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Stopping External Casing Corrosion

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Abstract

This paper is an overview of coated and non-coated well casings in corrosive formations. Failure trend studies of externally un-coated well casings indicate a prevalence of external casing failures due to corrosive formations. Some casing failures have been documented in as little as twenty-four months. Well casings coated with advanced technology epoxies have improved the service life of these wells significantly. This paper describes the key learnings from these applications.

Introduction

Current successes in hydraulic fracturing techniques have lead to an extraordinary increase in drilling activity around the world. This recent boom in drilling activity has caught the attention of the general public and government regulators alike. One concern of particular interest is the use and protection of fresh water resources. Modern completion techniques require large amounts of fresh water to fracture hydrocarbon producing zones. There is also growing concern from the general public about completion chemicals and production fluids potentially contaminating freshwater sources. Maintaining casing integrity is essential to oil and gas production as well as protecting freshwater zones. Historically, Operators have employed several methods to isolate wellbores and production fluids from freshwater zones. Many of these protection methods have been used with differing amounts of success depending on casing design and metallurgy, cementing practices, wellbore geology and numerous other factors. One isolation method that is often overlooked is protective coatings for the externals of well casing.

Protective coatings have commonly been used in the Oil & Gas industry for decades as the first line of defense against corrosion. Coatings are known to be an effective and economically efficient method for protecting metal structures against the effects of corrosive environments. They are used on everything from the rig floor to pipelines and just about everything in between. Why is it then, that we overlook protective coatings as a corrosion control method for well casing? Well casing is often exposed to the following corrosive conditions:

- Microbiologically-Influenced Corrosion (MIC)
- Dissimilar Metal Corrosion
- High chloride or acidic subsurface water attack

Microbiologically-influenced Corrosion (MIC) is the deterioration of metals as a result of metabolic activity in microorganisms. Many instances of accelerated corrosion in the Oil & Gas industry can be attributed to Sulphate Reducing Bacteria (SRB).

Dissimilar metal corrosion is caused by dissimilar metals electrically coupled in a common electrolyte.[1] A practical example of this is mill scale on well casing. Mill scale is the black oxide layer formed on steel during the hot rolling process at the steel mill. The mill scale is more noble and less susceptible to corrosion than carbon steel and acts as the cathode while the carbon steel is sacrificed as the anode. This corrosion cell is accelerated when large areas of the casing are covered by the cathodic mill scale while small areas of exposed carbon steel act as the anode.

High chloride water is corrosive to carbon steel as it is more conductive than pure water. Chlorides destabilize the passive oxide layer that normally protects steel and readily support the electrochemical corrosion process. Acidic water is also highly corrosive to steel. Even mildly acidic water at high temperatures can cause corrosion perforations in well casings at alarming rates.
Each of these areas can be addressed, and to a large degree mitigated, with the use of protective coatings.

Introduce the subject and describe what is contained in the paper.

The Staus Quo

It has been reported that 70% of casing corrosion occurs externally and the remaining 30% is attributed to internal corrosion.[1] When casing leaks develop, production usually stops until the leak can be repaired or a liner installed. This can range from several thousand dollars in repairs and remediation to several million dollars in lost reserves if severe corrosion requires a wellbore to be abandoned. When it comes to designing a well to prevent external corrosion, there are typically three places we start. The first is casing thickness and metallurgy. Based on known geology, information gathered from offset wells or during drilling, casing selection is made based on well design criteria. The well design is engineered to make sure the casing is of sufficient size, thickness and metallurgy to deal with completion requirements and production environments. If there is reliable evidence that a corrosive zone exists, one solution is to increase wall thickness to account for corrosion. The problem with adding wall thickness is that we are assuming static conditions. What if the sweet field we're drilling in today turns sour in 2 years or a formation uphole becomes a water-flood? Adding wall thickness isn't a strategy to prevent corrosion, it's a strategy to delay failure. The next area we turn to after wall thickness and metallurgy is cement. We look at cement as a secondary barrier against corrosion. The pH of cement is highly alkaline so a passivating oxide layer is formed and it's reasonably dense so we assume we've got protected casing. Unfortunately, cementing isn't perfect. We don't get a flawless 1" cement sheath around the casing from TD to surface. Even if we did, chlorides in brine water readily attack cement and the passivating oxide layer formed on the steel by the alkalinity of the cement.[2] Channeling of the cement (Figure 1), cement loss into highly porous formations, poor cement bond to casing, or simply not cementing at all can result in shockingly high corrosion rates. The third tool that is employed to prevent corrosion is Cathodic Protection (CP). This corrosion protection method has been successful in many areas of the world since the late 1940's and is probably the most widely accepted.[3] Will cathodic protection continue to be an effective solution in remote locations and at current and future well depths? Will regulatory bodies and insurance companies begin mandating additional corrosion protection requirements in order to minimize potential environmental impact? Is there a solution to add additional corrosion protection technology in order to make our current systems more robust and reduce potential for casing failure or environmental damage? Yes, advanced technology epoxies enable Operators to use lower CP voltages to penetrate deeper wells while adding powerful corrosion protection.

