Weatherford®

Two-Pod Mill

Extensive R&D improves milling performance

Drilling

Evaluation

Completion

Production

Intervention

Fishing services

- Abandonment services
- Fishing jars
- Fishing tools
  - Mills
- Heavy-duty wireline fishing
- Well repair

Extend mill life with Weatherford's two-pod mill

Weatherford's two-pod mill is designed and constructed to mill wellbore tubulars that are internally and externally cemented. With its enhanced geometry, this mill has exceeded the rate of penetration (ROP) performance of standard crushed-carbide and insert-dressed mills. This improved performance extends mill life by up to 500 percent compared to that of conventional mills. The number of trips required for milling operation and mill change-out are also minimized, saving valuable rig time.

The milling process

Milling is the process in which a milling tool (mill or rotary shoe) is used to grind away a fish, such as stuck tools, tubulars or loose junk in a wellbore. A mill can be used to dress the top of a fish, ream out a collapsed casing, ream tubulars with scale, remove a section of casing for sidetracking or deviating a well, and remove cement plugs.[1]

No matter how refined the process of drilling gets, there is always a need for some type of milling operation. It could be something as simple as lost or stuck pieces of the drillstring in the wellbore.

Conventional obstacles

Milling tools have been designed to suit just about every situation. There are junk mills, pilot mills, taper mills, watermelon mills, section mills and more.

One example is the milling of cemented tubulars, where the milling of the fish can be an incrementally slow and expensive procedure using standard mill designs. What makes cemented tubulars such a special case is that the tubular, when cemented, will inevitably tend to be eccentric to the casing. Additionally, the centerpoint of the mill could be impinging on the tubular material itself, a condition called coring. Coring, the most common cause of failure, is when a core point that has reached the center of a mill experiences zero velocity and is free-spinning on the tubular. At this point, the milling progress is prematurely halted with no further progress made. As a result, the ROP is poor, the mill life is reduced, the workstring has to be pulled, and the mill must be replaced. This process can add greatly to the overall cost of the operation.

Objectives for a new mill design

Weatherford engineers set out to design a new mill, one that would address the conventional problems of coring and increase the life of a mill, reducing overall operational costs.

Our personnel fabricated several iterations of mills during the development process. After extensive laboratory and field testing, a radically different mill-head geometry was introduced with far-reaching implications for increased operational efficiencies and cost savings.

[1]Hyne, N. 1991. Dictionary of Petroleum Exploration, Drilling & Production. Tulsa, Oklahoma: Pennwell Books.

Two-pod mill benefits

- Improve the overall efficiency of the milling of cemented tubulars
- Develop the tool for casing sizes from 5 to 13-3/8 in.
- Enable the tool to mill through hard-banded drillpipe, tool-joint connections
- Design mill-head geometry to reduce the impact of coring and enable milling on core point farther than conventional mills
- Incorporate extra-long mill heads and stabilizer pads to keep the mill stabilized and centered in the casing, reducing mill wobble and potential casing damage
- Include more total flow area (TFA) in the jetting ports in the mill head to improve circulation rates for better hole-cleaning capabilities

Laboratory testing

To obtain the optimum geometry for the initial development of the special cemented tubular mill, Weatherford conducted a total of seven rig tests in laboratory conditions using 22 mills with varying carbide material and shapes. To evaluate the performance of the new mill design in comparison with conventional mills, our personnel conducted the following tests.

The first test simulated an eccentrically cemented drillpipe in the casing, with both OD and ID areas filled with Class H cement with 30 percent nylon fiber filler. Our personnel tested different standard mill types and the two-pod mill. The results showed a 500 percent improvement over a standard mill life. Typically, field operating procedures call for less than 10,000 lb (4,536 kg) weight on mill (WOM) and up to 120 revolutions per minute (RPM). In this case, the WOM ranged up to 20,000 lb (9,072 kg) with 225 RPM. This improvement demonstrated that ROP on a cemented tubular is best at higher WOM and RPM than industry-standard procedures suggest. The two-pod mill more than doubled the ROP of standard mills with these parameters.

In the second test, our personnel tested how the two-pod mill performed against hard-banded drillpipe tool joints. Knowing the results of conventional mills, the mill was run in a test environment. A number of 5-in. OD drillpipe tool joints were placed inside a 7 5/8-in., 39-lb/ft N-80 casing to test 6.55-in. OD mills. Then, 4 1/8-in. OD tool joints were placed inside a 5 1/2-in., 17-lb/ft N-80 casing to test the 4.817-in. OD mills. The ROP of the two-pod mill was a significant improvement over standard mills.

Field testing

While the laboratory results were encouraging, the real benefits of the two-pod mill became clearer in actual wellbore environments. Weatherford identified five wells in five distinct regions of the world. All onshore rigs, these wells provided challenges most operators face all the time. Bringing in the strength and experience of Weatherford's MillSmart™ technology, the two-pod mill field performance met and surpassed all operational objectives.

