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Corrosion Testing and Evaluation of Inhibitors Performance

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Abstract

Choosing test methods that will analyze specific needs, like film barrier strength that real field settings is essential for the proper evaluation and development of inhibitors. The flowing loop and the bubble test are two examples of the first and second, respectively. Corrosion is measured by gravimetric, electrical noise, alternating-current impedance, potentiodynamic measurement, linear polarization and gravimetric. The inhibitors action can be analyzed in different corrosive environments. Their performance is studied in gas, liquid and solid form as per materials surrounding situations. Their surface coverage areas, coating efficiencies, barrier formation and scavengers qualities are studied at various surrounding, temperatures and concentrations on materials. In a hostile medium, materials interact with corrosive substances producing corrosion cell thus deterioration takes place inside and outside materials. Due to corrosion reaction galvanic, pitting, crevice, stress and others forms of corrosion observe on their surface. These forms of corrosion can be controlled by the use of inhibitors. The action of inhibitors corrosion rate of metals is minimised and enhance their physical, chemical and mechanical properties. They develop a protective barrier on the surface and check the osmosis or diffusion process of liquid and gaseous compounds. Some inhibitors are to be found in nano size so they inter inside of materials and stop internal corrosion. Few inhibitors works as scavenger for the removal dissolve oxygen in corrosive medium to control corrosion. Inhibitors occur in form of solid, liquid and gas and they can be used as per situations of surrounding environments. They are available in form of anodic, cathodic and anodic and cathodic inhibitors. Their surface deposition properties were studied by Langmuir, Freundlich and Temkin isotherm. They are bonded with base materials by physical and chemical bonding. Their bonding properties can be confirmed using activation energy, adsorption isotherm, free energy, entropy and enthalpy. Inhibitors surface areas are large so it low doses cover more surface and form a thin film on metal interface thus the attack of corrosive substances can be controlled.

Keywords: Inhibitors, Film barrier strength, Electrical noise, Potentiodynamic measurement, thermalparameters

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INTRODUCTION

Static Tests

In order to do this, a coupon must be exposed to a corrosive environment and kept dormant for a while. After that, the coupon is examined, the pitting is recorded, cleaned, and the weight loss and protection percentage are calculated. Continuous and filmed inhibition can be investigated, and the test can be conducted at various pressures and temperatures [1-5].

Stirred Flask (Bubble) Test

CO_2 (or mixed gases or H_2S) is bubbling through a stirred flask that is kept at a certain temperature.

Electrodes submerged in the flask are used to measure the rate of corrosion. To assess the inhibitor's partitioning in the oil and water, different oil-water mixes might be used. The formation quantifies filming speed and the degree of inhibition can be determined LCR (Linear polarization resistance), AC impedance, electrochemical noise tests and weight loss. [6-7]

Autoclave Test

High pressures and temperatures can be achieved using static, agitated, or swirled autoclave tests. The inhibitors are subjected to harsher circumstances during these experiments, allowing for the evaluation of their stability in harsh environments [8].

Rotating Cylinder or Electrode Tests

It is possible to test how shear stress affects on rate of corrosion and inhibitors film bonding strength using a flask with a spinning electrode assembly. It is possible to compute the shear stress and simulate turbulent flow in a pipeline under known hydrodynamic parameters. In a rotating disk device with a changing the speed motor, a cylindrical test specimen is fastened to the lower end of a shaft. The electrical contact to the revolving electrode is made using a slip-ring assembly [9].

The impact of varying shear loads and the presence of inhibitors is noted and observed. Corrosion rates can be determined using LPR, electrical noise, and AC impedance measurements. A stationary electrode and a spinning cylinder are used in one version of this test.

Flowing Tests

The flow conditions present in a pipeline are replicated in this test. Electrochemical measurements, circulating media analysis, and weight loss coupons are used in the experiments. As needed, the temperature, velocities, fluids, and acid gasses can be changed. Jet impingement investigations can use a modified version of the test [10]. High turbulence and mixed flow conditions are simulated by jet impingement on a microelectrode assembly or weight loss coupon. A transition zone with maximal shear stress, a centre laminar-flow region, and external zone where turbulence decreases proportionately to its distance from central portion will all be present.

Wheel Tests

Coupons are put in flasks or bottles with oil and water in them. The bottles are kept on a moving wheel or cylinder in a hot chamber for a predetermined amount of period after being cleaned of O_2, analysis of saturated acid gas and closed. After being taken out, the test coupons are examined and measured mass. Blistering and pitting corrosion and are observed, and the propensity of inhibitors to combine with the test oil to form a stable emulsion is also noted and documented. The coupons can be videotaped before being placed in the bottles or inhibitor can be introduced to the bottles [11].