Coatings

In order for coatings to work, they must protect the surface to which they are applied from the effects of the environment. They perform this protective function in one of three ways.

- Inhibitive Coatings
- Sacrificial Coatings
- Barrier Coatings

Inhibitive coatings, in addition to acting as barriers, actively assist in the control of corrosion by using pigments that provide an inhibitive effect (similar to corrosion inhibitors). Inhibitive coatings are generally not recommended for use in immersion service and therefore aren't used to coat well casing.

Sacrificial coatings are typically rich in zinc. Whenever a scratch or other damage occurs to the zinc exposed to the steel, the zinc acts as a sacrificial anode and corrodes to protect the steel. Sacrificial coatings are typically not used in immersion service or areas of high alkalinity. It is also important to note that at temperatures above 60°C/140°F, zinc may undergo a galvanic reversal whereby the zinc becomes cathodic to the carbon steel.

Barrier coatings keep moisture, bacteria and gases away from the steel surface to prevent corrosion.

While unfamiliar in some regions, shop applied organic barrier coatings are seen as the most effective method available to prevent external casing corrosion and improve effectiveness of cathodic protection systems.[4] In order to provide barrier protection, a coating must be resistant to abrasion, formation temperatures, SRB attack, low pH water, and high chloride water. It is also beneficial if the coating system can add some amount of surface roughness to the casing to improve adhesion of the cement. In an advanced technology epoxy coating system, there are several major advantages.

Some of these advantages are:

1. During the surface preparation of the casing, all mill scale is removed by abrasive blasting. This prevents the possibility of dissimilar metal corrosion since the cathodic mill scale has been removed from the casing.
2. Advanced technology liquid epoxy is immediately applied directly to the abrasive blasted steel in order to prevent surface contamination. This application technique insures proper film build of the epoxy coating. A chemical resistant membrane is then wrapped around the casing directly over the liquid epoxy. This membrane is saturated by the liquid epoxy in order to fuse the two components. A final coat of the advanced technology epoxy liquid is applied to seal the membrane and improve chemical and thermal resistance.
3. Advanced technology epoxy with the fused membrane is highly resistant to abrasion and permeation. This enables Operators to employ drilling with casing operations while using coated casing (Figure 3).
4. By fusing the membrane to the liquid epoxy coating, the surface of the casing now has an improved cement adhesion characteristic (Figure 4). Cement adhesion to casing with mill varnish and mud film has been shown to be less than 20psi. Conversely, casing with improved adhesion characteristics and the same mud film is shown to have a bond strength of 300-400psi.[4]
5. The advanced technology epoxy system has excellent cathodic disbondment resistance. This allows Operators to use coated casing in conjunction with cathodic protection systems. Coated casing provides better current distribution to well casings.[4]

Cathodic protection systems have been shown to protect coated casing with as little as 10% of the amperage as what is required to protect bare casing. [4]

6. Potential reduction in pollution insurance premiums.

With all of the advantages above, here are a few practical and tactical considerations for coated well casing.

1. Is special handling of the coated casing required? No, the coating system is designed to be extremely robust.
2. Are on location repair of the coatings needed? Potentially, if no cathodic protection is to be used.
3. Will the coating interfere with slips, tongs or makeup? No, the coating thickness is 30mils or 30 thousandths of an inch.
4. What about coating damage, won't scratches cause accelerated corrosion? No, not if cathodic protection is used. If we could coat casing with 100% integrity then cathodic protection wouldn't be required. Using coated casing and cathodic protection combined is a belt and suspenders approach to external casing corrosion.
5. Is coated casing cost prohibitive? No, not compared to a squeeze job, lost production, lost reserves due to abandonment or potential remediation costs of casing leaks.

