Designed for Cement and Scale Milling cleanout operations

- Carbide or PDC Updrill available
- Natural Diamonds - PDC cutters - TSD cutters
- Custom Designs with 7 day turn around
- Over 10 designs available
1.875" MD26, Natural Diamond Mill, serial number E-004

Set with exposed 4-6 spc and 6-8 spc processed round natural diamonds in the face along with 4mm TSD cubes near the center. Gage pads are flush-set with 1/8" TSD discs.

PDC Updrill cutters
1" API Reg Pin (also called AMMT)
TFA = .33

2.300" MD26, Carbid Updrill

Connection: 1-1/2" Reg, 4-1/2" Shank length, standard port size
3.700” MS26, Carbide Updrill

Connection: 2-3/8” Reg, 3.75 pass through smooth water ways 6” shank length.

3.800” MD26, Natural Diamond Mill

Set with exposed 4-6 spc and 6-8 spc processed round natural diamonds in the face along with 4mm TSD cubes near the center.

Gage pads are flush-set with 1/4” TSD discs.
PDC Updrill cutters
2 3/8 API Regular Pin
TFA = .55
Two-Assembly Window Milling Operations

Prior to this project, the 3.80\textprime \exit window was cut in a process that employed two bottom-hole assemblies (BHAs).

Based on the proposed directional drilling plan, the whipstock depth was selected to allow raising cutters, cooled tubing and circulation to the surface. The mechanical whipstock was set at the predetermined depth using an electric line (0.625 in. OD, 7-conductor line) lugging unit. In high angle wells, cooled tubing was used to deploy the whipstock. After the whipstock was set, the BH A was moved over the well exit and the milling operations commenced. Bottomhole assembly (BHA) #1 was used to mill the 3.80\textprime \exit window.

- 3.80\textprime \exit OD Bakar Carabas Triplet Mill (See Fig. 2)
- 2.7/8\textprime \exit positive displacement motor (pdm)
- 5-lb drill collars or 2.3/8\textprime \exit tubing (60 ft)
- Circulation sub (bell drop)
- Disconnect sub (bell drop)

Cooled tubing connector or crossover to drill pipe.

Geotherm with polymer abrasives was used to milling the lasing profile and exit window.

BHA #1 was run in the well and milling the profile nipple diameter from 3.80\textprime \exit to 3.80\textprime \exit OD. (End milling) sleeves are positioned 30-40\textprime \exit below the production packer. Minimum weight on the milling motor reduced the risk of blocking off tubing.

See Fig. 5 for the BHA.

After milling through the lasing profile, the assembly was run in the well to the preset whipstock. The window milling operation started off the mechanical whipstock. Due to the aggressive nature of the carbide mill, raising the window was the most critical part of the milling operation. After numerous motor stalls, milling/milling procedures to approximately 6 feet below the casing exit point. The average rate of penetration (ROP) while milling the casing was 1.2 feet/minute.

After the first pass through the casing mill, the BHA was moved to the exit window. A 3.80\textprime \exit OD Carabas slitter mill (See Fig. 4)

- 3.80\textprime \exit OD Positive displacement motor (pdm)
- 5-lb drill collars or 2.3/8\textprime \exit tubing (60 ft)
- Circulation sub (bell drop)
- Disconnect sub (bell drop)

Cooled tubing connector or crossover to drill pipe.

The most aggressive (3.82\textprime \exit OD) formation mill and a 3.80\textprime \exit OD string were used to enlarge the window such that a 2.7/8\textprime \exit OD polycrystalline diamond compact (PDC) bit and 3\textprime \exit OD directional milling assembly could pass through the window. Motor milling was also a problem with assembly H2 due to the aggressive nature of the string and formation mill. The formation milling sub assembly was also carbide, which tended to cause hangup (stuck free formation) or ball up (in hole formation). Some milling operations required multiple trips before a satisfactory 3.80\textprime \exit OD window was obtained. With marginal success, H2 cutters were added to the directional milling sub to improve formation breakdown. Several milling operations were encountered during the milling window. Most wells required extra trips to change out damaged motor parts (motors, stators, output shafts, etc.) caused by the multiple cutter failure due to unbalanced bucking. Also, extra trips were required to drill beyond exit point before the string reamers to wipe the lower portion of the window. To alleviate these problems, a goal was set to drill a 3.80\textprime \exit OD exit window in 3\textprime \exit casing through 4.5/8\textprime \exit tubing using one milling assembly.

