Hitting a moving target

Scot J. Laney, Elliott Group, USA, presents a targeted approach to anti-fouling coatings.

Fouling in centrifugal compressors can cause significant headaches in petrochemical processing. The fouling process is often complicated and depends on numerous variables. The causes may even be a moving target in some cases, as feedstocks change over time. Options to control fouling are limited. Typical options are either chemical injection to control temperatures and/or to aid in cleaning the flow surfaces, or coatings with anti-stick properties that prevent the foulant from building up in the first place. Some operators use both. Neither of these options are ideal, and there are trade-offs associated with each.

As a compressor manufacturer, Elliott Group has an interest in providing the best solution possible to operators. Like most original equipment manufacturers (OEMs), Elliott offers chemical injection systems, but most advances in this area correlate to the chemical injected. Given the implications of adding chemicals to the process gas, this

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option is best left to the user. For this reason, the company's primary focus is the development of improved coating options.

Industry standard coating systems

Several years ago during a technical conference centred on centrifugal compressor operation, Elliott Group asked participants about the use of coatings to deal with fouling issues. The responses were surprisingly polarised. In one group were those who use coatings regularly, with and without wash systems, believing that the cost is easily offset by extended run times. In the other group were those who prefer wash systems alone to deal with fouling because they do not believe coatings work. A subset of the second group included respondents who had a bad experience with coatings. To address these negative views on coatings, it makes sense to review the current state of industry standard coatings and how they are used.

The technology for the current industry standard coating systems was developed in the late 1980s. Original coatings developed nearly 40 years ago are still the most prevalent in the compressor industry, although there are some more recent coatings that show significant improvements in fouling resistance and durability, such as Elliott's Pos-E-Coat® Plus and Pos-E-Coat® 523. While there are minor differences in the composition of the coatings between suppliers, their descriptions and properties are nearly identical.

These industry standard coatings are applied to compressors in all services that cause fouling, yet the data sheets, and virtually all of the (albeit limited) published testing data on their fouling resistance, relates to hydrocarbon fouling. This type of internally generated fouling occurs when the process gas polymerises inside the compressor and condenses polymeric materials on the flow surfaces. Hydrocarbon fouling is extremely problematic, and in some cases can be spectacular, as evidenced in Figure 1 (top), where foulant with a tar-like consistency oozes from the compressor.

Unfortunately, these same coatings are also used, with little to no validation, in other services or conditions where the foulant originates as carryover from upstream processes. This type of foulant can be very different relative to internally generated foulant. Figure 1 (bottom) shows the build-up of chloride salts carried into a hydrogen recycle compressor. Not only do these salts restrict flow passages, they can also cause severe under deposit corrosion even in stainless steel and nickel based alloys.

This raises several questions. Firstly, are the current industry standard coatings truly suitable for these alternative applications, and is this possibly the root of some of the negativity surrounding coatings? Secondly, in an industry where every compressor is custom engineered specifically for each installation, is a 'one size fits all' industry-standard coating, based on 40-year-old technology, the solution to combat fouling?

Figure 1. Examples of fouling caused by internal polymerisation (top) and salt carryover (bottom).

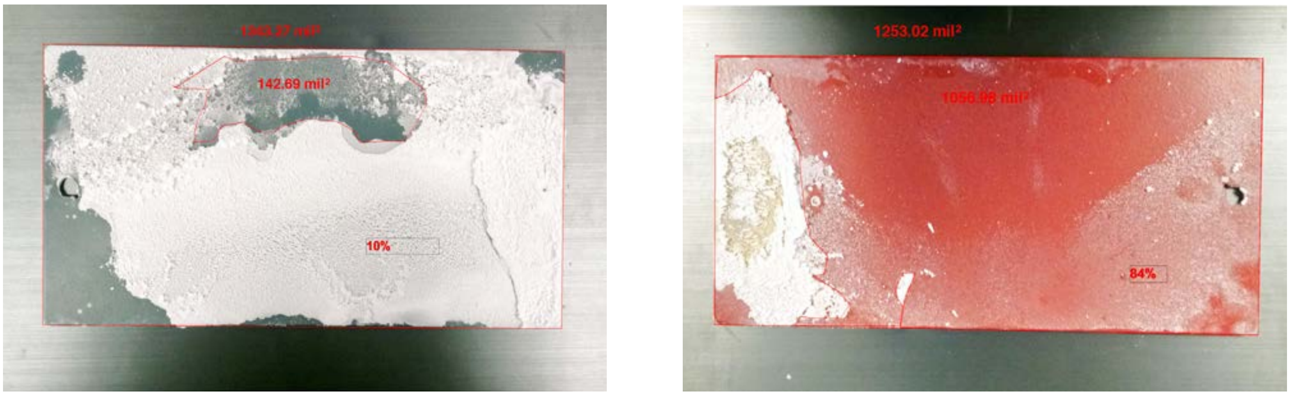

Figure 2. Results of the foulant adhesion test for Pos-E-Coat (left) and Coating 18 (right).

