

Hydroform Centralizers Technology Primer

The role of centralization in delivering high integrity cement jobs

Avoiding bad cement jobs may be the easiest way to maximize well life and minimize costly remedial work. Although centralization is only *part* of a good cement job, poor centralization is enough to compromise even the best designs.

This technical primer will describe well conditions that require particular care in centralizer program design and show how standard practices that overlook downhole realities can reduce the net present value of your wells.

Background

Providing hydraulic isolation and structural integrity are the primary functions of cement in downhole applications. Preventing flow of undesirable well fluids into producing intervals and of well fluids into either aquifers or other 'clean' zones is necessary for ongoing economic operation of any well. Any condition that allows unplanned fluid flow between zones decreases the value of the well.

Structural integrity of the well-bore also depends on adequate cement mechanical properties. Predictable, effective load transfer between the casing system and formation is necessary to prevent unintentional casing deformation. A continuous cement sheath of adequate thickness is a key structural component of the well.

Significant developments have been completed by service companies to improve hole cleaning, increase displacement efficiency, and manage fluid dynamics to maximize cement job quality. Good centralization does not replace a well designed cementing program – neither does the cement program replace the need to position the casing appropriately in the well-bore. Optimizing casing centralization is an effective strategy to minimize the risk of ineffective cement jobs and leverage cement program investment.

How well centralized does casing need to be? The answer is driven by the balance between the cost of centralization, the **effect of incremental centralization** on cement job effectiveness and consistency, and the **cost of unplanned fluid migration or structural failure**. The following discussion of down-hole mechanisms that can lead to inadequate cement performance will help well designers to arrive at the right answer for their application.

Mud Channelling

'Mud Channels' along the well-bore provide an unintentional down-hole flow path and enable well fluids to migrate between connected zones. Consequences range from early water breakthrough and lost production to remedial cement jobs or even a requirement to abandon and re-drill the well.

Channels are typically caused by ineffective fluid displacement during the cementing operation. Eccentric positioning of casing in the hole, resulting in unbalanced flow resistance around the circumference is a common source of channelling, although other less obvious mechanisms can cause a similar result.

Eccentric casing

Imbalanced resistance to fluid flow occurs when casing is positioned eccentrically in the well bore. Because fluid follows the path of least resistance, velocity on the wide side of an eccentric annulus is higher than on the narrow side. Figure 1 shows maximum velocity gradients for one sample case of a shear thinning fluid in an eccentric annulus. Note that flow velocities deviate very quickly as eccentricity develops.

Flow velocity gradients often result in unstable fluid fronts. When the cement on the wide side of the annulus advances faster than that on the narrow side, the leading material can wrap around the pipe thereby trapping a mud pocket. After a mud pocket is trapped it may, at best, be broken into smaller discontinuous pockets, but the final size and location can not be controlled. The best way to manage mud pockets is to avoid creating them!

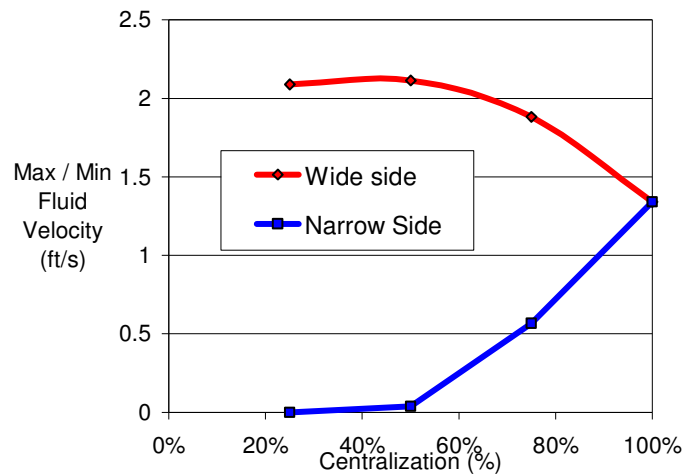


Figure 1 - Velocity gradient in eccentric annulus

Key seats

Drilling deviated wells of any appreciable depth requires that the drill string is pulled against the inside radius of the deviation and typically results in some degree of wear. Severe cases are commonly known as 'key seats' and often cause drilling challenges, but even modest wear that may be undetected during the drilling process can result in out-of-round hole geometry as shown in Figure 2.

When casing is run into the hole, the same loads that pulled the drill pipe to the inside of the deviation radius cause the casing to pull in against the wear groove. Figure 3 shows the expected position of casing installed with inadequate centralizers. Ribs that are either too weak to support the applied loads or are aligned with the pipe axis and cannot span the groove fail to centralize the casing.

Only centralizers with ribs that can both bear the load and span the groove can be expected to effectively centralize the casing as shown in Figure 4.

