

The Lean Profile: A step change in drilling performance

by A. Calderoni, A. Ligrone & C. Molaschi

ENI S.p.A./AGIP Division, Italy

ABSTRACT

With the conventional drilling technique, a general rule-of-thumb establishes that the surface and intermediate casing strings are to be run in holes with a diameter of up to 6-7 in. larger than the casing. This rule is based on the fact that:

1. it is difficult to drill a straight vertical well with conventional technologies;
2. the larger the casing diameter the stiffer the casing string.

The clearance between casing and open hole is then reduced to about 1" for the deeper sections, because of the higher flexibility of the casing strings.

This paper presents the "Lean Profile", an innovative drilling technique which aims at maintaining 1" clearance throughout the whole casing program, leading to a slimmer well profile but keeping the same size for the production casing string. To achieve this it is mandatory to adopt suitable drilling technologies that will be deeply discussed in the paper.

The "Lean Profile" has been successfully applied to some wells drilled from on-shore clusters with parallel vertical sections long as much as 2,000 meters. The drilling environment is challenging with problems such as formations' tendency to deviate from the vertical trajectory, wellbore instability and circulation losses. In this operating scenario the "Lean Profile" provided for dramatic time and cost reduction. In fact, the halving of the rock volume involved in the drilling process resulted in an outstanding drilling performance (-40% on drilling time with respect to standard technology), less material consumption and less waste production. The Lean Profile is part of the drilling strategy for some 30 wells in the Val d'Agri, southern Italy, with interesting cost saving opportunities. This paper summarises experiences and results from the field along with engineering considerations.

KEYWORDS

Drilling technology, drilling strategy, drilling cost, casing string, oil well, Italy

The Lean Profile

The meaning of the word “lean” renders the concept of this innovative drilling technique. Referred to an operation, lean means economical, cut to the bone, or if you like, reduced to the essential.

In our case, where the term “lean” is applied to a well, the Lean Profile is practically a redefinition of the well profile based on a drastic reduction of the existing clearance between casing outer diameter and the diameter of the hole where the casing is run. This leads to a “slimmer” casing profile which reduces the drilling CAPEX as a result of a series of beneficial effects.

This approach is not to be confused with the reduction of the clearance between casing ID and subsequent casing OD. Although this technique has been recently presented¹, it is based on the use of bi-center PDC bit which delivers poor drilling performance compared with standard PDC bits.

The reduction of volumes (i.e.: rock to be drilled) amounts to around 56% provides a comparison with a conventional profile. Of course, this has a certain impact on material consumption and drilling performance that will be presented in the following paragraph.

The application of the lean concept is based on the following requirements:

- absolute control of a vertical trajectory;
- use of flush (or near-flush) joint connections, because of the very small clearances between casing and open hole.

The first condition is today achievable because of the availability of automatic drilling systems. The Straight-hole Drilling Device (SDD) and its advantages were fully described in reference². Among these advantages, the SDD provides perfect control of vertical direction and therefore it gives the best environment for running casing in a reduced clearance.

Advantages of the Lean Profile

The main advantages of the lean approach are:

Better drilling performance. This is a direct consequence of the smaller volumes of rock involved in the drilling process. Experience showed that it is possible to reduce the drilling time by some 40%.

Less material consumption. A slimmer profile requires less material for casings, drilling fluids, cement and additives.

Lower environmental impact. Fewer drilling fluids used to drill a well means less drilling waste to be disposed (including a reduction in the transportation required).

Improved cementing. This is a consequence of the smaller holes drilled. In fact, in these conditions hole enlargement problems are less frequent. Also, the reduced clearance provided for a better hydraulics during displacement of slurries.

Reduced risk of stuck pipe. Drilling in a straight vertical hole with a **BHA** comprising just one or two reamers reduces the risk of stuck pipe due to the hole geometry (key seat). Also in the event of hole collapse, there will be a lower probability of cuttings/cavings forming a sticking point around some restrictions between the drillstring and borehole wall.

Reduced risk of drillstring failures. As stated in the previous paragraph, this is a consequence of no pipe rotation for steering control.

Improved safety. The use of the SDD, which operates in sliding mode, have the positive effect of practically eliminate casing wear due to drillstring rotation.

Also, having a lean straight vertical well provides a better environment for well control operations (i.e.: relief wells), because the position and depth of the well is defined accurately.

Critical technologies

The application of the lean profile requires attention to directional drilling, mud properties, casing running and cementing.

Directional drilling. The importance of accurate directional control for the lean profile has been pointed out in the previous paragraphs.

Perfect control of the well trajectory eliminates dog legs and reduces dramatically the torque and drag in the well, resulting in improved casing running, even in small casing-wellbore clearances.

This optimal control can now be achieved using systems like the Straighthole Drilling Device or other similar equipment.