Evaluating coatings for compressors in hydrogen recycle service

To answer these questions, Elliott recently conducted an evaluation of various coatings with a specific focus on their application in hydrogen recycle compressors. The coatings included Pos-E-Coat®, Pos-E-Coat Plus, several other related organic coatings, a novel superhydrophobic coating, a coating designed for fighter jet cockpits, and several popular consumer coatings for frying pans. The test regime evaluated coating performance in three key areas: fouling resistance, wear resistance, and corrosion resistance. The results were eye opening.

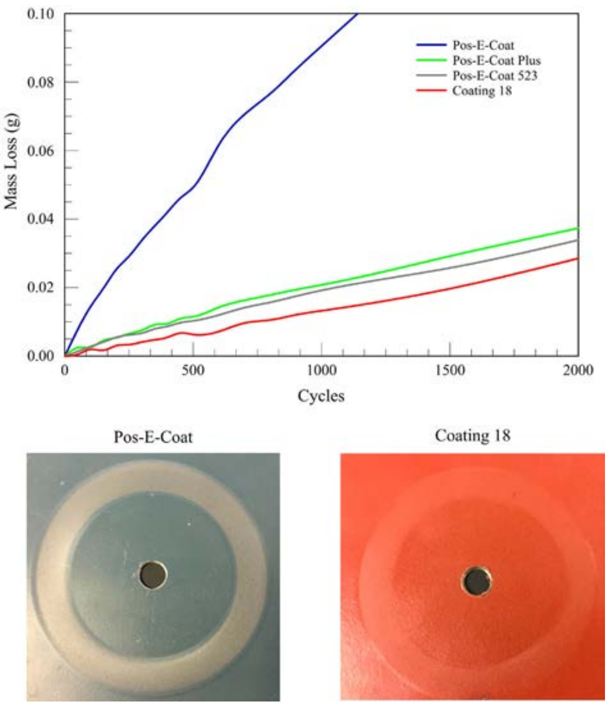

Figure 3. Results from wear testing using the Taber Abraser.

Fouling resistance

Fouling resistance is a 'must have' property for an antifoulant coating. To evaluate fouling resistance, a 5% NaCl solution, which was used for safety purposes, was sprayed through an atomising nozzle onto a specimen heated to 90°F. The spray was applied in 5 sec. bursts every 30 sec. An air blade activated once for every five 30 sec. cycles, blasting air at a low angle to simulate the stress from the gas flow and centrifugal forces. After 24 hours, the percentage of the coating area that was clean was measured. The worst coatings, including Pos-E-Coat 523, performed no better than plain carbon steel, and were completely encased in salt. The Pos-E-Coat sample had a clean surface area of 10%, and the surface area of the Pos-E-Coat Plus sample was 62% clean. The best performing coating, labelled Coating 18 in the project, had a clean surface area of 84%. Figure 2 shows a comparison of Pos-E-Coat to Coating 18 results.

Wear resistance

Many of the negative coating experiences that users faced related to the durability or wear resistance. Basically the coatings worked well for some short period of time before they wore away. The subsequent fouling was then as bad as, or worse than, before the coating was applied. The wear resistance of the coating was evaluated using a Taber Abraser per ASTM D4060. In this test, the specimen is rotated as an abrasive laden rubber wheel rolls against the surface. The weight loss of the specimen was measured

