



Sidetracking and Drilling in One Trip- Case Histories and Economical Analysis

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Abstract

Recent technological developments in sidetracking and cutting structures have demonstrated the possibilities of sidetracking an existing cased hole and drilling the well to total depth in a single trip. Discussions in this paper will cover specific case histories in the "Four Corners" area of the United States where sidetracking and drilling to total depth in a single trip was accomplished. The technical application of the system will be covered. Also demonstrating the feasibility to perform this task, along with economical analysis detailing associated cost savings compared to a well where tripping for a bit was required.

Introduction

Prior to new advancements in sidetracking it was standard practice to clean the existing wellbore and recompleat when production rates declined. If production was enhanced at all, it was generally short lived. Inherently, these practices were unsuccessful due to poor drilling and completion practices. Therefore, production was a function of the damage incurred during the original drilling and completion process. Often this could not be overcome due to constraints of the wellbore. Even when these obstacles were overcome using stimulation or fracturing technology, the limitations of sweep efficiencies through the reservoir still existed. Thus, much of the hydrocarbons were left in place as bypassed production. If deemed economical, expensive infill drilling programs ensued to tap the remaining hydrocarbons.

Sidetracking methods provide an alternative for economically recovering more of the original oil in place, often at accelerated rates. By utilizing existing infrastructures to access zones, the capital requirements and time are minimized. Advantages to sidetracking include:

- Elimination of original wellbore problems,
- Minimization of the amount of new hole to be drilled versus a new well,
- Utilization of existing infrastructure,
- Implementation of the latest fluids technology,

- Capitalization on advanced directional/horizontal drilling practices,
- Exploitation of existing reservoir boundaries (3D Seismic) and other recoverable reservoirs behind pipe,
- Multilateral technology.^{1,2}

As successful as many sidetracking campaigns have been, operational advancements to the system could still be made to reduce costs, thus enabling more oil to be recovered. This is accomplished by eliminating trips and bit runs from the program during the sidetracking process. In affect, deploying a system in the hole to sidetrack the well, and continue drilling to TD, without tripping out of the hole for a bit.

Sidetracking History

In the 1920's when whipstocks were first introduced in the fields of California, the primary use was that of a correctional device. This correction was either necessary to divert around a fish or to bring the well back to vertical. An alternate use of the whipstock was to drill relief wells in the event of a surface or underground fire. Later the tool was used to intentionally deviate the well from a vertical position. Thus, for the first time, whipstock sidetracking became a pre-planned operation and helped advance directional drilling.

During the 1920's and 1930's other methods such as knuckle joints and deflectors were used to deviate the well. All these methods were common when it was understood that geologic structures such as fault zones, stratigraphic traps, and salt domes could be directionally drilled. However, the performance of these deviation tools was not as predictable as whipstocks.

More and more, the word whipstock became synonymous with sidetracking. In the 1940's and 1950's, surveying technology advanced to provide a more accurate picture of the wells trajectory and deviation. Numerous products were developed for sidetracking during the period from 1950 to 1980. The hydraulic

section mill was the most noteworthy of these advances. Unlike the whipstock, the section mill removes 360 degrees of casing opposed to the smaller window provided by the whipstock. It became equally common during this period to either cut a section or mill a window.

In the 1980's hybrid carbide milling products were created and became commercially available. Typically numerous runs were needed to complete the section or to mill a useable window in the casing. By incorporating special carbides in downhole milling tools, the operational limitations changed from the mill to other rig variables such as the mud and pumps. Now the section mill could remove up to 100 feet in a single run at a very rapid milling rate. However, the metal cuttings from this operation have to be removed from the wellbore in a timely manner to prevent sticking of the milling assembly, thus the milling rate must be controlled to prevent problems. Once the section is cut, a cement plug must be set and allowed to harden to provide the platform for the well to be sidetracked. These cumulative operations are time consuming and impact the overall economics of the re-entry operation.

At this time whipstock technology had not progressed as rapidly as section milling. So it became very common in the late 1980's and early 1990's to mill a section to sidetrack the well. Operators were quite comfortable with this method and confident the well would be directionally drilled in a predictable amount of time. During this period the major service companies undertook individual projects in order to make the whipstock a viable alternative to section milling.

