FACTORING IN THE TOP 5

Gefei Liu, Pegasus Vertex, Inc., USA, examines five main factors that must be taken into account when centralising casing during cementing operations.

Creating a good casing standoff profile along vertical, deviated and horizontal wellbores is the first step towards a successful cementing job. Different types of centralisers are strategically installed on casing to achieve this goal.

There are four types of commonly used centralisers (Figure 1):

- The bow-spring centraliser's steel bows act as spring to push the pipe away from wellbore. The shape and stiffness of bows determine the restoring force, which is defined as the resistance force when a bow is compressed to ⅓ of its uncompressed height. The effectiveness of this type of centraliser is heavily dependent on the restoring force. For a casing in a deviated well, the side force, which pulls the pipe to either higher or lower side of borehole, varies along the depth, causing the variation of standoff at the centralisers along the pipe. API has minimum requirements on restoring forces. For example, for centralisers on 9 ⅝ in. casing, the minimum restoring force at 67% standoff is 1600 lbf. Most centraliser vendors exceed API requirements on restoring force.

- The rigid body centraliser uses solid blades to support the pipe. Because of the fixed blade OD, the standoff at the centralisers is the same even in a deviated well. Keep in mind that the casing between rigid body centralisers still sags.
- The semi-rigid centraliser combines the benefits of restoring force and blade. When the side force is big enough to compress the bow severely, it turns itself into a rigid type blade or a blade takes over in a supporting role.
- Mould-on centralisers utilise resin, carbon fibre and ceramic technologies to create blades, which are moulded onto casing. This kind of centraliser provides greater flow area than standard centralisers, helping prevent 'packing-off' while allowing for more even cement distribution.