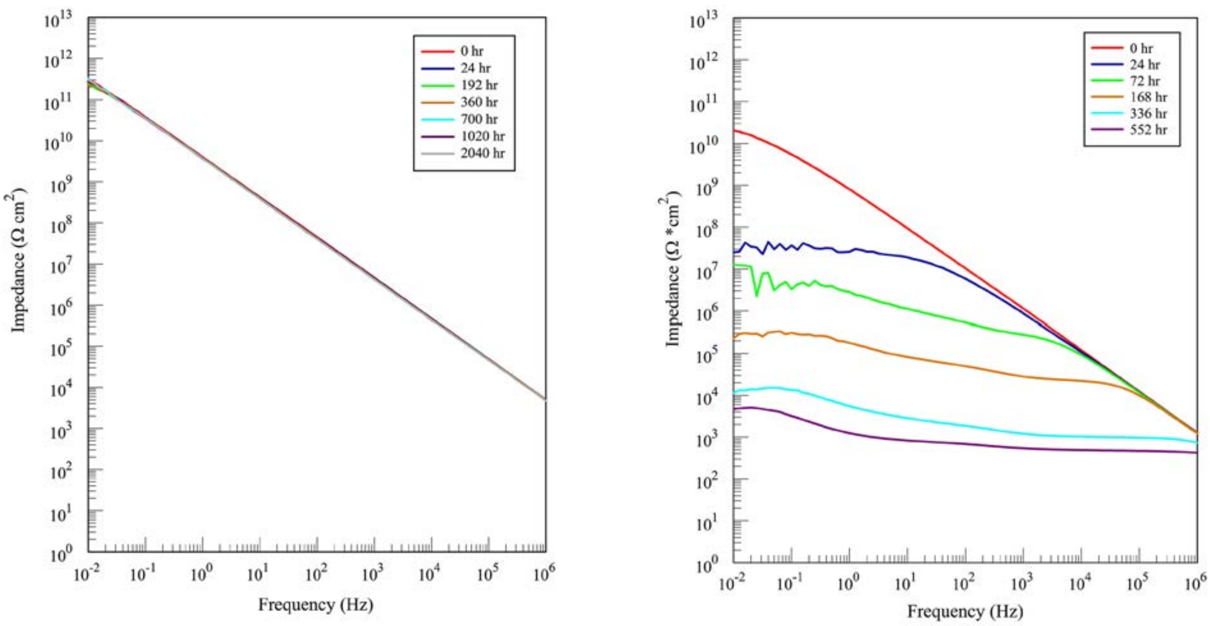

Figure 4. EIS test results in saturated ammonium chloride electrolyte for Coating 18 (left) and a coating that was permeated (right).

Figure 5. Exposed area of a permeated coating immediately after test (left) and after peeling back the coating to reveal the substrate (right).

with cycles and plotted (Figure 3). By a wide margin, Pos-E-Coat was the least durable coating tested. Pos-E-Coat Plus faired rather well, but showed more weight loss than Coating 18. While Pos-E-Coat 523 had similar weight loss results to Pos-E-Coat Plus, these values do not take density into account. This coating is denser by a factor of 5 or more than the rest of the coatings, so the actual material lost during the test was much less.

Corrosion resistance

The final key area evaluated was corrosion resistance, or the ability of the coating to act as a protective barrier. This is of vital importance in hydrogen recycle service since, as mentioned above, the salt deposits are very corrosive. Coating suppliers typically use a salt spray test to evaluate barrier properties. In this case, the use of a salt spray is applicable, but in general, it does not make sense for most applications. The results of a salt spray test are also very subjective. For this reason, electrochemical impedance spectroscopy (EIS) was used for the evaluation. This method can replicate the relative ranking of a salt spray test in a fraction of the time and gives several advantages, such as the ability to use more relative electrolytes, providing quantitative results, and giving some insight into the corrosion processes at work. The electrolyte used in these tests was a saturated ammonium chloride solution. Ammonium chloride is typically the main salt found in the foulant in hydrogen recycle compressors. Tests were performed at various times over a 500 to 2000 hour exposure period. After 2000 hours, Coating 18 and Pos-E-Coat Plus had little to no change from the values at the beginning of the test. They acted as perfect barrier coatings, as shown in Figure 4 (left). Pos-E-Coat behaved similarly over that period, but started to show signs of being permeated by the electrolyte. Pos-E-Coat 523 showed some corrosion in the results, but was found to be cracked after the test. Another interesting result from some of the other coatings that were rapidly permeated was that the aluminium in the base coating was aggressively attacked by the electrolyte. Figure 4 (right) shows the EIS results from a coating that behaved this way, and Figure 5 shows the exposed area after the test was completed. This indicates that the use of the aluminium filled cermet base coating is probably not a good idea in a hydrogen recycle application.

Conclusion

At the end of the project, it was easy to conclude that Coating 18 was superior to the others in a hydrogen recycle application. It had the best fouling resistance by a large margin, was one of the top performers in the wear testing, and edged out Pos-E-Coat Plus in the corrosion tests. It also did not utilise the aluminium containing bond coating in most of the other coatings tested. It is also very clear that while the 'one size fits all' approach has been successful, significant gains in coating performance can be achieved by using a targeted approach to coating selection.