Composite pipe offers advantage for short-radius

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DRILLING OPERATIONS ARE limited by the materials used to manufacture drill pipe. Composite drill pipe (CDP) is available or under development that weighs one half or less than the equivalent, highest quality steel drill pipe. Further, with CDP it is possible to incorporate a signal transmission capability within the walls that will allow real-time monitoring of downhole conditions while drilling. The **US Department of Energy (DOE)** has recognized the need to bring this advanced technology to fruition and has joined with **Advanced Composite Products and Technology Inc (ACPT)** in a program to make CDP available to the drilling industry.

This program has successfully placed short radius CDP in the field and is currently completing the development and testing of extended reach and deep water CDP. In a continuing effort, both the capability for real time signal transmission and extending the physical and mechanical characteristics of the CDP are under development to meet the rigorous conditions of Deep Trek operations.

Because the CDP has the potential to be lighter (half the weight of steel) and maintain required performance properties, it is considered one of the technologies potentially essential for ultra-deepwater resource development. Onshore, it will allow the existing fleet of drill rigs to extensively increase the reach of their drilling capability. And, as a third benefit, it has significant potential to enable high speed communications (for smart drilling) up the drill pipe because of the ease of placing wiring and/or fiber optic leads within the body of the drill pipe.

While use of composites has increased dramatically in recent years, the cost and performance of these structures has kept them from being used more widely. With the advance of carbon fiber technology, composite structures are beginning to have the performance capabilities to compete with steel. In addition, now that carbon fibers are getting cheaper and pipe designs more sophisticated, the opportunity exists to develop a pipe that can be cost effective when compared with steel.

MANUFACTURING OF CDP

Composite drill pipe 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 an epoxy resin around a metal mandrel. This length is then cured before the mandrel is removed and recycled. The cured pipe section is finish machined and coated for abrasion resistance. As a final preparation, normally done in the field, standard elastomeric "centralizers" are added where required. Both the centralizers and the abrasive resistant coating can be field repaired. More extensive wear, should it occur and not be too severe, can be repaired by recycling the CDP back through the factory. Steel drill pipe protectors (rotating or non rotating) can also be incorporated into the design.

Existing facilities have been modified to allow pilot plant production of 30 ft sections of CDP at ACPT in Huntington Beach, CA. Additional capacity will require the incorporation of automation and continuous operation to the winding, curing and machining functions. ACPT is working closely with **Omsco**, a unit of **ShawCor Ltd**, to establish marketing levels and schedules. These results will determine the schedule and extent of pilot plant upgrade or the necessity to build a full scale, continuous operation CDP production unit. At a future time, a full scale manufacturing plant will be installed to expand production rates and allow production of Range 3 CDP, which will have even higher strength-to-weight ratios.

Specifications for both nominal 6-in. and 3 ⅜-in. CDP have been finalized, materials for the composite tubing, adhesives, and abrasion coatings have been selected based on laboratory testing, and a composite tube/metal tool joint interfacial connection has been successfully tested (the tool joints in CDP are metal).

Samples of 3 ⅜-in. CDP for use in a short radius well drilling operations were provided early in 2002 and field evaluated in full scale drilling operations in 2003. Commercial short radius CDP is now available (from ACPT). The nominal 6-in. composite drill pipe will be ready for initial drilling operations in 2004. Anticipated pricing is in the range of 3-5 times the cost of comparable steel.

APPLICATION

Initially, the impetus to develop "cost effective" CDP was only the potential for weight savings, estimated to be less than 50% of comparable steel pipe. Further examination has better defined the potential advantages of CDP.

Composite pipe experienced minimal wear during testing and in-ground evaluation.

Unlike any metal drill pipe, the CDP can easily be designed, ordered and produced to meet specific requirements for specific applications. To increase tension and compression strength more longitudinal fibers are used. Similarly, more hoop fibers will increase pressure capability and more fibers at a nominal 45° will improve torque capacity. In like manner, fibers with different properties are available and can be used to increase properties (at higher cost) or provide more economical CDP if the highest properties are not necessary.

Where different loading conditions are to be encountered, the CDP can be designed for the particular application. The mechanical properties are well established and are strictly a function of the resins and fibers used and the orientation and amount of fiber in the CDP tube. This will allow any sections of the CDP to be optimized for the given requirements. The new designs can then be fed into the computer controlled tube-winding machine and specific CDP sections will be produced for specific applications.

COST ISSUES

Cost issues must also be considered. In production, CDP will cost on the order of 3-5 times "standard" S-135 steel drill pipe. Several items need to be addressed in this regard.