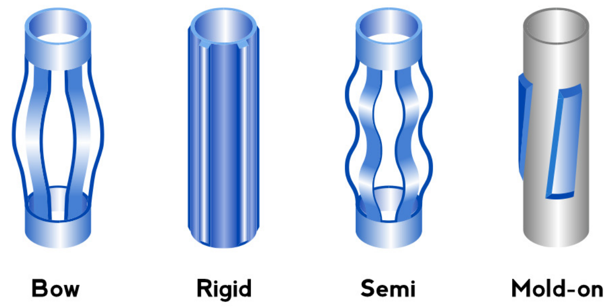

Figure 1. *Four different types of centralisers.*

$$\text{Standoff} = \frac{C}{A - B}$$

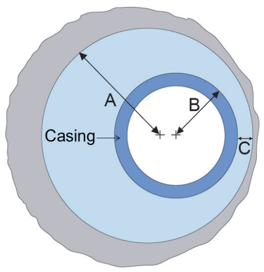

Figure 2. *Casing standoff.*

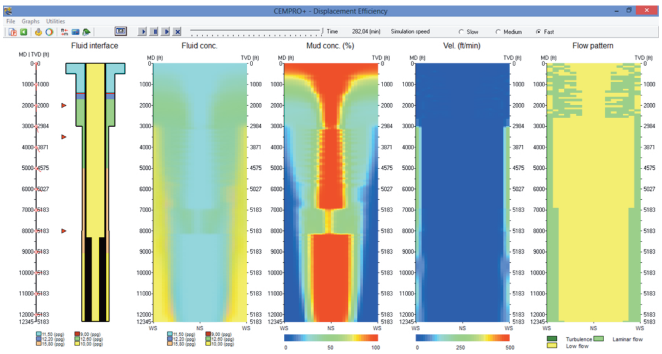

Figure 3. *Displacement efficiency for casing standoff of 0%.*

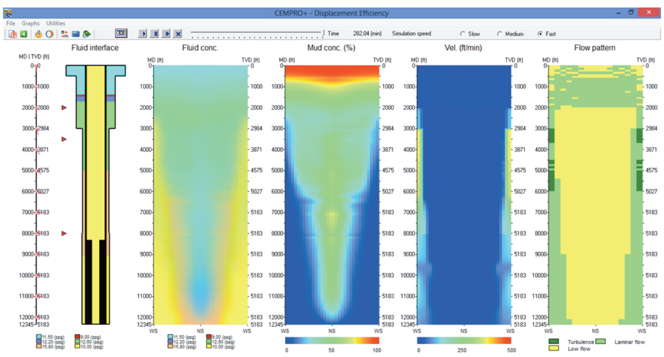

Figure 4. *Displacement efficiency for casing standoff of 70%.*

Centraliser usage is huge: approximately 10 million centralisers are used globally every year. The question still remains: "Are we using too many or too few?" The challenge that both operators and service companies face is to place the right amount of centralisers at the optimum positions on the casing. While operators may be conservative, service companies tend to be liberal in selecting the number of centralisers for a given application.

To describe casing centralisation, the concept of standoff needs to be defined.

The standoff of a perfectly centred casing is 100%. When casing touches wellbore, the standoff is 0%. Regardless of centraliser type, the goal is to provide a positive standoff, preferably above 67%, throughout casing string. Incomplete mud removal causes a poor cement seal and non-productive time. A good casing standoff helps to reduce the mud channelling and improves the displacement efficiency. Figures 3 and 4 illustrate the impact of casing standoff on displacement efficiency. The third track in Figure 3 shows the mud concentration in the annulus after a cementing job with 0% casing standoff.

There are some large red areas, representing high percentage of remaining mud, in the narrow side (NS) of eccentric annulus.

Everything was kept the same except the casing standoff, which was changed to 70%. Now the displacement efficiency improved significantly, as shown in Figure 4.

Casing deflection between centralisers obeys the laws of physics and engineering analysis can help both operators and service companies arrive at an optimised number and placement of centralisers for a particular well. These are the five things that affect casing centralisation:

- Well trajectory.
- Casing size and weight.
- Fluids inside the casing and annulus.
- Centraliser properties.
- Centraliser placement.

Well trajectory

Well trajectory is normally expressed in terms of survey data, consisting of measured depth, inclination and azimuthal angles. It defines the shape of the well path and thus has a great impact on the direction and magnitude of side forces pulling the casing string to the wellbore. Figure 5 shows the magnitude and direction of side force distribution on a casing in a horizontal well.

For a casing section in a build-up or horizontal section of wellbore, the weight of pipe pulls the casing toward to the lower side of hole. The blue lines indicate that the casing touches the lower side of wellbore. The upper section of casing string has to sustain the weight of lower casing sections. This creates tension force along the casing string. Wellbore doglegs cause the resultant force to pull the casing toward the upper side of hole, as indicated by the red lines. Therefore, casing string in a deviated or horizontal well always touches either the wellbore's upper or lower side.

Generally speaking, horizontal or extended reach wells require more support from centralisers to maintain a good standoff profile. Taking an example of casing (OD 4.5 in., 15.1 lb/ft, ID 3.826

in.) in a 12 ppg fluid, to achieve a standoff of 70%, the spacing (the distance between two adjacent centralisers) required decreases steadily, as the wellbore inclination angle goes up, as shown in Figure 7. Therefore, the number required to obtain a standoff of 70% for a given length of casing goes up as the wellbore deviates.

Figure 8 illustrates the decreasing of standoff for casing with given centraliser spacing of 20 ft, 40 ft, and 60 ft, respectively. It can be seen that the casing standoff will drop below 70% when the inclination angle reaches 30˚ for a spacing of 60 ft.

Casing size and weight

Casing weight determines the gravitational force, which pulls the pipe toward the lower side of borehole. The heavier the casing string, more or stronger centralisers are required. The term 'casing weight' refers to the weight of pipe in air. When the casing string is in a well, it is always immersed in one or more fluids. The buoyancy force exerted by fluids opposes the weight of casing and tends to lift the casing upward.

