



Post Perforation Debris Removal

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This paper was prepared for presentation at the AADE 2006 Fluids Conference held at the Wyndam Greenspoint Hotel in Houston, Texas, April 11-12, 2006. This conference was sponsored by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author/s of this work.

Abstract

Effective downhole Debris management is always a challenge. Improper post perforation cleanup leads to the potential failure to sting in with seal assemblies after perforating, sand control stimulation and critical failure to shift mechanical flow control devices during the life cycle of a well. These failures were seemingly random events; however new post perforation debris removal techniques and applications have shed light on why these problems have been occurring. Direct effects of this phenomenon are loss of rig time, production, increased costs and possible loss of the wellbore or zone of interest. Modification of existing tools, the application in conjunction with each other and proper placement of the same has proven to be effective in mitigating some of these risks. Use of these tools has lead to the discovery that possibly more perforating gun debris was left in the hole than was previously assumed.

A matrix is established that defines several parameters to select candidate wells that possess the potential of difficult debris management. Parameters considered include well deviation, downhole completion tool configuration, perforations length, shot density, carrier type, charge type, packer plug retrieval tools, perforation technique and circulation method used prior to retrieving/latching the plugs. Candidate selection guidelines for the application of these tools with case histories are presented.

Introduction

As completion and wellbore designs become more complex, effective downhole debris management is becoming more critical and necessary. Wellbore debris is responsible for a variety of problems associated with well completions.

The perforating phase of the completion operation is a predominant source of debris. Some of this debris will be left behind in the wellbore if not cleaned effectively and as a result hinders subsequent operations. The amount of debris depends on and can vary depending the following parameters.

- Perforating charge type
- Length of perforations
- Shot density
- Displacement efficiency – mud to brine
- Type of charges used

Total debris elimination becomes even more critical in the following situations or well architecture design

- Deviation at zone
- Deviation uphole
- Internal Isolation Strings
- Completions requiring slick line intervention
- Completions requiring coiled tubing intervention
- Mechanically actuated valves or sleeves
- Selective or Dual completions
- Deepwater completions
- Packer Plug applications – J or Grapple type
- Polished bores or packers that seals will sting into
- Casing/Liner size

The need for debris free wells in the above situations has resulted in an increased interest in post perforation debris management¹. This paper discusses a new approach to effectively removing perforating debris under difficult well conditions.

Debris Management Tools - Application

This pertains to wells with single and two or more zones and most importantly deviated wellbores.

Packer plug retrieval

In order to prevent debris from collecting around the retrieving neck of a packer plug, operators have dumped sand to cover the packer plug neck. Subsequent operations would involve washing debris, sand and retrieving the plug. Operators also utilize carbonate in lieu of sand since it can be dissolved with acid if it packs in too tight around the packer plug retrieving neck.

This methodology will fail in a highly deviated well as the sand cannot be dumped successfully on the plug and more importantly if the wellbore is highly deviated as

described earlier effective debris removal will not be facilitated.

Additionally, debris removal typically involves reverse circulation of fluid and viscous pills with a potential for fluid losses. Utilizing the downhole debris tool in conjunction with boot baskets, magnets and various fishing tools one can retrieve a packer plug effectively and minimize or eliminate these losses.

Larger annuli above and deviation angles ≥ 50 deg.

One scenario may be no deviation or minimal deviation at the zone of interest but a high angle of deviation up-hole. An example would be an S type well or conversely an L type well.

Debris may be circulated off of the packer plug or the low side of the casing above a sump packer but due to insufficient fluid velocity in the larger annulus up-hole may allow debris to be deposited on the low side. This may give one a false indication of a clean wellbore due to the fact that the packer plug could be retrieved or seals stung into a bore.

Single or multiple casing strings with no deviation, low-density completion fluids and non-viscous fluid.

Debris will not make it to surface if there are rate limitations and will be re-deposited on top of the packer plug making it difficult to retrieve, or when the plug is pulled, it may allow the debris to fall back in and around the seal bore.