Evolution of the Trip Window Milling System

Based on the low torque generated, a diamond mill was chosen for the most promising milling deployment.

The first attempt at a 3.80\textprime \exit OD exit window used a mechanical whipstock in a 4.25\textprime \exit OD 12.8\textprime \exit 8410 LWD tool. Three carbide mills had been cut without success. To test the window, a 3.80\textprime \exit OD diamond mill (See Fig. 5) replaced the carbide mills. Minimum motor milling and smooth milling licensed the window to be cut in approximately 7 bhp. The window exit was enlarged with a string reamer on the subsequent trip. Total milling time including the string reamer trip was approximately 18 hours. The 3.3/8\textprime \exit OD directional milling assembly passed through the exit window without problems.

Based on the correct rpm milling success, the next 3.80\textprime \exit OD window through 4.5\textprime \exit tubing was cut in 5.2\textprime \exit casing whipstock using the cemented diamond mill. After milling for 3.80\textprime \exit OD exit window using 4.5\textprime \exit sliding, the cemented diamond mill was modified with a slightly higher rpm to allow the mill to cut through the casing. The window exit also appeared to have cut into the top of the whipstock try instead of sliding down the try and cutting the casing wall. Based on the try distance from the casing wall, the cemented diamond mill was modified with a slight bezel on the edge to allow the mill to cut up to the edge of the casing to the pinch point of the whipstock. The milling operation then proceeded with the modified cemented diamond mill. The window exited the casing in 16 hours.

The 3.80\textprime \exit OD exit window was cut in two trips using the redesigned one-step diamond mill (See Fig. 7). This first trip cut the 5\textprime \exit window and 16\textprime \exit formation. On the second trip the window was cleaned and elongated using a string reamer that was added to the BHA. With a smooth OD (See Fig. 8) with carbide on the leading and trailing edges to lengthen and round the window.

The 3.80\textprime \exit OD window drilled in 4.5 hours with one motor mill and drilled and elongated for 2 hours. Both operations went very well. Total window milling time, including trip time was 18.5 hours.

With the initial 2-trip milling test, most of the 3.80\textprime \exit OD exit window has been drilled in one trip using the following assembly (bottom-up):

- Hughes Christmas EP 0261 diamond mill
- Baker 3.80\textprime \exit OD string mill 5-2/8\textprime \exit
- High speed positive displacement motor (740 rpm) RPM range: 150-250
- 2 joints, 2-3/8\textprime \exit PIP 6 tubing (for stiffeners)
- Ball drop circulation sub
- Ball drop disconnect
- Carbide connector (diamond type)

This milling system has proven to be very reliable. The diamond mill and smooth OD string mill have substantially reduced torque requirements and motor cutter failures (broken teeth).

Conclusions

By combining the diamond mill with the smooth OD string reamer into one assembly, at least one trip has been eliminated from the through tubing window milling operation. The milling time starts when the first assembly is picked up and continues through milling and running of the window until the last window assembly is picked up. Fig. 9 shows the average milling time for one trip through tubing is 15.6 hours, which is a 12 hours savings as compared to the two-step carbide system.

Combining the two milling tools (diamond mills and carbide string reamer) into one BHA produced a successful one-step trip milling system.

Similar milling operations have been conducted successfully in conventional jointed pipe applications. One trip milling operations would obtain greater time savings as the jointed pipe operations due to the longer trips times involved.

Acknowledgments

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Opinion: The authors of this paper are those of the authors and are not necessarily shared by BP, other Probux Roy Working Interest Owners, Hughes Christmas or Baker Oil Tools.
References
Coil Tubing Bit Pricing

- pricing is based on standard models
- any engineering or featured changes may incur increased pricing

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