SIDETRACKING SYSTEMS FOR HARD FORMATIONS: CASE HISTORIES AND APPLICATIONS

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ABSTRACT

Sidetracking systems, and more specifically whipstock technology, have evolved to the point where only one trip is required to accomplish the casing exit. However, most of these systems have been deployed in simple applications, where the formation outside the casing is relatively soft. More difficult applications, such as those where harder formations must be entered during the casing exit operation, have been bypassed, additional trips planned, or alternate cutting structures utilized to complete the operation. These contingent plans for sidetracking in harder and/or formations are often economically prohibitive in additional equipment and time.

This paper will discuss the application, operation, and case histories of an alternate cutting structure used in window cutting where hard formations exist. It will also cover the economic benefit derived by using this special cutting structure opposed to past methods.

SIDETRACKING APPLICATIONS

Prior to advancements in sidetracking it was standard practice to clean the existing wellbore and recomplete when production rates declined. If production was enhanced at all, it was generally short lived. Inherently, these practices were unsuccessful due to the constraints placed within the wellbore when it was originally drilled and completed. Meaning production was a function of the damage incurred during the original drilling and completion process that often could not be overcome within the constraints of that wellbore. And when these obstacles were overcome using stimulation or fracturing technology, the limitations of sweep efficiencies within the reservoir still existed. Thus, much of the hydrocarbons were left in place as bypassed production. To tap the remaining hydrocarbons, if deemed economical, expensive infill drilling programs ensued.

Sidetracking provides an alternative method for economically recovering more of the original oil in place, often at accelerated rates. By utilizing existing infrastructures to access zones, the capital dollar 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]

As successful as many sidetracking campaigns have been, there are still areas where this technology is an expensive proposition. Most notably, are areas where hard and/or abrasive formations exist at the point of exit. However, developments in cutting structures are making it possible to take advantage of the economics sidetracking offers in softer formations.

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 resounding success.[2] 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.[3] 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.

DESIGN AND DEVELOPMENT

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.

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.' (Figure 1)

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 hard formation casing exits.'

CASE HISTORIES

Testing: Utilizing the multi-ramp one-trip whipstock system, the field proven carbide mill design (Figure 2) 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 completed successfully, the mill was 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.

West Texas: In a chert formation in west Texas, a window was milled in 7" 29ppf P-110 casing using carbide mills. Three milling assemblies were run and a total of 28 hours was spent rotating to mill the window and 2 ft. of formation. Within a month, an offset well was sidetracked in the same formation. However, this time the new mill design was used. In a single run, the window was completed and eight feet of rathole drilled, taking only 3.75 hours to complete.

Colombia: The new mill design was tested on another two occasions in Colombia, South America in 1999. Both sidetracks were located in the Guadalupe formation, which is a hard abrasive sandstone that has compressive strengths ranging from 26,000 to 30,000psi. Operations called for the one-trip whipstock to be deployed with a conventional carbide mill to 17,865 ft., and that mill to be used to center point of the whipstock. The new insert mill would then be run to complete the window and mill the required rathole. The carbide mill cut 6.6 ft. of casing to center point on the whipstock in 6 hours. Completion of the window and the rathole was accomplished with new mill at a ROP of 5.9ft./hr. versus the 1.25ft./hr. of the carbide mill. Inspection of the cutters found them in gauge with some wear on the OD and face. Subsequent running of the directional assembly with a 1.5 degree bent housing motor traversed the window with no problems.

Same as the initial run, the whipstock was deployed to a depth of 14,915 ft., where milling commenced with a carbide mill making 6 ft. in 3 hours. The same insert mill was run, where the window was completed and 4.5 ft. of formation was drilled in 30 minutes. Wear characteristics were exceptional and the mill was in gauge.

The application in Colombia was to develop the reservoir using Level 2 Multilateral technology'.' This would save an inordinate amount of money in not having to drill grass roots wells to effectively drain the reservoir. Prior attempts to exit in this formation had failed miserably and had resulted in near catastrophic failure, meaning the original wellbores were nearly lost.

West Texas: Two offset wells again provided valuable data to cross reference in mill performance when exiting in hard formations. The initial well was to be sidetracked at 11,833 ft. in a sandstone formation exiting 7" 29ppf P-110 casing. As the window milling progressed, the behavior exhibited that of previous encounters with the chert formation, so notorious in the region. Upon further investigation it was discovered that there was indeed chert at the kick off point. Completion of the first window required two carbide mills, which were able to mill just over 6 feet in 15.5 hours, and a final mill run with the new mill. which milled 6 total feet in seven hours.

