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Review and Study of the Inhibiting Character of Coffee Husk Extract to Reduce Corrosion Rate in Stainless Steel-AISI 440 in 1M H2SO4 Acid Medium Validated by Techniques Electrochemical – EIS

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Abstract: - Corrosion problems in industrial sectors, it is necessary to use corrosion inhibitors, most of the compounds used in the manufacture of inhibitors are very toxic. The use of green corrosion inhibitors has been studied with great intensity for the development of sustainable economies that promote the care of the environment through ecological alternatives and of low cost. Plant extracts are biodegradable and represent a renewable source of chemical compounds. In this work the coffee husk was used as a corrosion inhibitor, the material studied was a stainless steel AISI 440 in 1M H2SO4 medium. EIS tests were performed to compare the inhibitory effect. The results showed that in fact, the addition of coffee extract in the solutions rich in sulfuric acid was able to inhibit pitting and localized corrosion in stainless steel.

Keywords: Corrosion, EIS, Mass loss, Carbon steel, Coffee

1. Introduction

The main cause of the corrosion of metals is a chemical reaction that occurs when they are in contact with their environment, which causes the gradual decomposition of said materials. Among the elements that enable this reaction are atmospheric agents, natural organic substances, gases, and liquids. The above process is accelerated by the exposure of metals to warm temperatures, acids, and salts. On the other hand, you have to know that, like metals, all-natural and artificial materials are exposed to decomposition, which can be accelerated by pollutants present in the air [1-5].

In this regard, pollutants in the air, for example, corrosive particles, originate from chemical reactions that occur between liquids and solids. Both, including salt and black carbon, come to interact with the molecules found within the metals, speeding up decomposition. Another cause of corrosion involves gaseous acid contaminants since they are directly or indirectly precursors of corrosive particles. Although the above causes generally affect metals, it must be said that the corrosion present in iron is the most important, recurrent, and serious [1-5].

▪ **Uniform or general corrosion:** takes its name from the fact that it acts in a relatively uniform or general manner on the surface of some metal, and occurs most frequently in humid spaces, marine or other corrosive environments, where the surface of the metals begins to corrode. degrade [1-5].

This degradation allows the formation of a layer of iron oxide, which over time becomes thicker, so much so that it falls off and a new one is created. Regarding how this phenomenon can be measured, we can consider the following points: Annual rate of material retreat: an example of this can be seen with carbon steel, which, if unprotected, can disappear in a marine environment about one millimeter per year [1-5].

Weight loss suffered by an alloy when in contact with corrosive fluids: this is normally measured in milligrams per square centimeter of material exposed per day. It is the most well-known and detectable type of corrosion. Since only in extreme cases can it cause severe damage, this phenomenon is treated more as an aesthetic problem than as a more serious issue [1-2].

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▪ **Localized pitting corrosion**: is a phenomenon that causes the formation of cracks or small cavities on the surface of metallic materials. These cracks can grow large enough to puncture the wall of a pipe. It frequently occurs in high chloride environments at high temperatures.

When the protective oxide layer on the metal surface of a material degrades, the metal is prone to losing electrons, causing the iron to become a solution at the bottom of the crack, advancing toward the surface. top and rust, giving rise to iron oxide, also known as oxidation [1-5].

Additionally, the concentration of the iron chloride solution in a crack can increase and become more acidic as the crack deepens. These modifications cause an acceleration of the growth of the cavity, which in turn affects the perforation of the walls of the material, giving rise to leaks, in the case of tubes [1-2]. Moisture and contaminants in the atmosphere react with metal surfaces causing them to corrode. There is an alternative to protect metals without the need for grease or paint, we are talking about the application of inhibitors. Corrosion is a common phenomenon suffered by all metal structures, products, and parts, which in many cases is almost impossible to avoid, but it is possible to control it. [1-6].

In the chemical, oil, naval, construction, transportation, and communication systems industries, among others, preventive and corrective maintenance expenses are incurred. In the case where paint coatings are applied, corrosion inhibitors are added to improve their efficiency. The use of inhibitors is the most widespread method to avoid or reduce the reaction that exists between the surface of the metal and the oxygen of the surrounding medium. The most common application is to prevent internal corrosion in oil, gas, acid, and high-velocity fluid pipelines.