If the number of runs to mill a window could be reduced, the whipstock would provide a faster means of exiting the well and accelerate the drilling objectives. In addition, eliminating the required cement plug and the necessity of circulating large amounts of steel cuttings out of the well would further reduce the time and cost associated with section milling. However, most whipstocks required from three to five trips in order to set the whipstock anchor, mill the casing, pull out of the hole and provide a useable window to accomplish the drilling objectives. The number of required trips combined with past unpredictable whipstock/mill performance made these systems economically prohibitive in most cases.

The 1990's marked continual improvements in whipstock technology. By the mid part of the decade, the number of trips to complete a window had been reduced to one. (Figure 1) Equally important was the reduced risk associated with whipstock operations. Today the preferred method for re-entry is the whipstock, with the section mill coming in a distant second.

Cutting Structures

The evolution of sidetracking has in large part been due to advancements in cutting structures. Early advances in cutting structures utilized crushed carbide to mill steel in downhole applications. In the 1970's the Diamond Speed Mill was introduced to sidetracking applications with success when harder formations were encountered.³ The 1980's saw the advent of hybrid carbide milling products. As these products became commercially available downhole milling technology rapidly advanced. Over the next decade, sidetracking rapidly became a day to day planned operation and by the mid 1990's the majority of sidetracking was being performed by cutting a window. This operation was, in most cases, requiring only one trip in the hole to accomplish the entire operation.⁴ However, when harder and/or abrasive formations were encountered at the kick off point, multiple trips were required and the window was most often completed using a diamond speed mill.

Milling steel with a diamond speed mill has proven to be a lengthy undertaking in the window milling process, and conversely, milling formation with carbide, of any form, can be just as lengthy an undertaking in completing the window operation. It was these problems that propelled research into alternative materials that would satisfy both criteria, milling steel and drilling formation.

Design and Development

Beginning in 1997, development began on materials for cutting structures that would exhibit the benefits of carbide, for milling steel, and the benefits of Polycrystalline Diamonds (PCD), for drilling formation. Laboratory testing was carried out on various materials in a sidetrack milling simulation and their ability to cut various grades of casing. Examination of the cuttings in size, shape, and appearance were evaluated, as well as the cutter's condition after the operation.^{5,6} (Figure 2)

It was concluded that certain PCD could in fact withstand the impact forces encountered when milling casing in a window operation. This was a major advancement, since it has been well documented that Polycrystalline Diamond Compacts (PDC) when used in milling steel degrade rapidly due to the heat and vibration, and an overall lack of durability. By optimizing the diamond enhancement within the composition, a material of superior strength and toughness was created. The characteristics exhibited by the material made it a candidate for casing exits and drilling formation.⁷

Case Histories

Testing: Utilizing the multi-ramp one-trip whipstock system, the field proven carbide mill design (Figure 3) was retrofitted with PCD inserts. It was proven through two trial tests that milling the window and formation with

the same material was possible. With the initial testing successfully completed, the mill was then redesigned using bit technology and principles. This force balancing design approach, with peripheral milling design produced a more stable mill that would last longer during milling and drilling and increase the rate of penetration in formation. Resulting from this redesign was a concave mill face with 100% PCD insert coverage on the lead mill to aid in directional drilling applications, and repositioned nozzles that optimized the cooling and cleaning of the cutters. (Figure 4)

Field Trial 1: The durability of the new designed mill was field tested following the trial tests. The first field trial was in a chert formation in west Texas. In a previous offset well, a window was milled in 7" 29ppf P-110 casing using carbide mills. Three milling assemblies were run, with a total rotating time of 28 hours required to complete the window and 2 ft. of formation. A month later, when sidetracked in the same formation using the new mill, the window was completed and eight feet of rathole drilled in a single run. Total rotating time was 3.75 hours. Analysis of the mill showed very little wear on the gauge OD and very little chipping of the inserts. This was further proof of the durability of the structures under a high impact and vibrational environment.

These sidetracks were being performed at over 12,000 ft. and historically were taking three to five mill runs to complete the window. In many of these cases the window had to be completed with a diamond speed mill. By performing the casing exit in one run, two to four round trips were saved. Thus the cost eliminated the associated equipment and service during that extra time.

