Limited Entry Revolution

Improving cemented liner completions with advanced ball-drop technology

Oil and gas producers have succeeded in boosting production from horizontal wells in unconventional reservoirs over the last decade. This is attributed to advances in directional drilling, longer laterals, multi-stage stimulation techniques, and changes in completion strategy, such as tightening stage spacing. A study in the Haynesville and Bossier shales shows a 22% production increase (4.5 to 5.5 Bcf) per well[1], as average stage spacing fell from 272 to 150 ft between 2011 and 2013.

Completion designs have also trended towards higher fluid and proppant volumes. The associated costs may not be justifiable, depending on production results. In a low-priced oil and gas market, producers must find a way to improve current production levels while improving operational efficiency and lowering costs. An ideal completion solution provides:

- Rapid execution
- Reduced well interventions
- Optimized stage spacing
- Maximize cluster efficiency

[1] Kaiser, M., Yu, Y. Haynesville Update – North Louisiana Gas Shale's Drilling Decline Precipitous. Oil & Gas Journal 111.12 (2013): 62-67

Challenges of Plug-and-Perf Limited Entry Completions

Completion Time

The plug-and-perf method for completing cemented liner wells is mature and proven, having been applied to thousands of wells. While this technique is known for being flexible and simple, it is inherently inefficient, requiring trips in and out of the well for each stage to detonate perforation charges and set bridge plugs. This process also requires more fluid relative to other systems, adding significantly to costs.

Operational Risk

Tripping in and out of the wellbore adds to non-productive time, and increases the likelihood of encountering problems. Wireline can get stuck in the well if a bridge plug does not release. In the case where perforation charges do not detonate, additional time and safety risks are incurred. In these situations, operators may choose to mill out or abandon the stage.

Unless the toe stage uses a hydraulically opened tool, coil tubing is used for the first stage to convey the perforating charge. In these cases, friction in long laterals makes it difficult to push the bottomhole assembly to sufficient depth to begin treatment. The lower stages of the lateral are effectively lost if the assembly does not reach the toe of the well.

Using the plug-and-perf technique, each interval is overdisplaced by the fluid used to pump the next stage of perforation guns and bridge plugs. As a result, near well conductivity may be lost. Moreover, due to the order of operations, bridge plugs and charges are run into the well together. Plugs cannot be pressure tested between stages because wireline equipment is not rated to withstand high pressures.

Millout

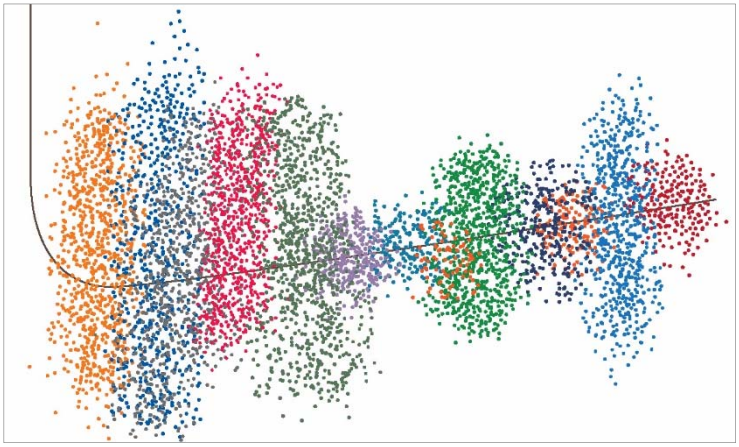
Coiled tubing operations are required to mill out plugs at the end of traditional plug-and-perf completions, as well as every time that

a plug unintentionally pre-sets. Moreover, plug conveyance may be possible on long horizontal wells, but plug removal may be difficult. This is particularly an issue for wells with low reservoir pressure[2]. Low reservoir pressure equates to low annular velocity, which means it is difficult to flow plug parts back to surface and increases the risk of stuck coil.

Cluster Efficiency

Even distribution in each treatment zone is one of the major technical challenges of limited entry. Studies have shown that on average, only 20% to 30% of perforation clusters contribute significantly to production[3].