Talking about inhibiting corrosion means delving into a wide variety of products that are applied to complement corrosion protection in paints, gas and liquid extraction processes, storage, and transportation [1-2]. A substance that, added in small quantities to a corrosive medium, reduces or eliminates its aggressiveness is called a corrosion inhibitor. Also known as a delay catalyst (slows down the oxidation process), it is characterized by forming a moisturizing, oily and transparent protective layer. The action of inhibiting refers to the fact that it stops or prevents chemical reactions between the surface and the oxygen of the surrounding medium.

It is a chemical product (with chromate, phosphate or molybdate salts) that is added in small concentrations to:

● The surface of the metal to isolate its surface from moisture and oxygen.

● The corrosive or corrosive reactive medium to reduce or eliminate its reactivity.

The objective is to reduce the corrosion rate to less than 0.1 mm per year under conditions of localized internal corrosion and high-velocity fluid erosion [1-7].

Characteristics of corrosion inhibitors

● They chemically and/or physically coat metal surfaces

● They form a protective layer that insulates the surface from moisture

● They form a protective layer that prevents contact between the metal surface and oxygen

● Can neutralize the acidity or alkalinity of the metal surface

● They prevent the circulation of electrons between the metal and the medium

The action of inhibitors is carried out in two main processes, the first involves the transport of the inhibitor to the metal surface and the second involves the interaction between the inhibitor and the surface forming a layer. The layer formed can protect the surface from the surrounding environment, or it can deliver its electrons to the surrounding medium to avoid the oxidation process.

When added to the electrolyte solution in the surface preparation process, some chemical agents produce polarization (positively or negatively charged) by concentration on the metal surface, creating the protective layer. The efficiency of inhibitors is a function of the type of metal (or alloy) in a given environment; That is, if

there are minor variations in the chemical composition of the metal or in the composition of the solution (environment), they significantly alter its efficiency.

In general, they are effective for ferrous alloys at temperatures below 149°C. The selection and amount of inhibitor used depends on the environment, metal type, desired protection time, and expected temperature [1-7].

Considerations for inhibitor selection

● Type of metal to be protected against corrosion

● Effective protection time (days, months or years)

● Application method (immersion, spraying, brushing, among others)

● Type of protection required (in process, storage or shipping)

● Handling of the piece and removal of the fingerprint

● Type and thickness of the desired coating

● Storage, packaging and/or shipping conditions

● Temperature, humidity and environmental conditions

● Removal methods (if required)

● Interaction with subsequent processes (if not removed)

● Environmental, health and safety requirements

● Type of product desired (oil/solvent-based or water-based) [1-8].

▪ **Application methods**

They can be applied by: brushing (brush), immersion (immerse the piece in the liquid inhibitor) and spraying (aerosol). They also come impregnated in products such as: packaging paper, packaging plastic, corrugated packaging cardboard and adhesive tapes [1-8].

▪ **Types of corrosion inhibitors**

According to their origin, they are classified as inorganic synthetics (arsenates, chromates, phosphates, molybdates), organic synthetics (acetylenic alcohols, amides, aromatics, amines, thiols), natural (plant extracts, animal origin, minerals) and residuals (waste sludge). Chromium salts perform this function in automobile radiators; However, if the little inhibitor is added, the small and localized anodic areas are left unprotected and the corrosion process is accelerated.

Soluble oils, amines and organic substances are applied in pipes, heat exchangers. They are used in cooling systems or heat sinks such as radiators, cooling towers, and boilers [1-8].

▪ **Inhibitor for background paints**

For any type of protective paint on metal, it is recommended to apply at least three coats of paint on the surface. The corrosion inhibitor is applied to the first layer of paint; in the case of paints, zinc chromate is applied. Because there are no perfect layers of paint that are free of pores, after applying the primer paint there are exposed areas, even adding another layer of paint does not guarantee that the existing pores will be covered. To eliminate these exposed areas and uniformly protect the surface, a corrosion inhibitor is added to the first layer of paint, then the other layers are applied. It should be applied in paint coatings on pipes in docks, marine structures, cranes, and parts in seaside environments [1-9].