Mud properties. Optimal use of the SDD requires circulation rates of up to 3,800 l/min (17 1/2" drilling phase) and a minimum value of 3,000 l/min. Therefore it is necessary to ensure optimal solid control and cutting transportation, above all when a large amount of cuttings are produced.

To date, environmental constraints have made the use of OBM impracticable in the Val d'Agri. Therefore, when WBM is used it is necessary to take into consideration the use of shale inhibitors and lubricant additives to prevent formations from instability phenomena.

Casing running and cementing. Casing running -Perfect verticality control and mud system conditioning are key factors in successful casing running. These requirements allow for a calibrated vertical hole and the maintenance of a thin elastic mud cake in layers where filtration may be a source of differential sticking problems.

Centralisation can be considered, but the risk created by the small clearance has to be carefully evaluated.

Running speed is another factor to consider in order to avoid surge effects and prevent the casing from becoming stuck while running. Typical running speed adopted have been 6-7 m/min (16" casing) and 4-5 m/min (13 3/8"). A key factor for minimising surge pressure while running casing is the viscosity of the drilling fluid in which the casing is run. Low values of plastic viscosity and yield point will help control surge pressure.

Typical values of plastic viscosity have been 19 and 24 cp for the 16" and 13 3/8" casing string respectively. As to yield point values, they have been 15 and 19 Pa for the above casing strings.

Cementing a casing in a small annulus gives rise to some concern due to the higher pressure drops compared to standard techniques. In fact, during cementing planning it is important to verify the potential risk of formation fracturing caused by the increased ECD (Equivalent Circulating Density), especially for surface formations. The use of low viscosity slurries can be considered.

Field experience

The first applications of a lean casing profile have been applied to some development in the Val d'Agri, Basilicata region, southern Italy (Monte Enoc 9 OR, 1997, Monte Enoc W1, 1998).

To be noted is that with the Lean Profile technology, drilling can start with a smaller bit diameter, to reach a production casing string which has the same diameter as that achieved using a conventional profile.

At Monte Enoc 9 well the lean concept was applied to the 17 1/2" and 14 3/4" sections where the holes are cased with 16" and 13 3/8" casing respectively.

The following tubulars were used:

- 16" T95 84# Hydril 521;
- 13 3/8" L80 72# Grant Prideco FJ

These correspond to the following clearances:

- 1.140 in., 17 1/2" hole for the 16" casing,
- 1.372 in., 14 3/4" hole for the 13 3/8" casing.

To be noted is the fact that the profile used for Monte Enoc 9 had the same number of casing strings of the conventional profile. As a matter of fact, the solution of formation instability problems, as a result of the lean technique, allowed one intermediate casing string to be eliminated from the profile of the Monte Enoc W1 well.

The improvement of the hole stability is a result of using a drilling system like the SDD. The consequence of the high degree of accuracy in the vertical direction control is the elimination of time consuming reaming operations, which are a source of wellbore instability.

Also, when hole stability is time dependent, the use of a system that allows for outstanding rates of penetration reduces the effect of hole ageing.

The SDD does not operate in the rotary mode therefore this, in addition to the low level of BHA stabilisation, eliminates the mechanical impact of the drillstring against the wellbore wall.

Moreover, the quality of hole which the SDD can provide in terms of hole geometry (e.g.: ovalisation) must be taken into consideration. The resulting hole which is more in-gauge is also more stable than a hole with irregular geometry.

The elimination of a casing string from the well profile allowed for a further improvement of the drilling performance.

The trend is clearly positive, in particular for Monte Enoc W1 where the elimination of a casing string led to an average drilling time reduction of some 40% compared to conventional techniques. This, we believe, is a sign of the step change in the drilling performance. As previously stated, this results were obtained in development wells.

The last experience with lean casing profiles is with **Rocca Rossa 1**, which is wild cut well currently being drilled in the Basilicata region. The original casing profile was conventional and it was reviewed adopting a lean profile as per Monte Enoc 9 OR .

TD of the 17 1/2" hole and 13 3/8" were set to 1200 and 2600 m respectively. A special casing shoe was used for the 16" string ("reciprocating shoe") with 16 3/4" stabilising ribs. The string got stuck at 545 m and pulled out of hole. During the subsequent run to ream the hole considerable drag was experienced. The second attempt to run the 16" casing (with a conventional casing shoe) failed at 632m, where the string was cemented.

Likely, the pronounced formations' dip (40°-60°, with soft and hard formations interbedded) somehow resulted in the development of ledges. These, coupled with the static deflection of the casing (that can be up to 1 in. according to API specs) resulted in a sticking mechanism. As a confirmation of the presence of ledges in the hole, the sonic log recorded prior to casing running was disturbed by some vibrations generated during the its run. In fact, we believe these vibrations were caused by the ledges.

The 14 3/4" hole, from bottom of 17 1/2" phase (1286 m) to 2672 m, was drilled using a bit with lag pads which provided for a stabilisation point (1/16"-1/8" undergauge).