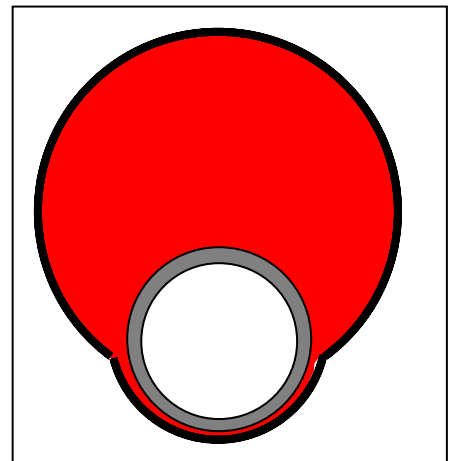


Figure 2 - Wear on inside radius of deviation created during the drilling operation

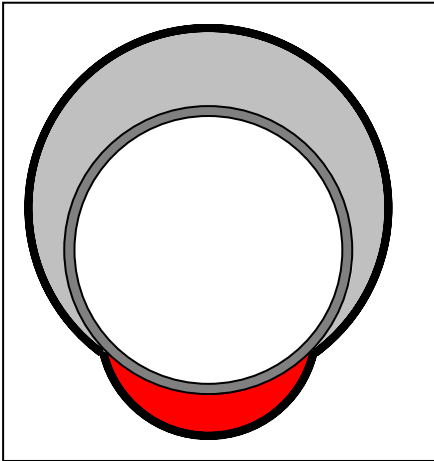


Figure 3 – Casing pulled against the inside deviation radius with inadequate centralization

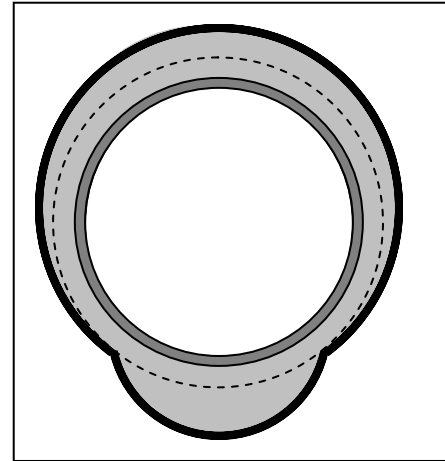


Figure 4 - Casing with full 360° coverage rigid centralizer pulled against the inside deviation radius

The consequences of a poor cement job can be severe. Incomplete mud removal increases risk of mud film or mud channels that allow communication between subsurface zones or to the surface. Resolving these problems is a high cost activity. Failure to separate fluids properly as they are pumped downhole can devalue the best well designs and lead to ineffective mud removal or contamination that prevents cement from ever setting up.

Minimizing and managing eccentricity of casing in the open hole is a low cost way of improving cement job quality providing that other cement program design elements are sound.

Optimized centralization plans are based on knowledge of critical hydraulic isolation zones, understanding where side loads, and therefore potential eccentricities, are large, and ensuring that eccentricity is predicted and managed.

How much eccentricity is there? How much matters?

Because no well bore is perfectly vertical or straight, casing is always pulled against one side of the open hole. The magnitude of this eccentricity depends on local open-hole geometry, centralizer radial stiffness, and side load. Eccentricity must be managed, or designed, to avoid unintentional flow imbalances that compromise hydraulic isolation.

Centralizers are required to react load from the casing to the formation to position the casing within the 'design' centralization range. Interaction between the casing, centralizer, and formation is complex, but can be modelled analytically. A robust analysis engine manages the interaction of controlling variables such as:

- Formation bearing capacity (ability to resist centralizer rib loads),
- Centralizer/formation bearing area,
- Centralizer rib stiffness,
- Casing geometry,
- Open hole geometry, including effect of washouts, and
- Well trajectory.

Failure to consider the relevant variables results in wrong answers, inadequate centralization, and increased risk of ineffective cement jobs.

Given that casing is always loaded against the side of the open hole, eccentricity must be managed. Eccentricity magnitude can be calculated with reasonable accuracy (if you're careful) and used as input for fluid flow analyses to predict flow velocity gradients and identify potential trouble zones.

Effective mud displacement can be achieved through careful fluid rheology selection to ensure either turbulent or plug flow. In either case, greater casing eccentricity increases flow velocity gradients and therefore the risk of leaving mud channels behind. Opportunities to better centralize casing, minimize fluid velocity gradients, and reduce this risk are expected to increase well value.

Structural Integrity

Holidays in the cement sheath can compromise casing integrity, particularly in compacting reservoirs or thermal applications. When the combination of axial loads, bending, shear, and pressure loads exceeds material strength, plastic deformation of the pipe and/or casing connections occurs. While plastic design of casing strings can be an effective way to manage extreme loading conditions, care must be taken to anticipate how the casing system will respond to the range of possible load cases.

In general, incremental loading must be accompanied by incremental resistance or an unstable softening condition results. The cement sheath serves to transfer load from the casing to the formation and to support casing in the radial direction. Interruptions in this support provide an opportunity for casing to buckle and therefore weaken, or soften. Because locally buckled casing is weaker than the adjacent sections, incremental loads drive displacement into this local deformation and rapidly reduce the ability of the casing to carry the necessary loads. Maintaining a continuous cement sheath capable of transferring these loads and supporting the casing is necessary in critical well casing systems that rely on the plastic capacity of the pipe and connections.