Field Trial 2: The new mill design was tested on another two occasions in South America. Both sidetracks were performed in a hard, abrasive sandstone with compressive strengths ranging from 26-30,000psi. Operations called for the one-trip whipstock to be deployed with a conventional carbide mill to 17,865 ft., and the mill to be used to center point of the whipstock. The new insert mill was run to complete the bottom half of the window and the rathole. In both sidetracks, the new mill completed the window and rathole successfully at ROP's four to six times faster than the carbide mill was able to mill. Wear characteristics were exceptional on both insert mills and each was in gauge. Subsequent running of the directional assembly with a 1.5 degree bent housing motor traversed the window with no problems. This marked the first successful sidetracks in this formation. Prior attempts to exit in this formation had resulted in near catastrophic failures.

The application for these sidetracks was to develop the reservoir using Level 2 Multilateral technology.⁸ New wells in this area were taking nine months to a year to

complete and costing millions of dollars. Using this technology eliminated having to drill grass root wells to exploit the reservoir.

Colorado: Late in 1999, the new sidetrack system was chosen for a well in Colorado. This was due to the value added economics it afforded in not tripping out of the hole to pick up a bit and drill the lateral wellbore.

The whipstock was picked up and the mill attached via the shear bolt. (Figure 5) The system was then deployed in the hole on 3-1/2" IF HWDP. At depth, pressure was applied to the system and the whipstock was anchored in the 7" casing. Milling of the window was completed in 3 hours.

The lateral wellbore was drilled in 9 additional hours and extended 560 ft. from the kickoff point. Drilling was performed using rotary from surface. Analysis of the bottom hole assembly using computer modeling placed the build rate at 3-4 degrees per 100ft. The drilling objective was to place the new wellbore into a virgin area of the reservoir.

Advancements

The applications to date for sidetracking a well and drilling ahead have been relatively simple in design. As this technology is proven, the applications will be increasingly more difficult, both from sidetracking and drilling. It will be these applications that push the envelope of technology to further extremes. Already field trials have begun where a hydraulic set whipstock is deployed with a steerable drilling assembly. The obvious challenge is to lock the motor in place during the orientation of the assembly and then unlocking the motor when desired, allowing it perform its function. This represents just one challenge on the mechanical application side, which will be followed by extending the drilling curve to greater lengths, so eventually lateral lengths of thousands of feet will be drilled without ever tripping out of the hole.⁹

Conclusions

The evolution of sidetracking dates back to the early 1900's, where the equipment to perform this work was crude and used simply as an alternative to going around a fish in the wellbore or to correct the direction of a hole. Advances in metallurgy and cutting structures for sidetracking progressed from crushed carbide in the 1950's to diamond speed mills in the 1970's to hybrid carbide in the 1980's, and to diamond enhanced carbide in the 1990's. Through this evolution, the proficiency in sidetracking has improved to where it is now possible to mill through casing and continue drilling. This reduces operating costs making it feasible to implement this

technology in a variety of different applications.

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Nomenclature

HWDP = Hevi-Wate Drill Pipe

OD = Outside Diameter

PCD = Polycrystalline Diamond

PDC = Polycrystalline Diamond Compact

ROP = Rate of Penetration

TD = Total Depth

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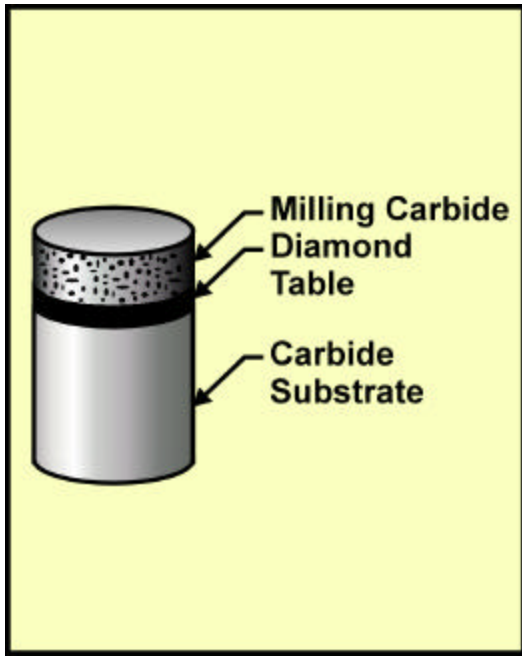


Figure 1 – PCD Cutter



Figure 2 – Carbide Mill



Figure 3 – New Mill



Figure 4 – Mill Whipstock Attachment