Bolt Corrosion Prevented by Corrosion-Inhibiting Spray-On Thermoplastic

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ABSTRACT

Numerous industrial facilities, especially offshore oil and gas installations, are plagued by bolt corrosion problems. With a limited record of success in prevention or cure, material loss from corrosion is often factored into maintenance planning, with bolt replacement as a solution when integrity is threatened.

An increasing focus on overall maintenance as an essential part of reducing problems in safety-critical systems makes the prevention of corrosion effects on basic components such as bolts and fasteners an increasingly important goal. This paper describes a corrosion-inhibiting sprayable thermoplastic system that has demonstrated success in the provision of extended corrosion protection on both new and rusting bolts in extreme conditions.

The system uses purpose-built equipment to spray a thermoplastic material containing inhibiting oils to encapsulate the substrate. The paper includes a review of current bolt coating systems and describes the thermoplastic system, together with field case histories showing how this product has effectively prevented or stopped on-going bolt corrosion issues found in offshore oil and gas production systems as well as the in mining industry and on LPG tankers.

Keywords: alloy, bolt, corrosion, encapsulation, fastener, flange, gas, inhibiting, offshore, oil, plating, sprayable, thermoplastic, valve, zinc

INTRODUCTION

In 2003 Karl Fischer reviewed offshore experiences with bolts and fasteners for the NACE Conference shortly after a long-term study of bolting materials and their performance in various service conditions commenced.[1] The study was motivated by a need to understand how best to protect bolted systems from the effects of corrosion without a constant need for maintenance. Material selection and factory-applied coating systems were the main focus of the study but Fischer was also keen to see what remedial measures might be available in the event of failure and it was for this reason that the potential use of a corrosion-inhibiting sprayable thermoplastic system as a post-corrosion treatment was explored as part of the study.

Corrosion has always had the potential to cause catastrophic failure in infrastructure such as gas pipelines.[2] In the case of bolted systems however, it is more like a death of a thousand cuts, as the progressive corrosion of fasteners affects the safety and function of the systems they are holding together.

Fischer enumerated the various bolt materials used in marine environments:

- Low alloy steel
- Copper-based alloys
- Nickel-based alloys
- Stainless-steel alloys
- Titanium-based alloys

Because of the cost and availability of corrosion-resistant alloys, low-alloy ASTM A193 B7 and A320 L7 steel bolting systems make up the majority of marine oil and gas facility fasteners.[3] Because of their lower resistance, some form of corrosion protection will normally be applied. In a Bulletin, Badelek and Moore speak of their company's experience in the North Sea, where a number of factory-applied bolt coating systems for low-alloy steels were evaluated:

- Zinc & Cadmium Electroplate
- Polytetrafluoroethylene (PTFE) Coating
- Sheradising
- Spun Galvanising

Of these, only the spun-galvanised bolts appeared to offer any corrosion resistance, with other coatings failing in as little as a few weeks.[4]

Similar results were obtained in the initial findings of the Fischer study, where all but one of a similar range of coatings exposed in the splash zone failed in 18 months, despite an exhaustive search for the most suitable candidates (Figure 1). Failures in washer coatings and materials were even more pronounced than those in the fasteners.

Figure 1: PTFE coated 8 µm zinc electroplated low alloy fastener after only 18 months of testing in the splash zone

The zinc/nickel plated L7 bolts shown in Figures 2 to 5 are from a newly constructed platform in the North Sea before it was commissioned. Typically, in a laboratory salt spray test, a zinc/nickel coating would be expected to last at least 1,000 hours before ‘red rust’ occurs.[5] An accelerated test such as this is designed to demonstrate the potential longevity of a coating system on the basis that the test conditions are so extreme, the lifetime of the coating should, for example, be 10 years under normal conditions if it could last 1,000 hours in a salt-spray cabinet.

Offshore however, conditions are far from normal; 1,000 hours is only 6 weeks. The bolts in these photographs have been exposed to constant salt-spray conditions for more than a year.