MillSmart technology

An engineered approach to milling operations, *MillSmart* technology encompasses a wide range of proven products, services and technical resources developed and refined by the world leader of milling and fishing services. Because each job is different, the ruggedly constructed two-pod mill uses CustomCut™ tungsten carbide inserts, improving mill performance and durability.

Real Results

Well 1: East Texas, USA

In an onshore well in East Texas, a total of 128 ft (39 m) of 2 3/8-in. tubing (in a 7-in. casing) was cemented 100 percent inside and outside. The top of the fish was located at 13,500 ft (4,115 m), and the bottom was at 13,628 ft (4,154 m). After an attempt to wash over the fish proved unsuccessful, a 6-in. OD concave conventional mill was deployed, which only milled 9 ft (3 m) before the core point was reached. A second traditional mill was run with similar effects, leaving 110 ft (34 m) of tubing still in the well. The two-pod mill was run, and the entire 110 ft (34 m) of the tubing was milled in 15 hr, at an average ROP of 7.3 ft/hr (2.2 m/hr).

Well 2: West Texas, USA

The second well had a total of 533 ft (162 m) of 2 7/8-in. external upset entry (EUE) tubing, complete with a setting tool and cast-iron bridge plug (CIBP) cemented inside and outside in 5 1/2-in., 17-lb/ft casing. The top of the fish was located at 5,267 ft (1,605 m), and a 16-ft (5-m) stub of tubing was sticking above the cement line. The tubing was left in the hole after backoff. A conventional mill run was made with a 4 3/4-in. junk mill, but only achieved 8 ft (2.4 m) of penetration. A 4 3/4-in. two-pod mill was deployed and, in a total of four runs, completely cleaned out the well.

- Mill 1 milled out 170 ft (52 m) in 35 hr, milling the balance of the stub (8 ft, 2.4 m) and 162 ft (49 m) of the cemented tubing.
- Mill 2 milled out 111 ft (34 m) in 20 hr before a downhole motor failure, necessitating the two-pod mill be pulled, even though the mill was not worn out.
- Mill 3 milled out 214 ft (65 m) in 30 hr before being pulled.
- Mill 4 milled out the balance of 41 ft (12 m), together with the setting tool and the CIBP.

A total milling time of 85 hr was needed to mill out 495 ft (150 m) of tubing for an average ROP of 5.82 ft/hr (1.77 m/hr). The longest mill life achieved was 214 ft (65 m), while the average was 133 ft (40.5 m).

Well 3: Louisiana, USA

A well in Louisiana had two cement retainers cemented in 5 1/2-in., 23-lb/ft casing, with tubing-conveyed perforating guns on the top at a total depth of 17,343 ft (5,286 m). The two-pod mill successfully milled the perforating guns, the two cement retainers and cement in one run, resulting in a total of 333 ft (101 m) at an average ROP of 18.5 ft/hr (5.64 m/hr).

Well 4: India

This well had a total of 585 ft (178 m) of 2 7/8-in. EUE tubing left cemented inside and out in 5 1/2-in., 17-lb/ft casing. A total of four new two-pod mills were run to mill the tubing at an average ROP of 3.7 ft/hr (1.1 m/hr). The low ROP was caused by the rig's equipment not being capable of producing the required RPMs for the two-pod mill to mill efficiently. The average mill life achieved on this job was 146 ft (44.5 m).

Well 5: Argentina

This well had 33 ft (10 m) of 2 3/8-in. tubing, together with a bridge plug cemented inside and out in a 5 1/2-in., 15.50-lb/ft casing. The two-pod mill milled the tubing, including the bridge plug, in 2.5 hr, at an average ROP of 13.78 ft/hr (4.20 m/hr). The mill head showed little evidence of wear after retrieval.

Features, Advantages and Benefits

Laboratory testing and field results provided an excellent verification of the design and capabilities of the two-pod mill.

- With an average ROP of 8.27 ft/hr (2.52 m/hr)—65 percent better than the target ROP of 5 ft/hr (1.5 m/hr)—and an average mill life of 105.5 ft (32.2 m), the two-pod mill extends the efficiency of milling operations beyond conventional milling techniques, saving valuable rig time and costs.
- Advanced mill-head geometry improves ROP and extends mill life, minimizing the number of trips required for the milling operation and for mill change-out, saving valuable rig time and operating costs.
- Extra-long heads and stabilizer pads keep the mill well stabilized and centered in the casing, reducing mill wobble and minimizing the risk of casing damage.
- Increasing TFA in the jetting ports in the mill head, coupled with watercourses, improves circulation rates for better hole-cleaning capabilities.

Weatherford's two-pod mill with **MillSmart**℠ technology is a winning combination for all mill operations. For details, contact your Weatherford representative or visit **weatherford.com.**

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