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Composite Drill Pipe Perfect Fit for Short-Radius Drilling

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With much of the nation's "easy-to-produce" oil and gas gone, many U.S. companies are looking for lower cost methods to recover the oil and gas that was bypassed when many of the nation's fields were first developed. Short-radius horizontal drilling is one technology that is being used to recover oil and gas from bypassed zones, many of which are shallow and of low productivity. However, one of the challenges facing the short-radius drilling industry is the need for reliable drill pipe that can withstand the stress of drilling through short-radius-of-curvature bends for extended periods of time. A new, lightweight, flexible drill pipe engineered from space-age composites rather than steel has the potential to fill that need, extending the life of existing wells as well as reducing the cost of drilling new horizontal wells.

Short radius drilling is being used by some companies to re-enter older, vertical wells and drill horizontal laterals into oil- and gas-bearing formations previously deemed uneconomic. These horizontal wells can encounter several hundred, or perhaps even several thousand, feet of reservoir rock, allowing them to drain substantially more oil or gas. But the sharp radius of curvature of a typical short-radius reentry well— from 20 to 80 feet—can create stress and fatigue damage that significantly decreases a drillstring's life and reliability.

A new flexible composite drill pipe (CDP), which was developed by Advanced Composite Products & Technology, Inc. (ACPT) under a cooperative agreement with the U.S. DOE's National Energy Technology Laboratory, overcomes this problem. Although more expensive than traditional steel pipe, it can remain bent for extended periods of time without suffering fatigue damage. Fewer pipe failures occur, less pipe is needed, and the pipe can be reused in multiple wells, leading to a significant decrease in drilling costs.

CDP could bring new life to thousands of idle wells drilled in the early 20th century. In many fields, oil-bearing formations previously considered uneconomic lie 100 feet or less below well TDs or were bypassed because the reserves were not considered significant when the well was drilled. Using short-radius drilling to drill a horizontal well into these formations could bring many of these older wells back into production without the environmental disturbance that drilling new wells from the surface would create.

CDP Manufacturing Process

CDP consists of a composite material tube with steel box and pin connections. The tube is manufactured by winding a composite material consisting of graphite fibers and epoxy resin around a metal mandrel and then curing it at high temperature. The mandrel is then extracted and reused, while the cured pipe section is finish machined, coated for abrasion resistance and attached to the metal box and pin connections. Final preparation involves the addition of standard elastomeric centralizers before the pipe is run in the hole. Both the centralizers and the abrasion resistant coating can be repaired in the field. More extensive wear damage, as long as it is not too severe, can be repaired at the factory.

Advantages of CDP Over Conventional Steel Pipe

In addition to its application to short-radius drilling, CDP shows promise for enabling the economic development of oil and gas resources in other challenging locations. Because CDP combines light weight (less than ½ the weight of steel) with the performance properties of steel pipe, it is considered one of the technologies needed for resource development in extended reach (ER), ultra deep (UD), and deep directional drilling (DDD) applications. Onshore, it will allow the existing fleet of drill rigs to drill at much greater depths. CDP also has significant potential to enable technologies requiring high-speed communications (“smart” drilling technologies) through the drill pipe via the embedding of cables and/or fiber optic leads within the body of the drill pipe. With the weight of the CDP at 40 to 50 percent of steel, the loads to be transported and the weight that must be supported by drilling platforms are significantly reduced. These reductions can provide very substantial cost savings for deep drilling and deep water drilling activity.

CDP can easily be customized to meet specific requirements for specific applications. For example, to increase tension and compression strength, more longitudinal fibers are used. Similarly, more hoop fibers can be added to increase pressure capability and an increase in fibers angled at 45 degrees will improve torque capacity. In this manner, CDP can be designed for the expected loading conditions of a particular application. The specifications are then fed into a computer-controlled filament winding machine and application-specific CDP sections produced on demand.

Tool joints made from various metals, including non-magnetic stainless steels, can be furnished as an option. The addition of non-magnetic connections to the non-magnetic composite body of a CDP joint may be beneficial when using certain directional drilling instruments. Also, corrosive resistant tool joints along with the carbon fibers/resin body make this pipe a suitable tubular for use in high H₂S/CO₂ drilling environments.

Performance Characteristics Compare Favorably to Steel

Current drill string performance limits are controlled by the strength-to-weight ratio of steel drill pipe. Materials with higher specific strength ratios can increase these limits in all three directional drilling zones (ER, UD, DDD). For example, according to drill pipe manufacturer Omsco, Inc., 6 5/8-inch, 27.70 Grade S steel drill pipe in 10 lb/gal mud has an allowable depth of 32,000 feet. With comparably sized CDP the allowable depth increases to at least 50,000 feet.