Figures 2 and 3: zinc-nickel plated L7 bolts on stainless steel flanges

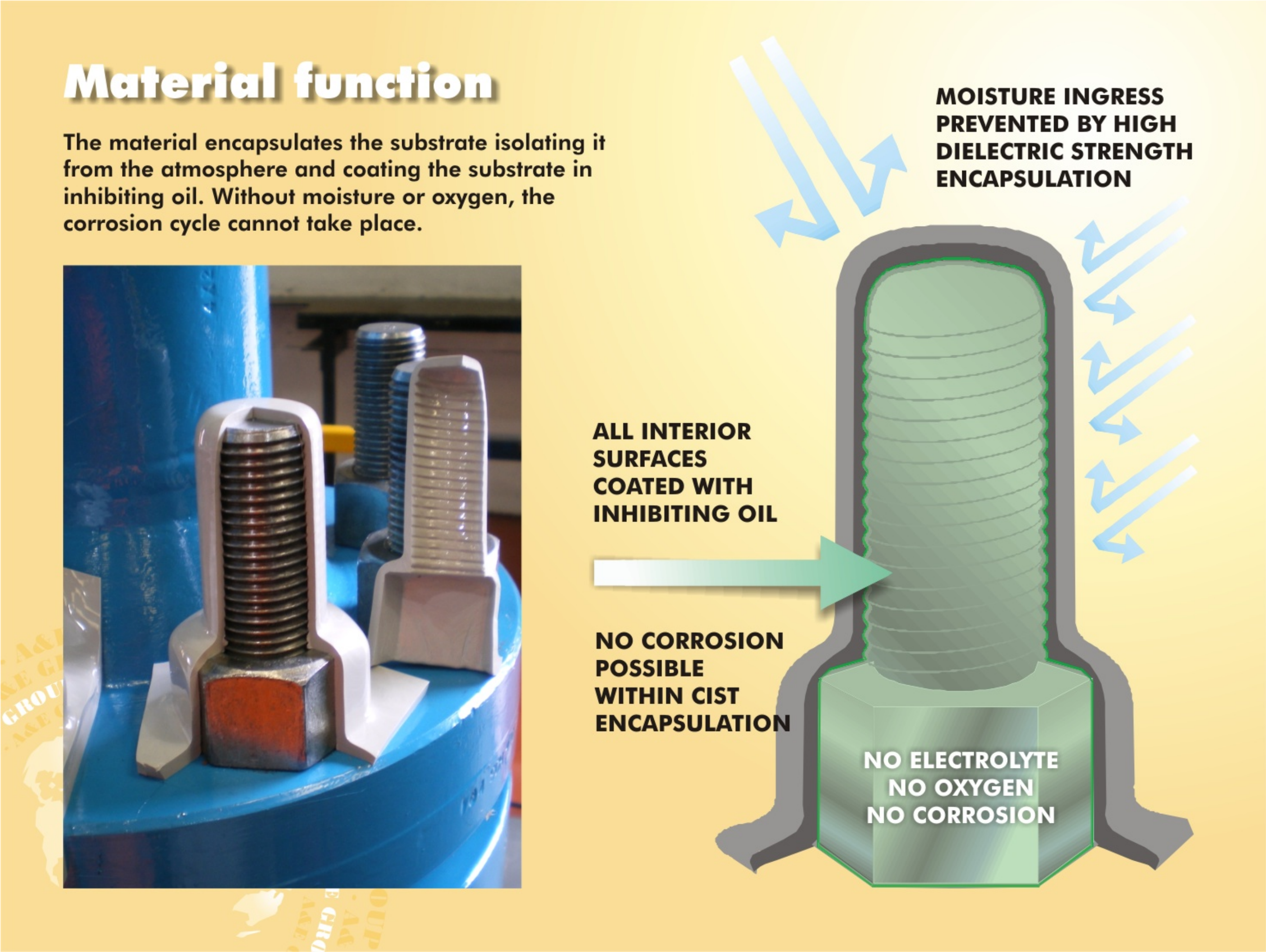
Figures 4 and 5: zinc-nickel plated L7 bolts on a mixed stainless/carbon steel substrate

High levels of bolt corrosion on offshore structures are not uncommon and may be exacerbated by galvanic and crevice corrosion. In both the illustrated examples, the bolts are carbon steel; in one case the bolts are fastening stainless flanges, in the other, a combination of stainless and carbon steel. In such situations, low-alloy bolts are extremely vulnerable to galvanic effects.