Drilling was concluded before reaching the planned TD set at 3200 m, due to formation instability problems in some clayish formations. Prior casing running, over a total of 267 casings 54 were discarded because of their high values of static deflection .

The sonic log was recorded without the vibration problems encountered in the previous phase and this, we believe, proved the new bit design to be effective in removing the ledges. As a matter of fact, the 13 3/8" casing string was successfully run at 2646 m.

Cost considerations

The economic impact of the technology is significant. To make an assessment of this, it is worth looking at the well Monte Enoc W1 and make a comparison with the best well drilled in the area with conventional technology. This is the case of Monte Enoc NW1 . For comparison, this well is preferred to Monte Enoc 1, because of its proximity to Monte Enoc W1 and because it is more recent.

The comparison can be restricted to the 9 5/8" drilling phase because no differences exist in the technology used to drill the subsequent hole sections.

Therefore, upon completion of the 9 5/8" drilling phase, we have the following situation. One well, Monte Enoc NW1 (casing point @ 3215 m), was drilled with conventional technology in 134 days with a cost of \$31,500 per day, which includes rig rental and all other drilling services.

On the other hand, Monte Enoc W1 (casing point @ 3180 in) was drilled with the Lean Profile technology in 81 days, say with the same cost per day but with the additional cost for the different drilling technology (i.e.: the SDD). Also, it must be considered the net saving for the less material consumption and less waste volume to be disposed.

The drilling time saved at Monte Enoc W1 is therefore 53 days, which corresponds to a time compression of some 40%. This result **turns** in a cost saving of \$1,699,500 . The total cost saving for less materials consumption and less waste disposal is estimated to be some \$583,000 .

The cost for the SDD on Monte Enoc W1 is estimated to be some \$648,000 .

Therefore, for the Val d'Agri scenario, the economic impact of the Lean Profile technology on drilling Capex is as follows:

Drilling days	-1,699,500
Material and waste disposal	- 583,000
Cost of the SDD	+ 648,000
Net economic impact per well	-1,634,500

This value is to be considered within the oilfield development project, which in the case of the Val d'Agri, worth drilling some other 30 wells, thus making the economic impact of the Lean Profile technology significant to make us notice it.

From this simple analysis it appears evident that:

- the additional cost for the technology (i.e.: the SDD) is nearly paid by the cost saving that comes from the less material consumption and less requirement for waste disposal;
- the drilling time saved and the daily fixed cost are the variables that affect the economic impact the most.

Clearly, major savings resulting from the change of the drilling technique are relevant to drilling time reduction. This holds particularly for the drilling context we are describing, which is the Val d'Agri. In fact, in different drilling environments, where high rates of

penetration are commonly achieved, the room for drilling performance improvement can be much less.

Conclusions

The Lean Profile, which is a new approach to casing profile design, has been successfully applied to some wells in the Val d'Agri, having a positive impact to the drilling CAPEX.

Also, the technique has been applied to a wildcat well having a failure in one casing running. However, possible causes and solutions have been outlined.

This technique is now part of a drilling strategy within the development of the Val d'Agri field, southern Italy.

However, to date the application of the Lean Profile is limited to vertical holes. This fact restricts the application to vertical onshore wells and offshore exploration wells.

However, rotary steerable systems will generate some optimism about the possibility of extending this technique to other operating environments, because these systems reduce well tortuosity (and friction) also in deviated holes.

Therefore, future application will regard offshore field development and, in general, the well profile as a whole.

Deepwater drilling in particular is an environment where the lean profile technique may provide for substantial advantages. As a matter of fact, designing wells with smaller clearances between open hole and casing OD results in slimmer well profiles and therefore smaller rigs and BOP's can be used, while at the same time optimising production tubing sizes.

Acknowledgements

We thank ENI AGIP Division for permission to publish this paper. A special thank to Sergio Fazio, who put his best mud engineering expertise in this project.

References

1. Barker, J., W., : "Reduced-clearance casing programs offer numerous advantages", World Oil, May 1998.
2. Ligrone, J. Oppelt, A. Calderoni, J. Treviranus; "The Fastest Way to the Bottom: Straightthole Drilling Device - Drilling Concept, Design Considerations, and Field Experience", SPE Paper 36826, Europec 96, Milan, Italy.
3. Claus, C., Thomas, B., Bernhard, E., Sperber, A., Trach, T.V., Wohlgemuth, L.: "KTB- 4 Years Experience at the Limits of Drilling Technology, SPE/IADC 29912, 1995 SPE/IADC Conference, Amsterdam, 28 Feb.-2 Mar., 1995.

SI metric conversion factors

cp X 1.0×10^{-3} = Pa . s

ft X 3.048×10^{-1} = m

ft² X 9.290304×10^{-2} = m²

ft³ X 2.831685×10^{-2} = m³

in. X 2.54×10^0 = cm

lbf X 4.448222×10^0 = N

psi X 6.894757×10^0 = kPa

*Conversion factor is exact.