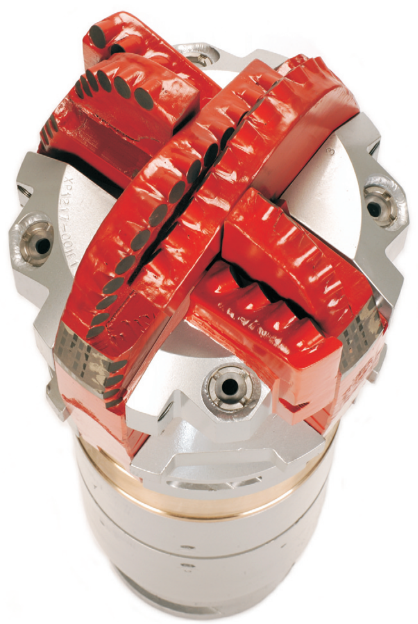
Expandable drill bit provides significant advantages

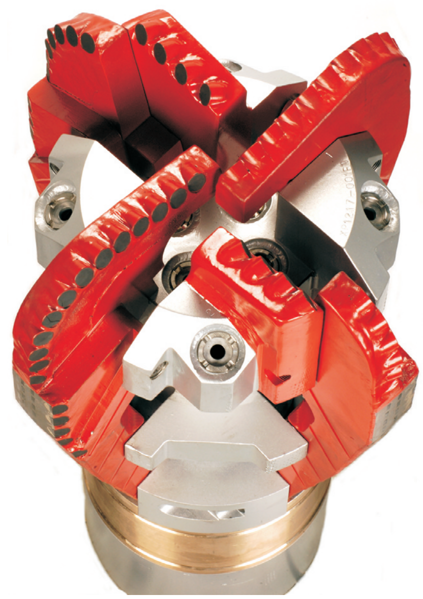
IT HAS LONG been recognized within the drilling industry that the ability to drill an increased diameter borehole, having passed through a restricted casing and/or tubing diameter, can provide significant advantages.

Among these is the ability to incorporate novel well construction techniques, using both solid and/or expandable tubulars, as well as drilling with casing possibilities, in which the casing is run immediately behind the bit. The opportunity to successfully incorporate these new techniques can thus enhance well struction problems and reduced drilling performance. One embodiment of the technique of drilling with casing requires a bit that can be retrieved through the existing casing string.

To achieve this and to maximize drilling performance requires a device with a formation cutting structure indistinguishable from a standard PDC drill bit but capable of being withdrawn through a restriction significantly smaller than the borehole size just drilled.

This concept leads to the possibility that a viable solution to the task of drilling





The expandable drill bit's closed configuration is shown on the left with the expanded mode on the right. During field tests with Unocal in Indonesia, weight on bit required to achieve a specificed controlled penetration rate was 39% lower than for offset tricone runs.

design to yield significant economic and well control gains.

Current techniques for drilling such increased diameter holes, such as bi-centered bits and under-reamers, have limitations on their ability to expand, while at the same time compromising the cutting structure presented to the formation.

Additional limitations include limited reaming and back reaming capabilities, as well as non-uniform directional response. This can lead to well con-

increased diameter holes could be a bit that offers substantial expansion capabilities while still presenting full cutting structure to the formation.

BACKGROUND

Traditional well construction techniques, with individual concentric lengths of pipe to progressively line the borehole, have been employed for many years. This leads to considerable structural redundancy of the casing used as a borehole liner as well as extra cost involved in both materials and logistics.

The need to isolate sections of the well during the drilling operation depend upon a variety of geological factors, such as abnormal pore pressure, wellbore instability and hydrocarbon or fresh water bearing zones.

The challenge is to develop well construction methods that address the traditional goal of lining the borehole from top to bottom, but in ways that are more predictable, reliable and cost-effective,

Current methods will never permit a single diameter bore hole to be drilled along its entire length, but new techniques have been recently developed that require a radical new approach to the drilling process itself.

Two techniques directly applicable to, and positively impacted by utilization of an "Expandable Drill Bit" are the use of expandable casing and drilling with casing.

The ductility of certain grades of steel permit significant amounts of plastic deformation to be achieved without detrimental work hardening such that it is feasible to increase the diameter of a pipe evenly and without unequal thinning of the cross section.

The development of pipe connections able to accommodate this increase in diameter has made the concept of mono-bore wells a reality.

In situations where borehole stability is a concern, lining the hole at the same time as drilling removes some of the uncertainty from the operation and achieves reduced annular space when used with concentric casing strings.

It may also be used with a mono-bore construction. Drilling with casing, however, also creates a whole new set of challenges and requires a re-think of traditional drilling practices.