First, the CDP represents an enabling technology. Its use will allow deeper and longer reach drilling than is possible with metal drill pipe. In addition, the drilling limit is often not the drill pipe; rather it is the lifting or torque applying capability of the rig. Another rig limitation can be the deck loads on a floating rig. Lighter drill pipe can extend both.

Second, when steel drill pipe is at its limits, special (expensive) precautions have to be taken. That is, the steel pipe, in order to be used in current maximum reach drilling, has more stringent manufacturing requirements and more stringent and frequent field inspections. It is not as robust a design when near the technical limits. Thus, even where steel pipe may be used near its technical limit, CDP will reduce the loads and operate at a smaller percentage of its limits, therefore becoming more robust. It is also noteworthy for these applications that the CDP will have much higher fatigue properties than the steel counterpart.

Third, with CDP we can easily tailor or customize the mechanical properties for its application and/or location in the drill string. For example, in an extended reach well, steel drill pipe would likely be used in the large vertical hole sections, while CDP would be used in the curve and high hole angle sections of the well. This allows optimization not possible when only steel drill pipe is used. Thus, even though CDP will always be more expensive than steel drill pipe on a joint-per-joint basis, the cost and performance of the total drill pipe string can be optimized.

Fourth, and very important, with the weight of the CDP at 40-50% of steel, the loads to be transported and the weight supported by the drilling platform are significantly reduced. These reductions can provide very substantial cost savings.

Fifth, when the capability to reliably transfer real-time signal (and power) across the metal tool joints is reduced to practice, the cost of drilling can be drastically reduced. This reduction will be effective in all drilling operations not just extended reach or deeper drilling.

PROGRAM DEVELOPMENT

The testing portion of this project includes initial material screening through final in-ground evaluation of market-ready CDP. The material screening and material properties verification portions are complete. Laboratory testing included verification of mechanical, thermal and environmental properties of resins, fibers and adhesives. Measurement of erosion and mechanical abrasion characteristics of interior and exterior coatings for CDP is complete.

The major difficulty in producing a commercially useful CDP has always been recognized as the interface between the composite tube (pipe) and the steel joints. In order to reduce developmental costs, ACPT broke the development and testing into two distinct areas: subscale design and testing, and full-scale design and testing.

One-third size (diameter) was chosen for the small-scale effort and the full-scale work was broken into full diameter pipe in 10 ft sections and full diameter pipe at the full length of 31.5 ft (shoulder-to-shoulder) of the metal joints.

To date, the one-third scale testing is complete. The one-third scale test specimens are 1.417-in. ID and have 12-in. of composite tube between the steel joints. Ten-foot sections of full diameter CDP have been fabricated and tested. Tooling, fabrication equipment and procedures are being prepared for building the 31.5 ft test units.

Twenty-six different one-third scale tension tests were completed. Fifteen different combinations of composite/metal joint interface and composite wall configuration were evaluated. After testing showed that a successful composite/metal interface design had been achieved, full size, 10 ft sections of CDP were fabricated and tested.

More recently, based upon the final 1/3 scale work and in order to qualify for short radius drilling, 3 ⅜-in. sections have been tested. The results of these tests proved that the full-scale requirements will be met.

Fabrication of specimens for "proof-prior-to-drilling" testing of the CDP is underway. This will include laboratory testing of full size nominal 5 ½-in. and 3 ⅜-in. CDP, and field-testing of 3 ⅜-in. CDP in drilling short radius wells has been successfully demonstrated. An alternate Range 3 design with a tube bore larger than the tool joint bore is under development. The dual bore diameter will further reduce circulation pressure losses.

REAL TIME DATA

A significant feature of CDP is that it can be designed to carry electrical power and/or real-time communication lines embedded in the composite walls. The problem to be solved is reliably transmitting a signal or power through the metal joints connecting individual CDP sections. Several approaches to solving this problem are currently being examined.

Direct Connect has been tried unsuccessfully numerous times. Several revised concepts are being investigated for ACPT by a competent engineering firm.

Acoustic Transmission has been explored with DOE funding by another contractor.

Inductive Transmission shows positive potential. Sandia National Laboratory is continuing to investigate inductive transmission. Inductive coupling has been considered and will be further investigated if the conceptual demonstrations show sufficient merit.

In anticipation of the development of a successful method for transmitting signals across metallic joints, Sandia National Laboratory has evaluated signal loss/transmission characteristics in CDP with wires incorporated into the walls of the pipe. The results proved conclusively that signal transmission can be accomplished. ■