Deepwater completions

The financial impacts of a second cleanout trip or an intervention due to left over debris are extreme.

Deviated wells that will require immediate intervention to shift sleeves or other fluid loss control hardware using slick line or coiled tubing.

Any debris left in the well bore can fall and rest inside of the completion hardware preventing slickline tools from reaching bottom or manipulating these bidirectional flow control devices. The same could occur with coiled tubing even though it poses a lower risk than slickline. Other implications as a result are loss of selectivity and production.

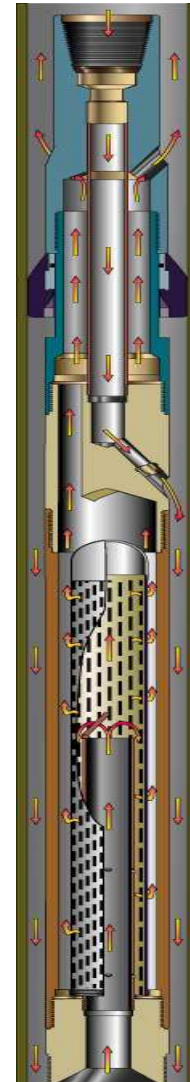
Wells with low bottom hole pressure and open perforations

Depending on rates and pressure required to circulate debris to surface, high equivalent circulating densities can cause fluid loss to formation and possible formation damage. Reducing pump rates to minimize fluid losses

will reduce fluid velocities which in turn will inhibit debris removal to surface.

Downhole Debris Filter Operation

A Downhole Debris Filter Tool utilizes an internal "spider" or internal crossover sub designed to divert fluid flow to the annulus where it exits below a casing pack-off element into the annulus. The fluid flows down the annulus and return up the work string. When the fluid and debris enter the tool it is directed through a slotted liner debris chamber, trapping debris. The fluid then returns to the annulus above the pack-off element to surface. A Downhole Debris Filter Tool can be placed at any location in the wellbore making it ideal for removing debris from problem areas in highly deviated wellbores such as liner tops, casing collars and tapered strings. Due to the flow path, minimal pressure is exerted across the perforations, reducing fluid loss and potential formation damage during the debris cleanup process. (Fig 1)



(Fig 1) DDF Flow Path

Packer Plug magnet description

On the wells that involve setting a zonal isolation “packer plug”, a magnet is built to fit into the packer seal bore/housing. Magnet selection depends on seal bore internal diameter, and available housing depth below the tool after the plug has landed. A built for purpose bull nose is attached to the bottom of the magnet to allow easy passage into the seal bore without damage. The top of the magnet is threaded into the bottom of the packer plug. There originally was a concern as to whether or not the magnets were bringing back gun debris or just metallic debris that was left along the wellbore as a result of tripping pipe. This concern was addressed by having a third party lab analyze samples from a particular case. The lab concluded the metal was not from the HPC 110 casing, but was from the carrier of the perforating guns. There was also evidence of explosive deformation of the metal. (Fig 2)

Fig 2 Excerpts from Report²

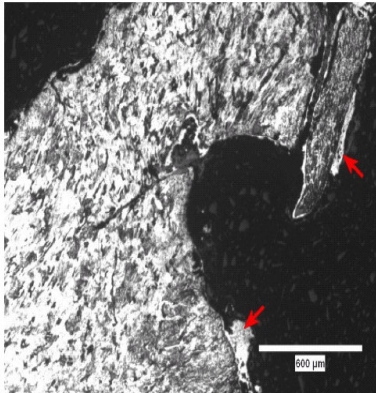


Figure 1 Nitral Etch 50X

Microstructure of the debris, showing evidence of explosive deformation and localized melting (arrows) of exposed surfaces.