One method of drilling a mono-bore well is to use a drilling device capable of passing through a restricted diameter, with the ability to drill a larger diameter hole.

Similarly, when drilling with casing, one method is to drill the borehole and then recover the drilling device through the bore of the casing just installed.

Two established products exist that can achieve this, bi-center bits and under-reamers, which between them currently take the bulk of the market share.

These products fall into distinctly separate categories, with relative merits and operating criteria.

Both suffer from significant drawbacks and it seems unlikely that future engineering developments would be able to make significant improvements in performance and application.

It was obvious that a completely different approach to the problem was needed, employing tried and tested drilling principles and solutions, in order to avoid a lengthy and unpredictable development schedule.

The present design of the expandable bit was prepared after considering a number of options and alternatives and was seen to embody the features associated with best drilling practice.

With the greater use of expandable well completion technologies, it is recognized that drill bits able to drill a hole with varying diameter will take an increasing market share.

DESIGN BASIS

The original design premise was to build a drill bit with a variable diameter PDC cutting structure using a simple, robust and reliable operating mechanism. Following assessment of a number of alternatives, a concept design with four moveable blades was selected.

This initially achieved an expansion from 8 ½-in. to 9 ⅝-in., although very early on this was increased to 10 ¾-in. This resulted in an expansion ratio of 20%.

The blade profile and cutting structure was identical to that used on **Weatherford's** range of fixed cutter bits, whose performance was well documented and understood. It was realized that this would not only make selection of the right drilling application much easier, but also achieve a significant performance improvement over existing oversize hole drilling methods, such as under-reamers and bi-center bits.

It also quickly became apparent that the design allowed much larger expansion ratios to be achieved with minimal alterations in the blade design.

The expansion mechanism is entirely hydraulically actuated by the pressure differential from fluid flowing through the bit. An internal coil spring is incorporated to return the blades to the closed position. This would occur every time flow through the bit stopped.

A half scale functional model was constructed from aluminum and rapid prototyped plastic components to demonstrate the operating principles.

EARLY DEVELOPMENT

During construction of the first model, it was recognized that a number of design improvements could easily be introduced without significantly altering the original design premise.

The original operating mechanism concept of four blades pivoting about their rearmost end in a housing was retained, but now attached to an outer hydraulic cylinder, and not carrying any axial drilling forces.

Rearward movement of the cylinder under the influence of pressure differential draws the blades over a profiled surface, causing them to open outwards to the expanded position. The blades are now retained in slots machined into the head of the bit as a means of transmitting the drilling torque.

Retaining pins mounted on the head act on grooves machined into the blades to actively retract the blades as the bit closes.

The entire drilling weight is applied directly to the head of the bit and on to the PDC cutting structure mounted on the blades. The blades are not directly loaded with any compressive forces applied to the pivoting end.

The pivot is only a means of locating the rear end of the blades. Pulling out of hole imparts a down thrust onto the blades, promoting a closing action in addition to that imparted by the return spring.

The addition of cutters along the gauge section of each blade enables the bit to effectively drill open from a smaller restrictive diameter to achieve full expansion.

A further model was constructed

embodying all the modifications identified during the early development phase.

COMMERCIAL DEVELOPMENT

In order to develop the expandable bit to a working prototype, a commercial venture with an end user was sought. Early discussions with Unocal Indonesia revealed a significant opportunity to use the expandable bit in a series of wells comprising other innovative technologies.

It was agreed, during March 2001, that a working prototype would be constructed with an operating range from 12 ¼-in. to 17-in.

PROTOTYPE DESIGN

Detail drawings were quickly prepared from the assembly general arrangement. A PDC cutting structure comprising 19 mm diameter cutters was identified as being suitable for the soft formation application in Indonesia.

One of the basic design principles was for the expandable bit to be fully field serviceable, with all mechanical components having an extended operating life. Only the blades would be replaced to present a new cutting structure. This concept enabled a number of operational advantages.

The blades could be supplied with an individual cutting structure to suit particular drilling parameters. Also each set of blades enabled a unique expansion ratio to be achieved within the maximum design diameter.

The blades could also be re-dressed with a new cutting structure a number of times before eventual replacement.

High strength corrosion resistant alloys were selected for all component parts coming into contact with drilling fluids, to improve reliability and extend service life.

In order to test the ability of the bit design itself to drill, a positive lock open mechanism was included for the first run to ensure that the first hole was drilled in gauge, obviating the need for subsequent logging trips.

The lock open device was achieved by using a split lock ring seated into grooves machined in the rear of the outer hydraulic cylinder and the shank. The feature was not included on subsequent runs.

FIELD OPERATIONS (1)

Initial field trials took place in Indonesia during July 2001 on two grass roots wells on a developed platform with good offset data.