APPLICATION OF CORROSION INHIBITORS IN INDUSTRY

Oil and Gas Applications

All employ inhibitors during prevent corrosion in working conditions function with drilling and stimulation fluids, producing wells, water injection systems, transportation and refining systems. External inhibitors are also used to stop stored tubular items from rusting. The metal to be protected, the corrosive conditions and corrodents' characteristics, and the equipment design parameters all influence their needs. The inhibitor's chemical makeup and how it interacts with the corrosive environment determine its capacity to create an impermeable, long-lasting coating. The formulation, synthesis, testing, and appropriate use of organic inhibitors in accordance with the specifications of specific method in the transportation and oil production industries are covered in this section [12-13].

Top of Pipe

It is quite difficult to impede the pipe when it is in a straight line. Liquids will not come into touch with this region unless there is slug or partial slug flow since the flow speed is lower than what is needed for turbulent velocity. It could be necessary to add a volatile inhibitor in such circumstances [14].

Wet Bottom of Pipe Water

It is seen that liquid can flow with the pipe's bottom most of the time. It is dependent on velocity as well as the distinct layers of water and oil. Concentration cells and pits may form beneath the deposits as a result of solids dropout at low velocities [15].

Turbulence Prone Areas

Low locations, solid deposits, small line buckling, and areas downstream of welds can all enhance turbulence and shearing stress, which can worsen corrosion. Periodically, liquid slugs are caused by low places. If there are solids present, turbulence exacerbates abrasion and erosion, removes protective scale, and may impair inhibitor function by removing the coating. Shear pressures must be tolerated by inhibitors [16].

Production Systems

In order to make batch treatment possible, the inhibitors must be compressed, added continually, film persistency in order to protect production tubing. Inhibitors must also be able to endure velocity effects under shear loads. Deviated (nonvertical) wells will wet the tubing more thoroughly on the low side, and in low-volume producers, the sole corrosive area may be a distinct layer of water on the low side [17].

Down Hole Pumps

The inhibitor coatings are employed in rod-pumped wells to lessen rod abrasion on tubing because of their lubricating qualities. In many wells, the inhibitor must work in the presence of oxygen in order for air to enter through the annulus. Scaling and velocity effects an cause down-hole centrifugal pumps to malfunction [18].

Surface Equipment

The velocity effects on separators and other vessels create stagnant areas problems occur in equipment areas such as wellheads, chokes, and vessels. The concentration cells deposits can create scales and solids. Bacteria growth may occur in these areas [19].

Injection Process

Polymeric inhibitors are used in certain areas which concerned with secondary recovery of waterflooding, tertiary recovery CO_2 and micellar fluids. Inhibitors can be dissolved properly and viscous properties and be able to active with surfactants and polymers applied in these the fields. Surfactants may be used with inhibitors to control injection rates in produced water injection systems [20].

Water Treatment Systems

Corrosion inhibitors play a crucial role in water treatment systems where they help protect pipelines, storage tanks, and processing equipment from aggressive water conditions. In cooling water systems, inhibitors such as chromates, phosphates, and molybdates have traditionally been used to form protective films on metal surfaces.

Modern water treatment programs often employ combinations of inhibitors to create synergistic effects. For example, zinc compounds are frequently used with phosphates or phosphonates to provide enhanced protection against corrosion in cooling water systems.

In boiler water treatment, different inhibitors are used depending on the operating pressure and water chemistry. Volatile amines are commonly used for steam condensate protection, while oxygen scavengers such as Na_2SO_3 or N_2H_4 are employed to isolation of dissolved oxygen from feed water [21].

Process Industries

In process industries, corrosion inhibitors are selected based on the specific corrosive environment, operating temperature, and materials of construction. For example, in acid pickling operations, nitrogen-containing compounds like quaternary ammonium compounds are commonly used to protect steel during the cleaning process.In the food and beverage industry, only food-grade inhibitors are permitted. These typically include certain phosphates, silicates, and nitrites that are approved for use in systems that may encounter food products.In the pharmaceutical industry, stringent requirements exist for inhibitors used in water systems to ensure they do not contaminate products. Special consideration is given to inhibitors that will not promote bacterial growth [22].

Implementation Strategies

The implementation of corrosion inhibitor programs requires careful planning and execution. Key factors include as**:**

Dosing Method: Continuous injection is preferred for maintaining constant protection. Batch treatment may be used where continuous treatment is not feasible [23].