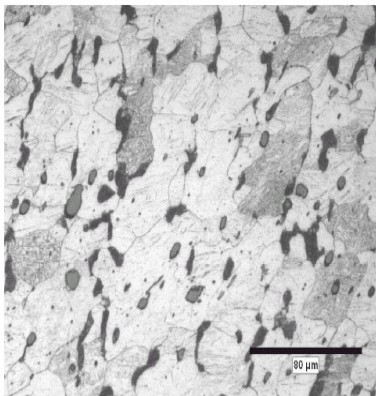


Figure 2 Nitral Etch 400X

Microstructure of the debris, showing cold-worked ferrite and pearlite with small round inclusions.

In-string magnets

The in-string magnets used in this application are the type used in cased hole applications as opposed to drilling. These are designed with maximum exposure of the magnetic rods for maximum draw distance and capacity. Centralization is also helpful to maximize capacity by keeping debris from dragging off of the “low side” as the tools are pulled out of the hole. (Fig 3)



Fig 3

Pre-Job analysis

To ensure proper tool selection and placement, a torque and drag-modeling program should be used. This program is used to predict any potential problems that can be encountered while running these tools. Concerns would be helical buckling while slacking off, ability to rotate due to torque restrictions in the lower sections of tapered workstrings in tortuous and highly deviated well sections. The second program predicts anticipated circulating pressures. The most important aspect is a simulating calculating the ECD on sensitive zones and is a good indicator to help position the

downhole debris tool on the workstring. The software will also predict flow regimes along the entire wellbore.

Standard retrieval procedure

On wells that involve setting a zonal isolation packer plug for the perforating process, a magnet is built to fit in the seal bore. This assembly is tripped in the hole below the perforating guns. The plug is set, and the perforating guns are placed on depth. The well is perforated, a pill may be spotted across the perforations and the guns are pulled out of the hole. The bottom hole assembly is picked up consisting of one or all of the following components:

- Packer plug retrieving tool
- In-string magnet
- Boot baskets

The working fluid is circulated both in forward and reverse to remove as much debris as possible with the aid of the previously spotted pill. The plug is then latched and retrieved. When at surface, the debris from the plug is measured and at this time a decision can be made as to whether or not a separate cleanout run is needed.

Retrieval procedure using a downhole debris filter tool

A downhole debris tool is utilized in scenarios as described earlier. The bottom hole assembly typically recommended consists of the following:

- Packer plug retrieving tool
- In-string magnet
- Downhole debris tool
- Boot baskets

The downhole debris filter is positioned either as close as possible above the perforations, just in the top of a liner or above the most severe deviation in a well with only one size casing string. When a down hole debris filter is used, only forward circulation is necessary, as all circulation below the pack-off element is effectively in "reverse". The enhanced velocity at bottom forces all debris to be carried up the drill pipe into the debris catcher. The plug is then be latched onto and retrieved.

Case History – Packer plug magnets

This case history is not intended to show an outstanding one-off run, but rather typical results. 7-5/8 casing to surface, 64° deviation, 47' perforations, 12 shots per foot. A magnet was run below the packer plug prior to perforating the upper zone. The retrieval BHA consisted of a Packer plug retrieval tool and an in-string magnet directly above the retrieval tool. The function of the in-string magnet was to ensure that no metallic debris was

left in the section of the well above the packer plug. In this case there was very minimal debris on the in-string magnet, which indicated that all of the debris on the packer plug magnet was from the area on top of the packer plug. The packer plug was successfully pulled on the first attempt and 8 lbs of gun debris were recovered on the magnet. The production assembly was subsequently run and stung in to the seal bore without incident. (Fig 4)

Fig 4 Typical Results



Case History –Packer Plug Magnet

7 5/8 casing, 30° deviation, 20' perforation interval 16 shots per foot. A magnet was run below the packer plug prior to the perforating of the upper zone. After perforating, a BHA assembly consisting of a packer plug retrieval tool was run. When the packer plug magnet was brought to surface it was carrying the maximum capacity debris. The operator elected not to make an additional clean out trip but instead chose to trip in the hole with the production assembly. The bottom hole assembly failed to sting in to the necessary depth. The assembly was pulled out of hole and a second wash trip was made. This was one of the early jobs using this configuration. A lesson learned was to incorporate additional capturing tools to keep the packer plug magnet from becoming overloaded. The addition of other tools may have helped reduce the amount of debris loaded on the magnets, which could have led to a successful first run.