While increased strength-to-weight ratio is always advantageous, each directional drilling zone places somewhat different requirements on the drill pipe. In ER (where Reach/TVD ≥ 0.75), the limits are associated with both radius of curvature (fatigue) and frictional effects from the combination of curvature and total weight. In short radius directional drilling applications, steel or titanium drill pipe will fail in a few hours whereas the CDP has a life expectancy of 1000 Hours, more or less, depending on the radius drilled and the

combined loads of tension/compression, torque and pressure. The properties of CDP can be tailored such that a radius of curvature as small as 20 feet is within the pipe's fatigue limits.

Successful Field Trials Support Commercial Application

Three field tests of the short-radius composite drill pipe (SR-CDP) have been completed. In all three tests, the SR-CDP was employed in a short radius drilling application where the well was being drilled from vertical to horizontal within a 50 to 70-foot radius. Also, only 5 to 9 joints of composite pipe were used in each test and the pipe was always positioned in the drill string to be in the turn section of the well. The first test was performed by Grand Resources in Tulsa, Oklahoma as they used the SR-CDP to re-enter an older vertical oil well which had stopped producing in 1923. Just below 1200 feet, drillers kicked off a new borehole that curved in a 70-foot radius until it became horizontal and then continued another 1000 feet horizontally. The pipe performed flawlessly during this test. Grand Resources then used the pipe in a second well, in which the pipe became stuck in the hole. During the effort to unstick the pipe, two joints failed; one joint broke in the middle and another broke at the metal connection/composite interface. Evaluation of the metal/composite interface break led to the interface being redesigned to create a bond that is much stronger. A review of the drilling records determined that the SR-CDP was not the reason for the pipe becoming stuck and that the mid-joint failure was a result of the extreme twisting and pulling forces applied during the effort to unstick the pipe, which also occurs in steel drill pipe.

The third field test was performed by JB Drilling in LeFlore County, Oklahoma. The SR-CDP was used in a new gas well to drill a 60-foot radius turn for a horizontal lateral at a depth of 1385 feet. A major difference in this test compared to the Grand Resources tests was that an air-hammer drilling tool was being used in this well. The air-hammer subjected the pipe to severe pounding stress, testing its fatigue life and mechanical strength. Along with the stress, the fact that the formation being drilled was very hard and abrasive provided an excellent test of the protective coatings used on the pipe. In this test the SR-CDP was run for a total of more than 160,000 cycles at an average RPM of 70, air pressure of 300 psi, and torque of 1,000 lb-ft. The pipe was subjected to momentary pulls of 12,000 pounds, 10,000 pounds of compression and 1,500 lb-ft of torque. Despite this rigorous testing, the pipe performed flawlessly and after a week of drilling showed little to no signs of wear.

Commercialization Underway

Following the successful completion of the field tests, ACPT began offering the SR-CDP commercially to drilling companies. The first order was placed in January 2004 by Integrated Directional Resources (IDR) of Lafayette, Louisiana. IDR's Tony Muller reports that the company is using the composite pipe to air-drill Gulf Coast horizontal wells and that the pipe is performing as expected. On location at one well in late July, Muller reported problems with steel pipe failing while drilling the lateral section and that IDR was using the composite pipe for all fishing operations, consistently pulling 20,000 to 25,000 pounds. As a result, IDR planned on using all of their available composite pipe

to complete the lateral section. The specifications of the SR-CDP in use by IDR are shown in Table 1.

Ongoing and Future Work Will Expand CDP Options

Work is ongoing to develop a 5-inch ID CDP (7-inch tool joints) that can be used in extended reach applications. This extended reach composite drill pipe (ER-CDP) will also have an additional feature that the SR-CDP does not have, in that it will also include a high-speed communications line built directly into the composite pipe. The ability to transmit data at high rates between the rig and the bit will offer the driller real-time operational control and optimization. The weight savings of this large-diameter CDP will allow operators to drill much deeper without increasing the size of the drilling rig, and in offshore applications will extend the reach capabilities of existing platforms. The prototype ER-CDP is expected to be completed in the spring of 2005, with field-testing to occur through the summer and fall of 2005.

Companies interested in purchasing SR-CDP or participating in the field testing of the ER-CDP, can contact the manufacturer, Advanced Composite Products and Technologies, Inc. in Huntington Beach, California at 714-895-5544, or via e-mail at jheard@acpt.com. For more information on the progress of this project contact Gary Covatch, National Energy Technology Laboratory's Strategic Center for Natural Gas & Oil, at 304-285-4589, or via e-mail at gary.covatch@netl.doe.gov/.