PROPERTIES OF 3-(VINYLOXY)HEX-4-EN-1-YNE AS A CORROSION INHIBITOR IN RECIRCULATING WATER AND HEATING SYSTEMS

Karshi State Technical University
Lecturer of the Department of Industrial Engineering and Management
Ergashev Laziz, son of Bekmurod
Tel.: +998 91 462 36 33
Student of Karshi State Technical University
Bobonazarov Asadbek, son of Habibulla

Abstract. This article analyzes the potential of 3-(vinyloxy)hex-4-en-1-yne for protecting metal surfaces against corrosion in recirculating water systems and heating systems. Organic corrosion inhibitors are distinguished by their ability to form a protective adsorption layer on the metal surface. A review of the literature shows that acetylene alcohols and their vinyloxy derivatives, especially in neutral and mildly alkaline media, can reduce the corrosion rate on steel surfaces. In recirculating water systems, corrosion is associated with dissolved oxygen, chloride and sulfate ions, hardness salts, deposits, and biofouling, whereas in closed heating systems one of the main factors is dissolved oxygen. The vinyloxy fragment, the unsaturated hydrocarbon chain, and the electron-rich centers in the molecule of 3-(vinyloxy)hex-4-en-1-yne may enhance its ability to adsorb onto the metal surface and form a protective layer. Therefore, this compound is considered promising either as a component of water-treatment reagents or as an independent organic inhibitor.

Keywords: 3-(vinyloxy)hex-4-en-1-yne, corrosion, inhibitor, recirculating water system, heating system, steel, adsorption, protective layer, organic reagent.

Introduction

Corrosion in industrial recirculating water systems and heating systems reduces the efficiency of heat transfer, shortens the service life of pipelines and heat exchangers, and may lead to emergency leakages. In recirculating cooling waters, especially for carbon steel, corrosion together with scale formation and biofouling creates a serious technological risk. In closed heating and cooling systems, dissolved oxygen is considered one of the main driving factors of corrosion; in the absence of oxygen, the cathodic reaction cannot proceed fully and metal dissolution slows down considerably. Therefore, the use of chemical inhibitors in such systems is of practical importance.

According to the modern theory of corrosion, organic inhibitors are adsorbed on the metal surface and form a protective film or enhance the stability of the oxide layer. A 2024 review article noted that organic compounds, especially those containing oxygen, sulfur, and nitrogen, can effectively protect steel surfaces against corrosion. Corrosion inhibitors are classified into adsorption, oxidizing, and precipitating types; adsorption-type inhibitors are among the most widely used groups.

Acetylene alcohols and their derivatives belong to the class of active organic anti-corrosion substances. In the oil and gas industry, as well as in acid treatment of metals, acetylene alcohols are mentioned among effective inhibitors. At the same time, experiments in neutral media on similar acetylenic-vinyloxy compounds have also shown that they can reduce the corrosion of steel.

Theoretically Grounded Inhibitory Properties of 3-(Vinyloxy)hex-4-en-1-yne

The molecular structure of 3-(vinyloxy)hex-4-en-1-yne contains a vinyloxy fragment, a multiple-bond hydrocarbon chain, and an electron-rich oxygen atom. Therefore, it can be regarded as an adsorption-type organic inhibitor. As a scientific conclusion, it may be emphasized that the π-bonds and the oxygen atom in the molecule can form donor-acceptor or physical adsorption interactions with the metal surface, thereby slowing down the electrochemical processes at both anodic and cathodic sites. Such an explanation is consistent with reviews on the general mechanisms of inhibitors.

Published data on similar vinyloxy derivatives support this assumption. For example, in a neutral medium, for St.3 steel, 2,5-diphenyl-5-vinyloxyhexyn-3-ol-2 exhibited protection efficiencies of 81.0% at 20°C, 75.1% at 40°C, 72.0% at 60°C, and 67.0% at 80°C; while 3,5-dimethyl-5-vinyloxyheptadiyne-1,6-ol-3 showed corresponding protection values of 70.0%, 65.2%, 49.2%, and 50.8%. The same study demonstrated that acetylene diols were generally stronger than their corresponding vinyloxy derivatives, although the vinyloxy derivatives still displayed significant inhibitory properties.

Thus, the following scientific hypothesis may also be proposed for 3-(vinyloxy)hex-4-en-1-yne: in aqueous systems it may form a thin adsorption-type protective layer on the metal surface, partially block active sites of the metal, retard the oxygen reduction reaction, and reduce the rate of metal dissolution. This conclusion is not based on direct experimental results for this exact substance, but rather represents a scientific inference derived from data on similar acetylenic-vinyloxy compounds and general information on organic inhibitors.