Fig 5
Packer plug Magnet

Case History – Downhole Debris filter

9-5/8 Casing, 55° deviation.

Debris removal using a “bailer” type tool was not totally effective in removing debris on the initial well on a multi-well project. This resulted in several missed attempts stinging in to a sump packer. The perforating company predicted that approximately 95 pounds of gun debris would be left behind. It was preferred that the perforations not be exposed to fluid loss and as a result reversing of fluid to clean the area above the packer plug.

A BHA consisting of an overshot with grapple, in-string magnets in conjunction with the downhole debris filter was run. The well circulated clean and the plug was retrieved without incident. 110 pounds of debris was recovered from the zone of interest. The completion tools were run successfully. The downhole debris tool was run on all subsequent wells and zones on the project. Figs (5,6, &7)



Fig 6
Sample of Debris Removed from the Downhole Debris Filter

Fig 7 Debris Recovered using Multiple BHA Configurations*

| Well | Trip | BHA | Debris Recovered (lbs) | | Perfs (ft) | Perfs (SPF) |
|------|--------------------------------------|-----|------------------------|---------|------------|-------------|
| | | | DDT | Magnets | | |
| A-9 | Displacement | 1 | 10 | 7 | NA | NA |
| A-9 | Post Perf, lower zone | 2 | 0 | 10.5 | 70 | 18 |
| A-9 | Post Frac, lower zone | 2 | Unknown | 0 | 70 | 18 |
| A-9 | Post Perf, upper zone | 3 | 98 | 12 | 65 | 9 |
| A-9 | Post Perf, upper zone | 3 | 20 | 10 | 65 | 9 |
| A-9 | Post Perf, upper zone, ret. plug | 4 | 3 | 5 | 65 | 9 |
| A-5 | Displacement | 1 | Unknown | 11 | NA | NA |
| A-5 | Post Perf, lower zone | 5 | Unknown | 8 | 33 | 18 |
| A-5 | Post Perf, upper zone | 6 | 87.5 | 2.5 | 33 | 18 |
| A-5 | Post Perf upper zone, ret. Plug | 4 | 30 | 10.5 | 70 | 18 |
| A-5 | Post Perf, upper zone, into packer | 2 | 30 | 1.5 | 70 | 18 |
| A-5 | Post Perf, upper zone, into sealbore | 7 | NA | 2 | 70 | 18 |

BHA's

- 1 Bit, Scraper, Brushes, Magnets, DDT, Scraper, Brushes, Scraper, Brushes
- 2 Stinger, Pop-Loc, Magnets, DDT
- 3 Overshot - no grapple, Magnets, DDT
- 4 Overshot with grapple, Magnets, DDT
- 5 Stinger, Magnets, PIT, DDT
- 6 Overshot - no grapple, Magnets, PIT, DDT
- 7 Stinger, Pop-Loc, Magnets

*Unknown indicates the tool was emptied and the debris disposed of on location so that it could be run again if needed.

Conclusions

- An effective downhole cleaning management plan should be implemented based on wellbore geometry.
- Correct application, number and selection of tools are critical to success.
- Of all the parameters measured, the two most critical factors to consider are degree of well deviation and perforation interval length.
- Even on wells without extreme geometry or perforation lengths, and under the best circulating conditions, some post perforation debris is left down hole if capturing devices are not used.
- Large, heavy post perforation debris is most effectively removed if it is captured downhole using magnets, downhole debris filters or other capturing devices.
- Serious consideration should be given to using debris capturing post perforation clean-up tools as the short and long term financial risk of completion hardware failure escalates.

Acknowledgments

The authors would like to thank BJ Services Company for permission to publish this paper. We would also like to thank the customers who have pioneered the use of these systems.

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