Fluids inside casing and in annulus

The buoyancy force calculation is further complicated by the multi-fluid configuration during a cementing job. When heavy cement slurry is inside the casing and a light drilling mud is in the annulus, the effective weight of the casing is at its greatest. On the other hand, when cement slurry is in place and displacement fluid, inside casing, the buoyancy is at its peak and the effective weight of pipe is at its lowest. Figure 9 shows the three instances of a cement job with corresponding casing deflection between centralisers.

When designing the placement for the scenario of cement slurry in place, it is preferable to have less effective casing weight, pulling casing string downwards. But when the cement slurry is inside casing during the displacement, the lower standoff could cause mud-channelling problems. It is better to study standoff for all the situations. To better design centraliser placement, the top of cement (TOC), cement slurry densities, mud weight, etc., all need to be known. The density differential of cement slurry and mud improves the standoff profile.

Centraliser properties

Not all centralisers are created equal; manufacturers are striving to improve the performance of their products.

For solid centralisers including mould-on type, the blade OD is the key parameter as far as the casing centralisation is concerned.

For bow-spring centralisers, the restoring force is the measurement of the strength of a centraliser. It is defined as the side force required to deflect the bow by ⅓ of its original height.

Since the bows on a bow-spring centraliser will deflect under the action of side force, the calculation of casing standoff is a little bit more involved: the amount of bow deflections on centralisers and casing sagging between them needs to be calculated. The standoff at the middle point of two centralisers, being the worst, is the result of these two contributions.

Centraliser placement

Once a well is planned, the casing designed, the cementing procedure prepared and the centraliser type selected, there are not many options other than placing centralisers strategically to achieve desired standoff. However, this can still be very important: poor spacing will result in poor standoff even with the best centralisers on the market.

With the help of computer modelling, centraliser placement optimisation becomes easy to perform for all types of wells. Ideally, this kind of optimisation should be carried out before each casing job. Consider an example of centraliser placement optimisation using CentraDesign software.

The example well has a kick-off point at 2000 ft. The previous casing (ID = 8.535 in.) was set at the same depth. The goal is to