An operating practice in place for these wells was controlled drilling in the riserless section, therefore rate of penetration could not be utilized as a performance measure; weight on bit required to achieve standard controlled drilling rate was used instead.

The first well drilled very well, the only major finding not expected was higher than tricone WOB required for controlled drilling (average of 6.1 klbs vs average of 3.2 klbs for tricone).

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Much higher than expected WOB was attributed to balling. The lock out mechanism functioned as designed. Overall drilling was very smooth and stable.

The second well utilized an above-mud line kick off technique for slot recovery. In the process, the bit drilled into junk on the seabed, sustaining a fairly high degree of damage to the cutters and blade leading surfaces.

While inadvertent, the junk drilling was a very good "test to destruction" for the bit. While the cutters were damaged, the operating mechanism still functioned as designed, a very encouraging finding.

OPERATIONAL FEEDBACK

Following the initial field trials, the bit was returned to the onshore operation facility for strip-down and inspection. It was evident that debris contamination along the underside of the blades could prevent the bit from closing satisfactorily. Also, drilling debris was entrained within parts of the blade guide slots.

After some debate, it was recognized that preventing ingress and entrapment of debris to the working parts of the bit would be impossible, so the alternative was to insure, as much as possible, that no entrapment could occur.

Accordingly, the slots in the head were considerably relieved, retaining only sufficient material to ensure necessary structural integrity.

The lower faces of the blades were also re-profiled, with a blunted knife-edge, to displace any solids accumulating underneath them. (The slots in the blades, engaging with the return pins, were replaced with grooves on the front and back faces and the pins were redesigned accordingly.)

In an attempt to provide a pressure sensitive open/closed indicator, small bypass ports were drilled into the head of the bit immediately below the lower face of each blade.

The lower face of each blade was provided with a rubber plug to prevent flow when the bit was closed. The ports would have the additional feature of washing out the lower face of each blade during drilling operations.

Some damage was evident to the bore of the hydraulic cylinder caused by contact with the outer diameter of the piston. Although the original design concept had attempted to keep the number of parts to an absolute minimum, to increase reliability it was decided to fit bronze wear rings between the piston/cylinder and cylinder/mandrel interfaces. These were retrofitted to the prototype and could easily be replaced in the field.

Flushing ports were also introduced into the hydraulic cylinder to enable cleaning of the actuating chamber and spring chamber without necessitating strip-down during field operations.

FIELD OPERATIONS (2)

Further field trials took place during January 2002 where the bit was used to drill a grass roots well in the same field as trials in 2001. Again, controlled drilling was mandated for the riserless section, thus WOB required for standard controlled drilling rate was used to gauge bit performance.

Overall, the modified bit drilled very

smoothly, much more so than on the first two runs. Required WOB showed a marked improvement over 2001 trials, less than 22% of that for a tricone bit. No external damage was noted. It was apparent that the bit, if not in controlled mode, would be capable of very high ROP.

FURTHER DEVELOPMENT

Following strip-down from these trials, some galling was evident between the blade pivot housing and the mandrel. Some of the scoring could have been caused by hard abrasive particles from the drilling operation.

Due to the success of the bronze wear rings in totally preventing damage to the sliding components of the hydraulic mechanism, it was decided to include a similar solution for the blade housing.

A new housing was machined to take a split bronze bushing and was fitted to the prototype bit; all other components remained unmodified.

It was also recognized at this time that there was a likelihood of drilling a 14 ¾-in. diameter hole in addition to the 17-in. diameter already identified. Accordingly, a further set of blades was designed to fit the other existing components. This particular expandable bit therefore has the capacity to drill holes ranging from a minimum of 12 ¼-in. to a maximum of 17-in., with any incremental size in between.

FIELD OPERATIONS (3)

Following minor work on the bit, additional field trials took place during June 2002. The location chosen was a third platform in the same field as the first three runs.

Overall drilling performance was very good. Weight on bit required to achieve specified controlled penetration rate was 39% lower than for offset tricone runs. The one problem that surfaced during dlese runs was mud solids packing off inside of the pressure chamber. Solutions have been instituted and are awaiting field trials for confirmation of success.

FUTURE DEVELOPMENTS

Developments of the expandable bit have proved the concept to be feasible and practical. Supported by continuous development in association with Unocal, this project has provided performance improvement and addressed all necessary operational issues.

At this time another size of expandable bit from 8 ⅜-in. to 12 ¼-in. diameter has been designed and is nearing prototype manufacture.

REFERENCE

This article is based upon SPE/IADC paper 79793, *Expandable Drill Bit Provides New Method of Drilling Increased Diameter Hole*, presented by **Martin D Brown**, **Unocal Indonesia**, and **Andrew D Gledhill**, **Weatherford International**.