Dosing Point: The inhibitor should be injected at a point that ensures good mixing and distribution throughout the system [24].

Concentration Control: Regular analysis of inhibitor concentration is essential to maintain effective protection levels.

System Monitoring: Corrosion rates should be monitored using linear polarization resistance techniques, electrical resistance probes or corrosion samples to verify inhibitor effectiveness.

Compatibility Testing: Prior to full implementation, inhibitors should be tested for compatibility with process fluids, other chemicals, and materials of construction [25].

Monitoring and Maintenance

The inhibition process can be properly to confirm that mitigation is achieved. Fe counts will provide a suitable indication for the amount of corrosion that takes place, and the original Fe loss can be calculated. It do not confirm about presence pits. Mn analyses can be estimated to substantiate. It is necessary to install LPR, corrosion coupons, and resistance probes in the system. The actual corrosion and pitting are observed in pipelines at selected intervals. Acoustic emission and magnetic flux devices may be used to monitor metal loss and pitting. Regular maintenance of inhibitor dosing equipment is essential to ensure reliable operation. This includes calibration of pumps, cleaning of injection points, and replacement of consumable parts. A comprehensive maintenance schedule should be established as part of the overall corrosion control program [26-27].

FUTURE TRENDS IN CORROSION INHIBITION

Green Inhibitors

Environmental concerns have driven significant interest in developing "green" or environmentally friendly corrosion inhibitors. These include plant extracts rich in natural compounds such as tannins, flavonoids and alkaloids that can be adsorbedon the surfaces of metals and develop thin protective films barrier. Examples include extracts from Azadirachta indica (neem), Aloe vera, and various spices and herbs.The advantage of plant-based inhibitors is their biodegradability, low toxicity, and renewable nature. Research is ongoing to identify the active components in these extracts and to develop standardized formulations that provide consistent performance [28-29].

Smart Delivery Systems

Advanced delivery systems for corrosion inhibitors represent a promising area of development.

These include:

***Microencapsulation**:* Inhibitors can be enclosed within microcapsules that release their contents in response to specific triggers such as pH changes, mechanical damage, or temperature fluctuations [30].

***Layer-by-Layer Assembly**:* This technique allows the controlled deposition of inhibitor-containing layers on metal surfaces, providing sustained release over extended periods.

***Stimuli-Responsive Polymers**:* These polymers can change their properties in response to environmental conditions, releasing inhibitors when corrosion is most likely to occur.

***Self-Healing Coatings**:* Combining inhibitors with self-healing materials enables autonomous repair of damaged protective barriers.

The Use of Nanotechnology in Corrosion Inhibition: Nanotechnology offers numerous opportunities for enhancing corrosion protection as:

Nanoparticles as Inhibitor Carriers: Nanoparticles with high surface area can adsorb and gradually release inhibitors, improving their efficiency and longevity [31-32].

***Nanostructured Coatings*:** These provide improved barrier properties and can incorporate inhibitors for added protection.

Nanoreservoirs: These structures can store and release inhibitors in response to corrosion initiation.

***Surface Modification*:** Nanostructuring of metal surfaces can enhance inhibitor adsorption and improve protective film formation.

Combined Protection Systems: Future developments will likely focus on integrated approaches that combine multiple protection mechanisms such as**:**

Inhibitor-Containing Paints and Coatings: These systems provide both barrier protection and active corrosion inhibition.

Inhibitors with Cathodic Protection: Synergistic effects can be achieved by combining inhibitors with impressed current or sacrificial anode systems.

***Multi-functional Additives*:** Development of compounds that simultaneously provide corrosion inhibition, scale prevention, and antimicrobial properties.

Digital Monitoring Systems: Integration of real-time corrosion monitoring with automated inhibitor dosing systems to optimize protection and minimize chemical usage [33].

CONCLUSION

It is very essential for observation of corroding part of materials. The study the surrounding environment which is accelerating corrosion phenomenon. Corrosive substances attack on materials to form a corrosion cell and start auto-redox reaction. There is various corrosion testing tools can applied for rate determination. Inhibitors can be used for control corrosion according to nature of corrosive medium in form of gas, liquid and solid. They can adsorb on the surface of base materials by physical-chemical bonding. Their boding formation mechanism studied by activation energy, heat of adsorption, free energy, enthalpy and entropy. Inhibitors adsorption phenomenon also confirmed by Arrhenius equation and Langmuir isotherm. Their coating efficiency and surface occupied area obtained by corrosion rate.

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