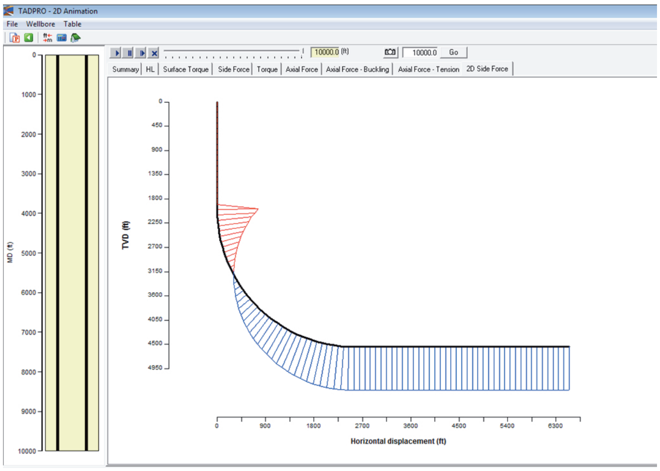

Figure 5. *Side force profile.*

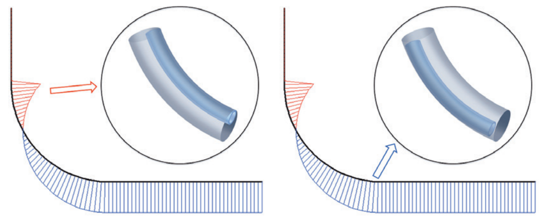

Figure 6. *Side forces with casing positions.*

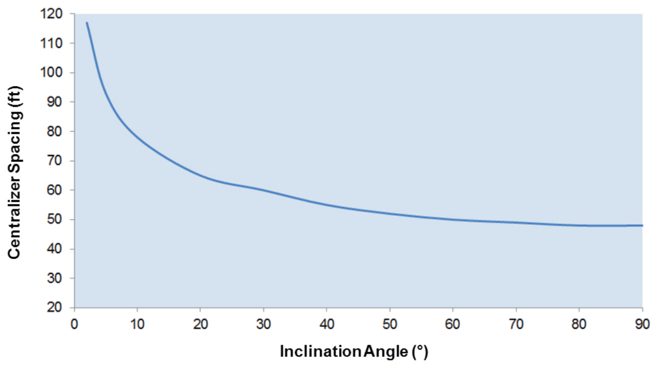

Figure 7. *Centraliser spacing versus inclination angle.*

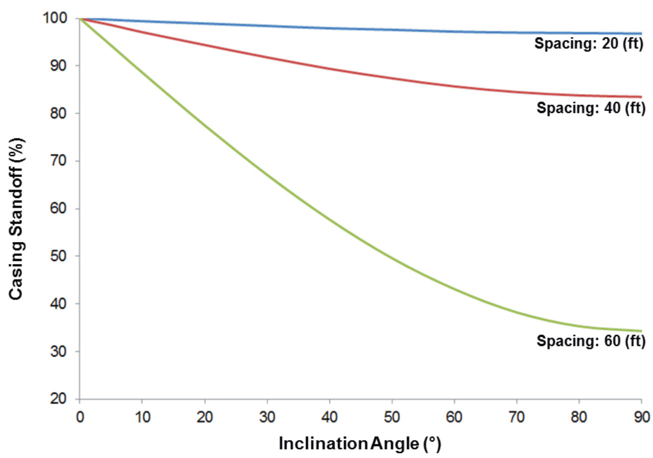

Figure 8. *Casing standoff versus inclination angle.*

centralise the 12 345 ft of 4 ½ in. casing, deviated from 0˚ to 90˚. The centraliser considered is a bow spring type with a restoring force of 800 lbf.

One approach to centraliser placement optimisation is to specify spacing using experience and then let software check if it yields a satisfactory standoff profile. Consider the following two cases: one with 40 ft (one centraliser per joint) and the other with 20 ft (two centralisers per joint) for the centraliser spacing. Figure 11 shows the resulting standoff profiles. The blue line is the standoff at the centraliser, while the red line is the standoff at the middle point between centralisers, which is always lower than that of at the centralisers. Since bow spring centralisers are being used, the standoff at the middle point between centralisers is the summation of casing sagging between them and the bow spring compression at the centralisers.

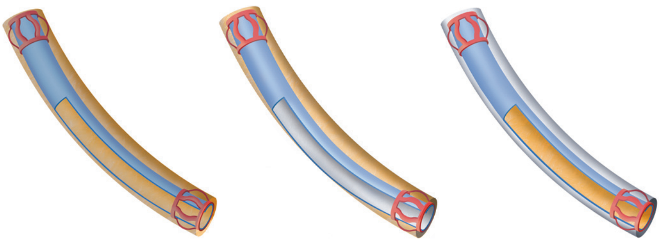

Figure 9. *Casing deflection between centralisers. (Left: prior to cementing job. Centre: Cement inside casing. Right: Cement in annulus.)*