Conclusions

In an effort to produce resources in the most efficient means possible, it is imperative that we employ effective corrosion prevention strategies. Coated casing with advanced technology epoxies is a successful technique to mitigate corrosion caused by SRB, high chloride water, acid gases, and low pH water flows. This strategy enables Operators to protect well casing in deeper more corrosive environments while improving corrosion protection effectiveness.

References

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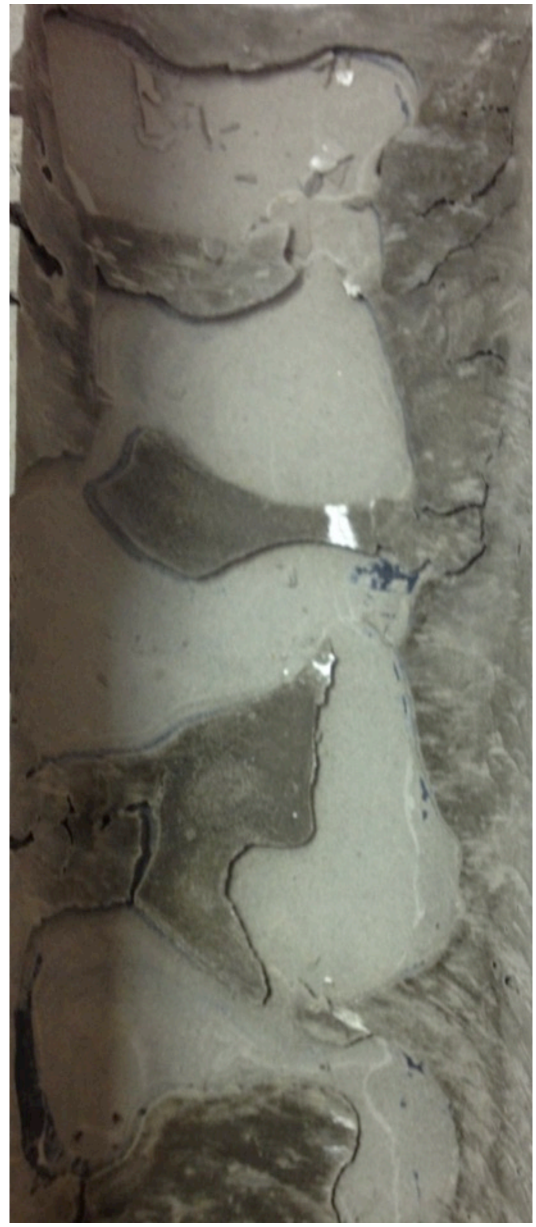

Figure 1: Cement Channeling in Lab

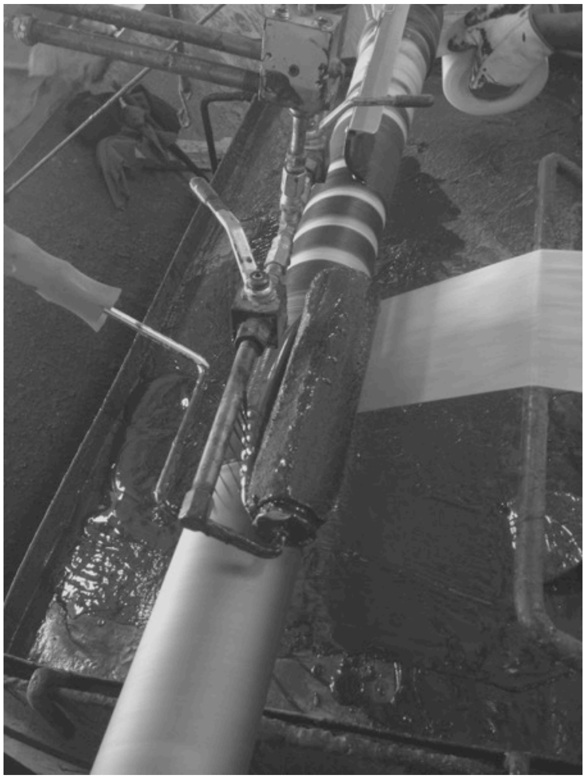

Figure 2: Advanced Technology Epoxy Application

Figure 3: Drilling with Casing Test of Advanced Technology Epoxy

Figure 4: Advanced Technology Epoxy with Improved Adhesion Characteristics