The subsequent offset well was sidetracked at 11,647 ft. Using the new mill in conjunction with a hydraulic set whipstock, the system was run in the well, oriented using a surface read out gyro, the anchor was set, and the window and rathole were milled. Figure 3 shows the mill attached to the whipstock with the hydraulic setting hose. Completion of the 8 ft. window required 9.5 hours and the drilling of 3 ft. of rathole required an additional 3.5 hours. Figures 4 and 5 show the condition of the mill after this run. The gauge of the mill was 1/16" under full and with minor chipping on several of the inserts. Overall, the mill was in quite good condition, based on the work it performed

In addition to the 5 runs on the new mill documented above, there has been an additional 12 runs in hard rock casing exit applications. These have been performed in west Texas, Columbia, Wyoming, Louisiana, and the Middle East, in rocks ranging in compressive strengths from 26-40,000 psi with varying degrees of abrasiveness. Most of these runs have been behind a standard carbide mill to complete the job when the mills stopped. In applications where the new mill was run initially, the windows have all been completed in one trip. Subsequent operations through those windows in every case have been unhampered.

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 material used for the 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. However, sidetracking operations in hard formations still carried a significant amount of risk and were very time consuming.

Technological advancements in cutting structures have made sidetracking operations in hard formations less risky and more predictable. In conjunction with the one-trip whipstock, these metallurgical advancements have made what was once an unpredictable, time consuming process, a practice with expectant results. In a single trip in the hole a useable window can be machined. This has driven costs down and made it feasible to implement this technology in a variety of different applications where hard formations exist at the casing exit point.

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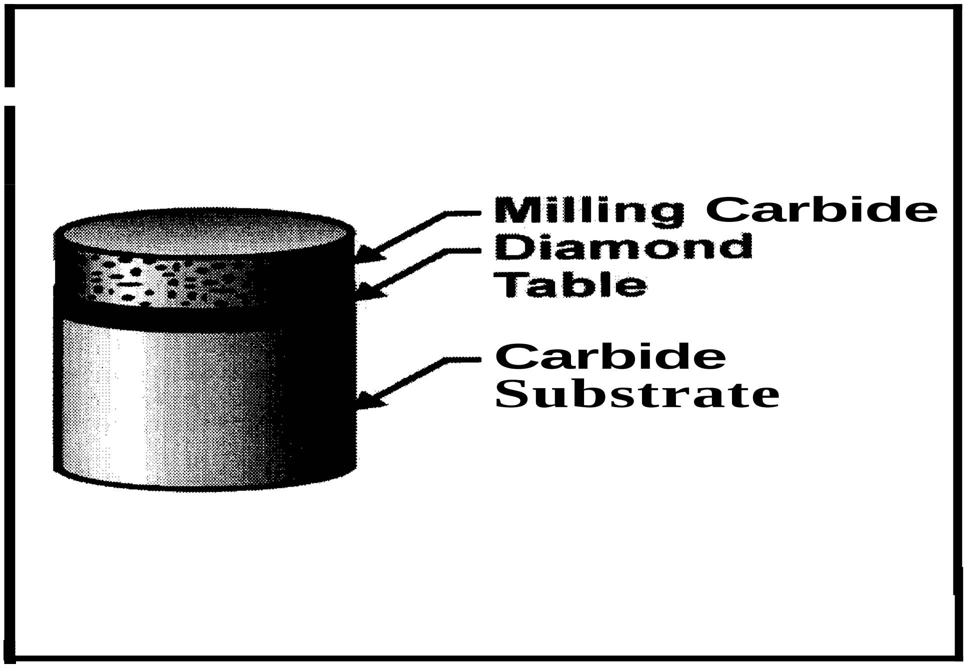