For this platform, the client insisted on remedial action before handover - which would normally involve either blasting and painting or replacement of the one million corroding bolts.[6] Because of the potential costs and delays involved, a review of potential solutions was undertaken which included the use of a corrosion-inhibiting spray-on thermoplastic (CIST) recommended by the client company as it had been using it for a number of years on a platform suffering similar failures in PTFE coated bolts.

CIST EXPLAINED

The system involves the application of a thermoplastic barrier coating material that contains corrosion-inhibiting oils. Although the material is a solid at normal temperatures, when heated to 170°C it becomes a sprayable liquid which can then be easily applied to any substrate configuration. Substrate preparation is minimal. Removal of debris and light wire brushing is sufficient. On cooling, the material returns to a solid state without any loss of its original properties. The result is a rubbery solid, continuous plastic coating which can encapsulate any size or shape of substrate. Because of the inhibiting oils, the coating not only provides a barrier to water and oxygen but also actively prevents the progress of the corrosion process (Figure 6).



Material function

The material encapsulates the substrate isolating it from the atmosphere and coating the substrate in inhibiting oil. Without moisture or oxygen, the corrosion cycle cannot take place.

Figure 6: diagram of principles

Figures 7 and 8: before and after application

The advantage of such a system is that it works at every level to protect a bolted assembly. Spray application adapts to any size and produces a coating that conforms to every contour of the substrate. The resulting outer skin acts as a barrier to the ingress of oxygen and water - and every surface within the encapsulation is in direct contact with the inhibiting oil as it works into every crevice. This allows CIST to be applied to substrates where corrosion already exists (Figures 7 and 8) and can prevent galvanic, pitting and crevice corrosion. Easy to remove and repair, small areas of the CIST material can be cut away for monitoring or maintenance and reinstated without affecting the overall performance.

CASE HISTORIES

Since 2003, CIST has been in use on North Sea platforms for remedial protection of failing bolted systems. In the illustrated case the PTFE and electro-plating on low-alloy carbon steel bolts had not performed well (Figure 9) and a rolling program of CIST encapsulation using an Enviropeel system was implemented to prevent further deterioration.[7]

Figure 9: an area of corrosion affected valves

Over the years both the operator and application engineers have removed sample applications from flanges to assess their condition. Inspection has shown that further deterioration of the bolts has been arrested by the CIST application (Figures 10 and 11).

Figures 10 and 11: sample removal shows previously rusting substrate and inner surface of CIST encapsulation coated with oil

Satisfaction with the performance of CIST on this North Sea platform directly influenced the decision to use the system for protection on a bridge-linked platform commissioned in 2008. A best practice specification for the use of CIST for bolt corrosion remediation is being developed by the company.[8]

Bolt protection requirements are not just the province of the offshore oil and gas industry. Gas transport systems in Malaysia and Canada have used CIST systems to protect flanges and bolted systems for onshore installations and long-term testing in the UK at a major gas terminal was successfully concluded in 2009 after 4 years of testing. Examination of the substrate following removal of the coating showed that oil was present on all internal surfaces and no corrosion had occurred (Figures 12 and 13). The terminal is directly adjacent to the North Sea and, while annual precipitation is low, the installation is subject to high salt and moisture levels.

Figures 12 and 13: Application in 2005 and following removal in 2009

On LPG carriers, flange bolts required repainting several times a year prior to the use of CIST which is used to protect flanges and valves on all deck pipework (Figure 14). The use of CIST has eliminated the need for repainting on such areas for these vessels.