Tracer diagnostics also validate the premise that the initial (heel-most) perforations in a cluster can quickly erode due to the high velocity flow of proppant slurry[4]. As these perforations enlarge, the rest of the stage is not effectively stimulated. This correlates to subsequent production being lower than expected.



Microseismic interpretation of ineffective plug-and-perf stimulation

[2] Aviles, I., Dardis, M., Jacob, G. “Infinite Plug and Perf – The Value of a Full Bore Degradable System” SPE-177736-MS (2015) http://dx.doi.org/10.2118/177736-MS

[3] Lecampion, B., Desroches, J., Weng, X., Burghardt, J., Brown, J. “Can We Engineer Better Multistage Horizontal Completions? Evidence of the Importance of Near-wellbore Fracture Geometry from Theory, Lab and Field Experiments” SPE 173363 (2015)

[4] Phelan, K., Adefashe, H., Casero, A. “Open Hole Multi-Stage Completion System in Unconventional Plays: Efficiency, Effectiveness and Economic” SPE-164009-MS (2013) http://dx.doi.org/10.2118/164009-MS

Solutions for Efficient Limited Entry Completions

Completion Program Adjustments

To reduce completion time, stimulation programs can be executed alternately; this is known as zipper fracking. Also, without adding significant cost, workarounds to reduce perforation erosion and improve cluster efficiency could include:

- Lower pump rate
- Use less proppant
- Use less abrasive proppant

A lower pump rate will reduce perforation erosion, but in general does not improve cluster efficiency, because limited entry requires a specific rate for pressure diversion. Furthermore, a lower pump rate impedes the ability to transport sand along the lateral.

Using less proppant reduces the conductivity and effectiveness of stimulation, and less abrasive proppants such as synthetics generally have lower compressive strengths and may not be able to hold fractures open.

These changes result in a less aggressive stimulation program, which may consequently lead to suboptimal fracture geometry, lower fracture conductivity or partial reservoir coverage—all leading to lower production.

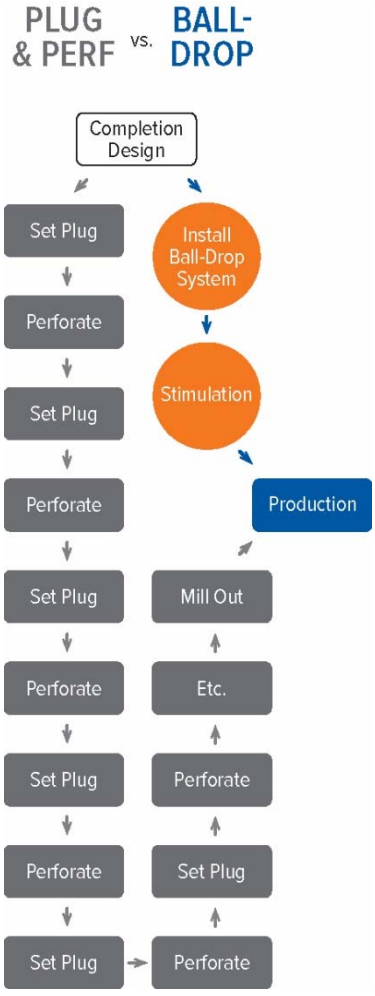
Degradable Elements

Degradable plugs and balls can be incorporated into a plug-and-perf system to reduce or eliminate millout operations. Composite plugs have low pressure ratings and have been known to be pumped down hole during treatment, allowing fluids to be lost to the previous interval. Metal bridge plugs with a dissolvable body have also been used; the slips and rubber still must be milled out.

The technology of dissolvable tools has been steadily becoming more reliable.

Intrastage Diversion

A relatively new technique using intrastage diversion has had initial success in reducing operational risk and millouts by decreasing or eliminating isolation plugs. Studies show that this has lowered costs while showing equivalent initial production[5,6].