Figure 1

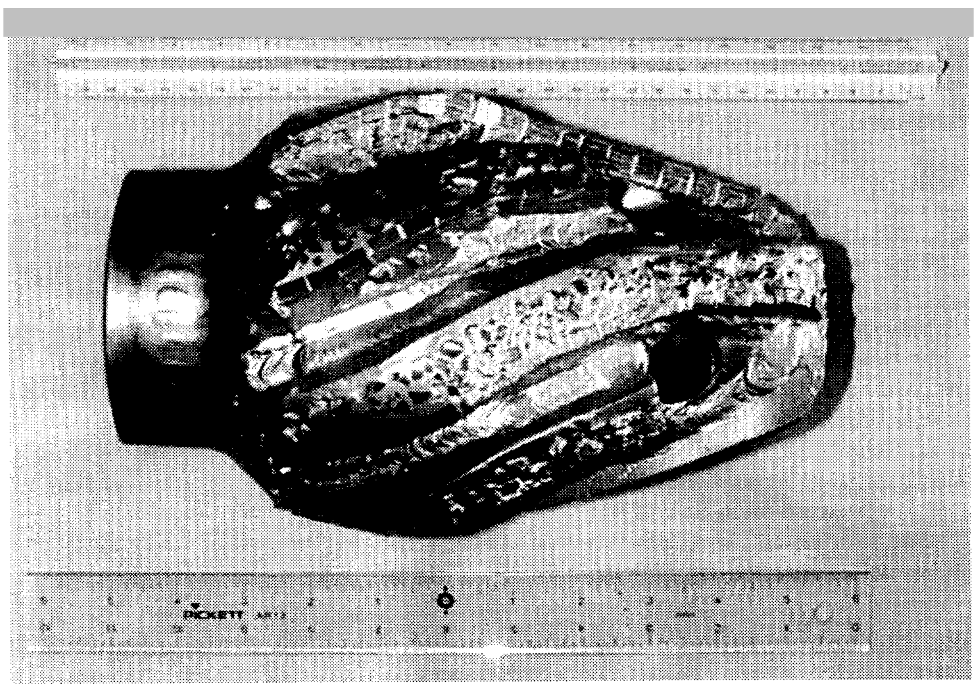

Figure 2

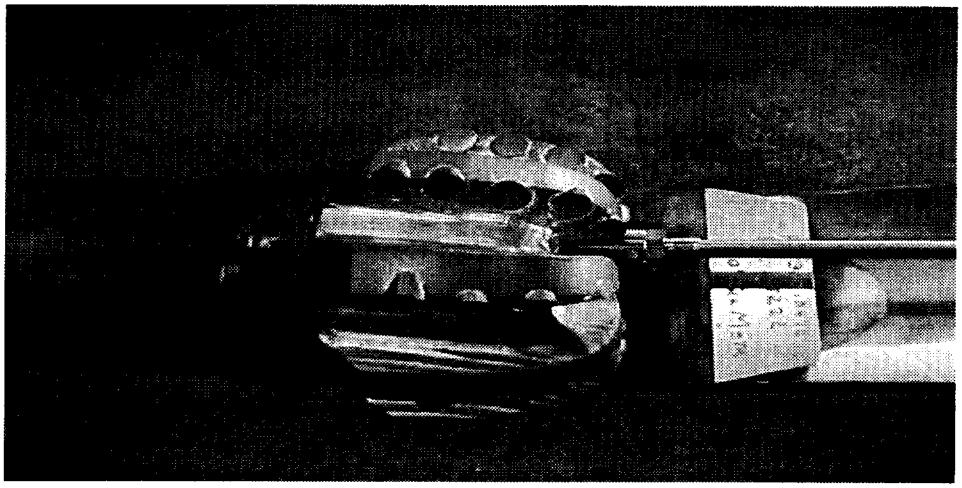

Figure 3

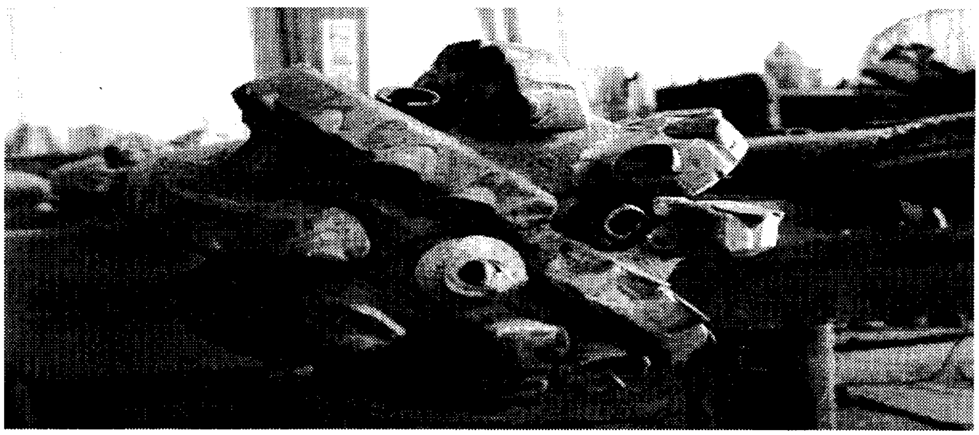

Figure 4

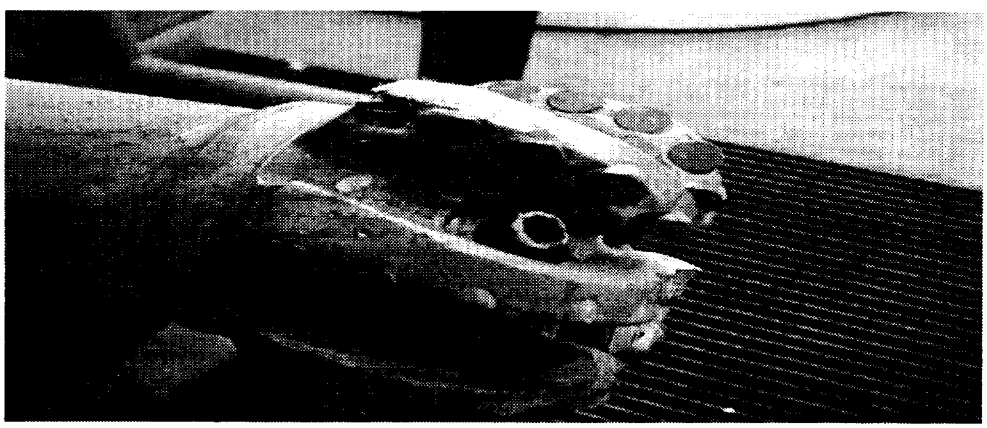

Figure 5