Figure 14: CIST protected deck pipework on LPG carrier

OTHER APPLICATIONS

The combination of inhibition and encapsulation has shown impressive results in other areas too. In the Australian mining industry the material was used by an engineering company to eliminate corrosion in stored equipment waiting for installation. Engineers for the client of the engineering firm were intrigued by the new material and asked for investigations to be undertaken to see if the material was suitable for use on operating equipment.

These engineers had a particular interest in application to conveyor bearings, where failures in as little as nine months were commonplace in some areas. As there were many thousands of bearings on hundreds of miles of conveyor systems, frequent replacement, at $7,000 to $10,000 for each change out, was a costly and time consuming process.

Before the applications could take place, tests on bearing temperatures and lubrication were undertaken as there was concern that the encapsulation might affect these areas. No contraindications were found, but testing did discover that CIST's lubricating qualities allowed it to be applied directly on to the bearing shafts without preventing rotation.[9] This allowed complete encapsulation of the bearing housing, combining corrosion protection and particle ingress protection in one application.

Test applications and subsequent field applications over the past five years have shown a 100% success rate, with no failures in any CIST protected bearings. CIST protection is now mandatory on all mining conveyor bearings for the two largest mining companies in Australia.

In Figure 15, removal of CIST from trial bearings shows the bearing housing to be unaffected while the unprotected roller shows clear signs of deterioration.

An analysis conducted by the mining companies of performance data from the trial and subsequent implementation of the CIST protection showed significant direct cost savings as well as reduced maintenance requirements and lower risk exposure levels.

Figure 15: removing CIST material from trial bearing shows impeccable condition of protected substrate

CIST PERFORMANCE DATA (2004 to 2009)

On stored conveyor pulleys

Return for replacement without CIST	44.5%
Failure rate with full CIST	0%

On operational pulleys

Average bearing life in original location:	9 months
Current bearing life in original location with CIST applied:	48+ months
Resulting component life increase:	500+%
Resulting saving in pulley changeout costs:	500+ %
Reduction in maintenance costs:	95 %
Percentage of CIST costs to rebuild costs:	10 to 15 %
Percentage of CIST costs to pulley change out costs:	5 to 7 %
Resulting percentage reduction in risk exposure:	90+ %
Anticipated increase in component lifetime:	500+ %

ASSET MAINTENANCE

The UK Health & Safety Executive (HSE), an independent regulatory authority charged with oversight of health and safety issues throughout the UK, issued a redraft of its 5-year Materials and Corrosion strategy document for the Oil & Gas Industry in September 2010.[10] This document is aimed at securing the life-cycle integrity of offshore installations and refers to the danger from the severe corrosive effects of the North Sea environment on its ageing infrastructure.

When it comes to external corrosion, its guidance is quite clear: operators are not only responsible for ensuring the integrity of safety critical areas but must also make sure plans and procedures are in place to ensure all plant & equipment are in good repair with respect to corrosion. It lists the following as areas for concern:

- Walkways and stairways
- Cable trays including fittings and brackets
- Bolted connections
- Flanges
- Pipe supports and pipes
- Valves

A variety of solutions exist for remediation of corrosion in these areas and CIST would not be practical in every category but the list makes it clear that preventing failure in complex assemblies joined by bolts and fasteners is a priority to meet safety concerns.

Such concerns exist all around the world and many ageing structures are suffering. CIST can provide a reactive solution to existing problems, with long-term pro-active effects that have eliminated corrosion entirely for some users and offers the potential to do the same in a wide variety of areas. And, because it is re-useable, recyclable and toxin-free, it's better for the environment too!

CONCLUSIONS

1. Long-term evaluations have shown CIST effectively prevents bolt corrosion in aggressive marine and mining service.
2. CIST provides bolt corrosion control for both existing and new build applications through encapsulation and inhibiting oil.

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