▪ **Liquid inhibitors**

Protection with paint coatings (epoxy) on pipes is complemented by the addition of liquid inhibitor to protect the internal wall of the pipe. In the oil industry, they are used in liquid form and are injected through capillaries (thin pipes) onto the pipe (which is in the well in small reservoirs), where they are deposited at the bottom of the well and when the oil is extracted it comes. wrapped with an inhibitor that protects the pipe as it rises to the surface. It is applied in the oil industry in extraction piping systems.

▪ **Oil-based inhibitors**

It is based on the formation of protective layers to prevent contact with water. It is not necessary to dilute it and it is used directly from the container. It can be applied by brushing (brush), dipping or spraying (aerosol). To remove inhibitor residues, it is necessary to clean them with alkaline degreasers or solvents. They are applied to prevent oxidation in products that will be stored indoors or outdoors for long periods [1-9].

▪ **Water-based inhibitors**

Water-based corrosion inhibitors modify the surface characteristics of the metal to decrease its susceptibility to rust formation. They are typically sold concentrated and require dilution with water, making them less expensive than most oil-based products. They are practically undetectable as they form thin, transparent layers when they dry, or applied by spraying, brushing or dipping. If removal is necessary, water-based cleaners are used. They are applied to parts that need preventive protection against oxidation that will be stored indoors for short periods of time (days, weeks), during shipments when combined with packaging, on products stored indoors for up to six months such as tools, bearings, screws, among others [8-10].

Inhibitors complement non-metallic coatings and are also impregnated in various packaging. They prevent the oxidation process from taking place and therefore corrosion. Each type of inhibitor is designed for specific conditions and metal types. Its use is generally little known, but it is highly efficient to protect metal surfaces; today it is one of the most important methods to minimize corrosion, to the extent that many operating plants depend on its successful application. The use of synthetic inhibitors brings with it high environmental impacts that generate environmental wear, aggressive chemical waste for the environment, not to mention that they generate toxic waste, which is why it is recommended to think about natural sources for the production of corrosion inhibitors. On the other hand, coffee is produced from coffee beans, which has great value as a Peruvian product and has great international trade, consolidating itself with export-quality production [5-8]. Coffee is exported in large quantities, with high agricultural demand in American countries such as Peru, Colombia, Brazil, and Mexico. However, the coffee husk is not used as much and is wasted. The methods use the internal fruit for coffee processing, the husk is not usually used, or in some cases, it is used as soil fertilizer. Which is a high-value waste, it is mainly composed of lignin, cellulose, parchment, silica, and ash [8-20].

2. Procedure

AISI 444 steel samples were cut into rectangular shapes of 30 mm long by 5 mm wide and 4 ml thick (5 sample condition), the samples were sanded at 600 micrometers and then placed in an immersion cell in a 1 M H2SO4 solution for 5 days. Under normal conditions. Figure 1 shows the scheme used for the mass loss tests, as can be seen, the samples were completely immersed in the solution. Figure 1 shows the scheme used for the mass loss tests, as can be seen, the samples were completely immersed in the solution. Subsequently, these had to be covered by the electrolyte composed of a 1M H_2SO_4 solution in the absence and presence of 10%/V of the coffee peel extract. After 120 hours (5 days), the samples were carefully removed and dried to be weighed again. The calculation of the corrosion rate was calculated according to the following equation:

$$Corrosion\ rate(mm/year) = \frac{\Delta m(g)\ \times 24 \times 365}{2700\ mm^2\ \times\ 0.0078\ \frac{g}{mm^3}\ \times\ Time\ test\ (h)}$$
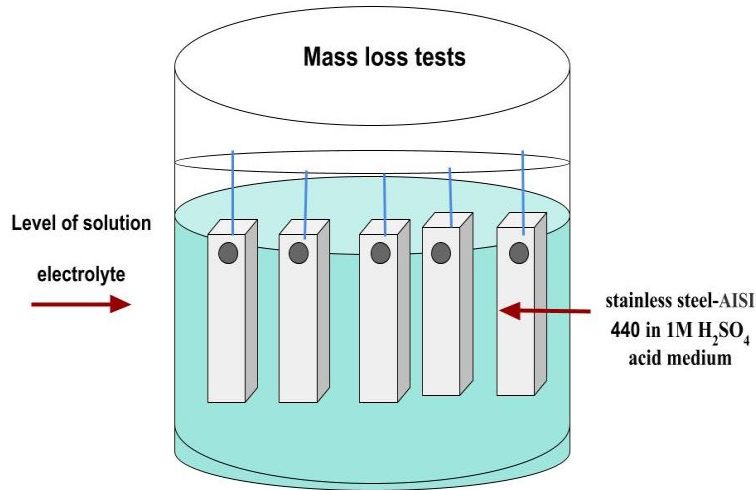
Figure 1. scheme used for the mass loss tests.

3. Results and Discussion

Figure 2 presents the results of the mass loss tests, which show an increase in the corrosion rate in the 5 days, which is caused by localized corrosion on the surface of the stainless steel. Remember that in the case where 10% coffee was present, the mass loss has presented a smaller increase when compared to the same immersion and evaluation time, which shows us the inhibitory effect in an acidic medium such as sulfuric acid.
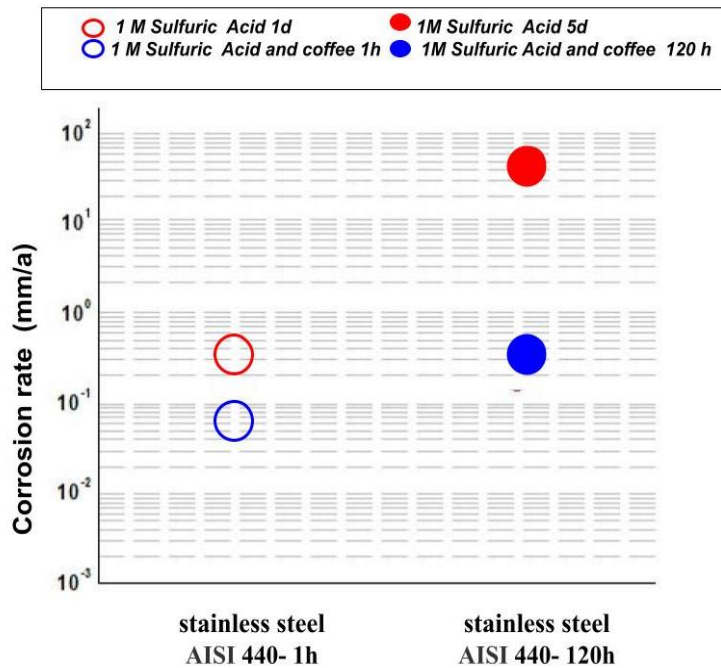

Figure 2. Results of mass loss tests on stainless steels in electrolyte composed of a 1M H_2SO_4 solution in the absence and presence of 10%/V of the coffee peel extract. After 24 and 120 hours (1-5 days).

The presence of sulfuric acid generates an acidic medium, which is used to simulate a sour environment found in various industrial processes. The literature cites acid as an accelerator of the reaction kinetics of the processes that involve corrosion in metal structures and although stainless steels are resistant, they can present pits, which is why studies that involve resistance and protection of materials are necessary. Including the use of inhibitors, especially natural ones based on products that do not cause harm to the environment. One of the most important

techniques is mass loss, which allows evaluation of the loss of thickness per unit of immersion time and determines that the coffee peel presents a barrier that allows for reducing the corrosion rate in the evaluated exposure time. 5 days.

4. Conclusion

- Mass loss corrosion techniques can be used in corrosion studies to evaluate corrosion conditions and speed.

- The results showed that the presence of 10% of coconut shell showed an inhibitory and resistant effect to acidic med

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