The Volant Solution

Rigid HydroFORM™ Centralizers

Volant HydroFORM™ Centralizers are robust, easy to run, provide positive centralization, and can be customized to fit a broad range of applications. Hydro-forming is a net-zero manufacturing process that delivers a high integrity one-piece construction with well controlled dimensions and predictable strength.



Centralizers must perform their intended function during the entire casing running operation, including getting through tight spots and freeing stuck pipe, to accurately position casing for cementing operations. Anyone who has pulled casing after failing to land the string at the desired depth can attest to the rigors of the downhole environment and the effect of those conditions on centralizer integrity. Only the strong survive. The one-piece construction of the Volant centralizer eliminates the potential for weld failure and the smooth profile minimizes the chance of hanging up downhole. Side load tests show that Volant's heavy duty centralizers can resist side loads greater than hard rock formation strength capacity with permanent deformation of about 0.05 inches.

Broad helical ribs provide 100% circumferential coverage and contact area adequate to distribute load over weaker formations. Rib helix angle and profile are designed to optimize strength, bearing area, and pressure drop during circulation and cementing operations. Each parameter can be customized to suit specific applications.

Volant HydroFORM™ Centralizers are well-supported technically. We understand that our customers need solutions and appreciate well designed products that are applied appropriately. Our approach is to consider the big picture when making recommendations. In this case,

positioning the casing in the well-bore to enable the best possible cement job is the primary objective. Applications engineering considers trade-offs between hydraulic isolation requirements, hole geometry, resulting side loads, and interaction of centralizers with the formation to find the right solution for the job.

Managing fluid velocity gradients

We've established that greater fluid velocity gradients increase the risk of bad cement jobs. Tools available to manage this risk are:

- casing centralization,
- fluid selection, sequencing, and flow rate, and
- flow orientation.

Positioning the casing near the centre of the open hole is a cost effective way balance resistance to flow and therefore minimize velocity gradients. However, perfect centralization is *never* possible and, because of washouts or open-hole trajectory inconsistencies, adequate centralization isn't always possible. In fact you don't always know about differences between planned and actual casing eccentricity!

Good fluid program design is necessary, but not sufficient to minimize risk of cement failure. Together, adequate centralization and good fluid program design effectively maximize cement job quality. Controlling annular flow orientation is a third tool available to reduce flow velocity gradients given any casing eccentricity and fluid program.

If 'swirl' can be induced and maintained in the annular flow, then high velocity fluid from the wide side of the annulus can be drawn into the narrow side thus flattening the velocity gradient. The challenge is to understand what conditions will result in sustained swirling flow. SPE paper 19542 – Analysis of Cementing Turbulators – describes an analytical solution to calculate the distance swirl propagates past a swirl-inducing device. The authors verify calculations against laboratory tests, and benchmark predictions against cement bond logs on real wells. Volant Products has developed a design tool based on this method to predict the distance swirl can be expected to propagate past HydroFORM™ centralizers given casing diameter, open hole diameter, fluid rheology, and flow rates. Some applications can benefit from swirl induced by devices in fixed positions, but others would require an excessive number of centralizer which could create other problems.

Swirl can be induced continuously along the well bore by rotating casing during cementing. Operators who have compared cement bond logs for wells with and without rotation report more consistent cement jobs with rotation. Better cement provides better hydraulic isolation and reduced risk of losing a critical well or allowing undesired and unplanned communication between zones.

The practice of rotating casing during cementing places significant loads on centralizers. Robust construction is necessary to prevent centralizer damage and loss of functionality. Volant HydroFORM™ centralizers are manufactured from a single piece of material into a smooth profile without any sharp edges that can hang up downhole or welded pieces that can break off. In fact, these centralizers are commonly hard faced and successfully used as stabilizers in Casing Drilling™ applications.¹

Mounting Options

Centralizers can be mounted on the casing in a number of ways to fit a variety of applications. First, they can be mechanically swaged, or crimped, onto the casing to provide positive axial positioning and prevent relative rotation between the casing and the centralizer. This is the preferred method of attachment for applications such as Casing Drilling™ that require extended periods of rotation. Second, centralizers can be floated between stop collars when centralizer rotation against weak formations is undesirable. Finally, the centralizer body can be drilled and tapped to enable set screw mounting to the casing body. This provides less security than the crimping attachment method, but is adequate for many applications and is readily performed at any field location.

Closure

Thank you for your interest in Volant Products' HydroFORM™ centralizers. We are committed to improving our product line and our understanding of our customers' needs and are interested in receiving feedback from you. Our web site describes a number of other products that may be of interest. Please visit us at www.volantproducts.ca to become more familiar with our offerings.

Volant utilises Noetic Engineering for analysis, design, and testing needs. Noetic's casing system analysis and design capabilities may be of interest to you. You can log onto the Noetic web site at www.noetic.ca.

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