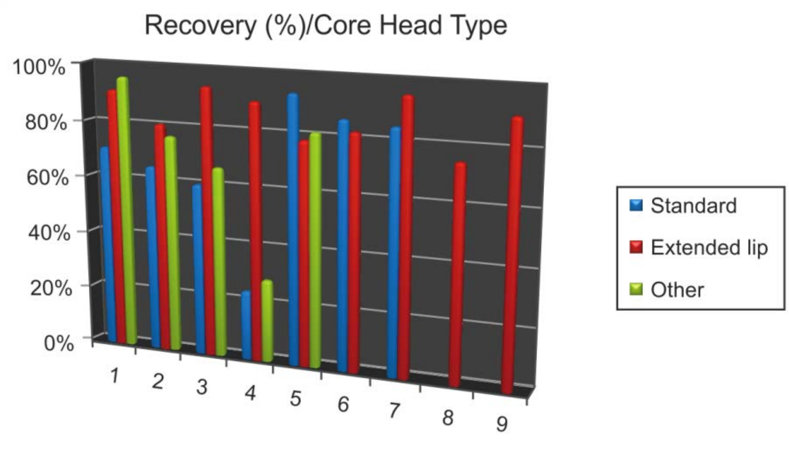

Fig. 7—Recovery percentages in the nine wells tested with the new core head designs.

Case History: Extended Lip Core Head for Unconsolidated Sands in Venezuela Applications

The final well to be cored consisted of 600 ft in an 8 1/2 in. section, penetrating highly abrasive formations. The operator challenged the service company to provide a core head design solution to increase the recovery in coring operations while minimizing the number of runs and maximizing savings.

The expertise and knowledge used during the coring operations in Well CMI-055 drilled in the Orinoco belt in Venezuela focused on selecting and designing the appropriate core head and core barrel length, as well as exercising the proper control of drilling parameters. In addition, accurate and timely decisions optimized the coring time by reducing tripping and producing core samples while maintaining hole integrity. The use of the extended lip core head minimized the turbulences caused by the impact of the fluids with the formation and helped to ensure the highest recovery rates obtained historically in the Orinoco heavy oil belt.

The 8 1/2 in. core head exceeded customer expectations and established a new field benchmark recovery percentage in the area. The extended lip core head cut more than 600 ft of core sample with greater than 84% recovery in this well, with an average greater than 87% in nine wells in the Orinoco oil belt. This result represents an increase of more than 20% recovery in the zone of interest (unconsolidated sandstone), which is the best overall recovery in the area.

Conclusions

- Extension of lip in the core head, helps ensure that the unconsolidated sandstone core is protected from the turbulence created by the fluid impact force, preventing it from affecting the core integrity by invasion and erosion.
- An appropriate extended lip length ensures that the impact force does not dissipate before it makes contact with the last cutting structure, maintaining its primary objective of cooling, lubricating, and minimizing the effects of fluid filtrate invasion and erosion.
- Forces generated by the column of fluid into the BHA, while the core is being cut and transferred into the inner tube, can be minimized limiting the core length to no more than 10 to 15 ft in non consolidated sands.
- A good lithology correlation is necessary to ensure the adequate core head selection and parameters to be used in each cut.

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