Intrastage diversion, more commonly used with plug-and-perf completions, is accomplished by pumping biodegradable fibers, gels, particulates, or frac balls between treatment zones. These materials can hold pressure against previous fractures or casing perforations to allow stimulation of other parts of the wellbore. Despite the initial success, there are some limitations to this method:

- For fibers and particulates, the magnitude of diversion is not known, nor is it known if the diversion is occurring near the wellbore or deep within fractures
- In the case of a gel-type of diverter, nonproductive time is increased between each stage to allow chemicals to set
- After a stage is treated with proppant, the size and shape of casing perforations is unknown – frac balls may not be large enough to seal or hold pressure against these openings

[5] Loya, R., Lahman, M. "New Interventionless Fracturing Technique Rescues Stranded Assets" E&P (Sep 2014)

[6] Ingram, S., Lahman, M., Persac, S. "Methods Improve Stimulation Efficiency of Perforation Clusters in Completions"; SPE Journal of Petroleum Technology 66.4 (2014); http://dx.doi.org/10.2118/0414-0032-JPT

Ball-Drop Completion Systems

Cemented ball-drop completion systems typically require half the stimulation time or less compared to a plug-and-perf completion. An Eagle Ford shale study analyzing plug-and-perf and ball-drop completion efficiency showed completion times of 5 and 1.6 frac days, respectively – more than 3 times faster[7].

A separate economic analysis on multi-stage completions shows a similar difference – 2 days (plug-and-perf) versus 15.5 hours (ball-drop) – also 3 times faster, along with a 22% cost reduction[8].

Current limited entry ball-drop technology typically use tools designed with keys or collets that can be repositioned out of the way, allowing actuation balls to pass through. The disadvantage of this design is that moving parts can be easily fouled by sand, which renders them ineffective. If balls or other parts get stuck, an intervention will be required.

QuickFRAC Cemented System

Packers Plus QuickFRAC® cemented system with QuickPORT™ IV sleeves is designed to reduce operational risk, completion time and millout for cemented liners, as well as improve cluster efficiency.

The QuickPORT IV sleeve uses patented squeeze technology to enable an actuation ball to pass through multiple ball seats, while maintaining integrity to hold high pressure for effective stimulation. This simplified tool provides the completion time advantages of ball-drop completions, but has approximately 40% fewer

QuickPORT IV Case Study

A producer in Oklahoma ran the first QuickPORT IV cemented sleeves in the toe of a well in the Mississippian formation. Five sleeves were run as one stage at the toe of the well. After the first stage was stimulated through a hydraulic toe sleeve, the 5 QuickPORT IV sleeves were actuated using one degradable ball and stimulated as per program, reaching a pump rate of 100 bbl per minute. The stage was completed in 2 hours less than a typical plug-and-perf stage. Stimulation of the stage was verified by the ePLUS® Retina™, a real-time downhole monitoring tool.

[7] Stegent, N., Wagner, A., Stringer, C., Tompkins, R., Smith, N. “Engineering Approach To Optimize Development Strategy in the Oil Segment of the Eagle Ford Shale: A Case Study”; 2013; SPE-158846-PA; http://dx.doi.org/10.2118/158846-PA

[8] McDaniel, B., Rispler, K. "Horizontal Wells with Multi-Stage Fracs Prove to be Best Economic Completion for Many Low-Perm Reservoirs”; 2009; SPE-125903-MS; http://dx.doi.org/10.2118/125903-MS

moving parts than previous limited entry ball-drop technology. By pairing the system with degradable ball technology, operators can reduce operational risk and millout requirements.

The QuickPORT IV sleeves are reinforced with tungsten carbide flow ports to prevent the issues seen with perforation erosion. Eliminating perforation erosion helps facilitate limited entry fluid distribution to multiple entry points. Pumping rates can be achieved as designed to place fractures correctly to achieve optimal fracture length. In this design, stages are not overdisplaced, increasing near wellbore conductivity.

Using a single actuation ball, many sleeves can be run as one stage in a cemented liner completion, optimizing the number of entry points along a treatment zone for each stage.

Conclusion

Many of the solutions to improve limited entry efficiency target one or two of the major challenges faced by operators in reducing costs and improving production.

Packers Plus QuickFRAC limited entry ball-drop system using QuickPORT IV cemented sleeves is one of the few solutions available that addresses many of the challenges faced by producers, including reducing completion time, operational risk and millout, while providing a solution to maximize cluster efficiency by preventing perforation erosion.

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