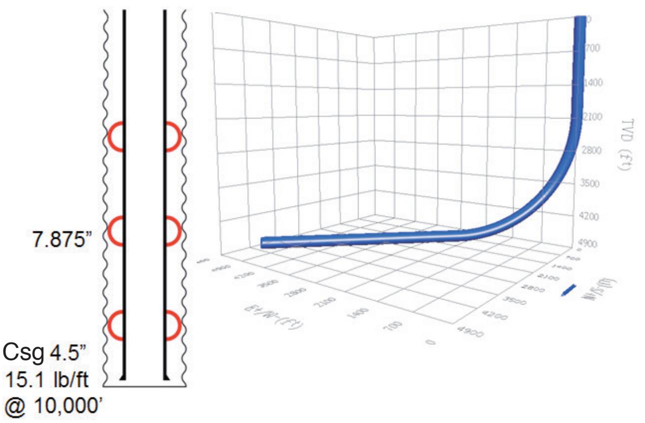

Figure 10. *Example well.*

For a spacing of 40 ft, the number of centralisers required is 251. From 2000 ft to 7000 ft (deviation from 0˚ to 30˚), the standoff is between 100% and 70%, which meets the minimum industry standard of 67%. From 7000 ft to 12 345 ft (deviation from 30˚ to 90˚), the standoff drops from 70% to 20%, which is problematic: a poor standoff profile at this section may cause potential cementing problems.

The natural way to solve this problem is to try two centralisers per joint (spacing of 20 ft). The new standoff profile is much better than the normal industry standard, but with the number of centralisers being doubled, this new approach may be too conservative, leaving doubts in the engineer's mind as to whether they are using too many.

Alternatively, the required standoff can be specified and the software will explain how to space the centralisers. With the required 70% standoff throughout 4 ½ in. casing, CentraDesign displays the following spacing necessary to achieve the specified standoff. The total number of centralisers used is 200, a significant reduction from previous approaches.

Logically, as the well builds up from 0˚ to 90˚ inclination angle, spacing decreases: the casing needs more support in more deviated or horizontal sections. A more advanced approach is to combine the software's 'Specify spacing' and 'Specify standoff' modes to yield the simple-to-install centraliser placement whilst maintaining a satisfactory standoff profile, by using the incremental spacing option. Optimised centraliser placement not only produces good standoff, but also increases efficiency of field installation of centralisers and avoids their excessive and unnecessary use.

Conclusion

Experience coupled with software technology enables both vendors and operators to conduct centraliser optimisation prior to field execution:

- Each well is different. Consider the five factors that affect casing centralisation.
- Select the correct type of centraliser and properties for a particular well.
- Use software to check the standoff profile for a specified spacing.
- Optimise the placement.
- Computer modelling reduces risk and saves money.
- Centraliser placement can make or break a good cementing job.

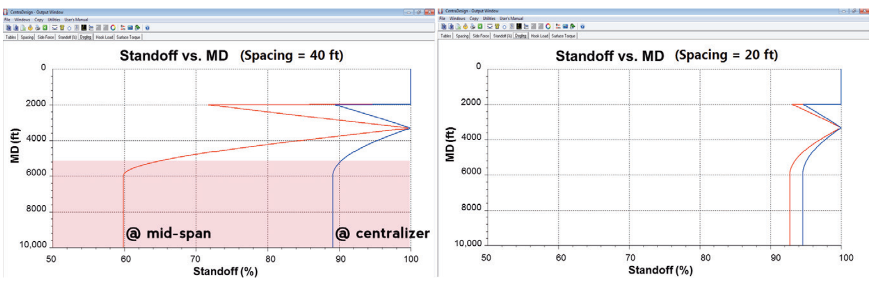

Figure 11. *Standoff profiles.*

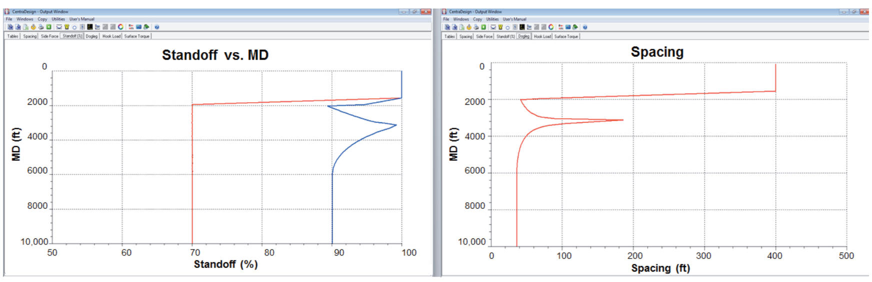

Figure 12. *Calculated spacing required to achieve 70% standoff.*

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