Application in Recirculating Water Systems

In recirculating water systems, corrosion of carbon steel usually proceeds in several stages: at the initial stage, the corrosion rate is high; then the rate decreases due to the thickening of the corrosion product layer; and later it enters a relatively stable stage. The initial period, when the inhibitor film has not yet formed sufficiently, is considered particularly dangerous. Therefore, the most important function of an organic inhibitor used in recirculating water systems is to adsorb rapidly onto the metal surface and reduce the aggressiveness of the initial stage.

The advantage of using 3-(vinyloxy)hex-4-en-1-yne in a recirculating water system is that such a compound may exert a surface-directed adsorption effect even at very low concentrations in water. In addition, corrosion control in recirculating waters is often performed in the form of a комплекс program: the combined use of corrosion inhibitors, scale inhibitors, and biocides leads to better results. Even in industrial recirculating water systems treated electrochemically or chemically, the combination of a suitable inhibitor with other water-treatment measures is recommended to control both corrosion and scale simultaneously.

In practical application, it would be advisable to test this compound in open cooling tower recirculating water systems, in heat exchangers, condensers, and steel pipelines. In such cases, the pH of the water, hardness, chloride and sulfate ion content, electrical conductivity, and dissolved oxygen concentration must be strictly monitored, because the corrosion rate in a recirculating water system strongly depends not only on the reagent composition but also on water chemistry.

Application in Heating Systems

In closed heating systems, the main corrosion factor is often dissolved oxygen. Practical observations and technical bulletins show that an increase in oxygen content accelerates the degradation of steel in pipes, radiators, and heat-transfer surfaces. Therefore, the first approach to corrosion prevention in heating systems is to reduce oxygen ingress, while the second is to use chemical inhibitors.

3-(Vinyloxy)hex-4-en-1-yne may be especially promising in closed heating systems as a component capable of forming an additional organic protective layer. This substance may adsorb on steel surfaces exposed to aggressive components in solution, limit the access of oxygen to the metal, slow down electrochemical reactions, and reduce the risk of under-deposit corrosion. However, in heating systems, such a substance is expected to be more effective not as a stand-alone agent, but when used together with deaeration, proper pH control, filtration, and, where necessary, classical inhibitors such as molybdate or nitrite. A technical bulletin on closed water systems identified molybdate and nitrite among the most effective inhibitors.

Therefore, the most appropriate model for using 3-(vinyloxy)hex-4-en-1-yne in heating systems may be interpreted as follows: it is introduced as an additional organic component in the main water-treatment program; that is, dissolved oxygen in the system is reduced, pH is kept stable, and the organic compound improves the integrity of the protective layer through its surface activity. This approach may contribute to the long-term stable operation of the system.

Discussion

The results reported in the literature for similar vinyloxy derivatives indicate that such compounds reduce steel corrosion in neutral media, although their efficiency is often somewhat lower than that of the corresponding acetylene diols. The same may theoretically be expected for 3-(vinyloxy)hex-4-en-1-yne. Nevertheless, considering that it is a smaller and relatively more mobile molecule, it may adsorb more rapidly onto the surface under certain hydrodynamic conditions. This may be especially beneficial during the initial stage of corrosion in recirculating water systems. These considerations are scientific conclusions that still need to be confirmed by direct testing.

To evaluate the actual technological effectiveness of this compound, it would be advisable to perform investigations on St.3 or steel 20 samples using the gravimetric method, potentiodynamic polarization, electrochemical impedance spectroscopy, and surface analysis methods. The 2024 review article indicated that polarization methods, impedance techniques, and SEM surface morphology are widely used for the evaluation of organic inhibitors.

Conclusion

In conclusion, 3-(vinyloxy)hex-4-en-1-yne may be considered a promising organic corrosion inhibitor for recirculating water systems and heating systems. Its inhibitory properties can be explained by the vinyloxy group, the π-electron system in the molecule, and its ability to adsorb onto the metal surface. The literature shows that similar acetylenic-vinyloxy compounds significantly reduce steel corrosion in neutral media. Therefore, it is advisable to test 3-(vinyloxy)hex-4-en-1-yne in practice both in recirculating water systems and in closed heating systems. In particular, it may yield good results as an additional organic adsorption component in a complex water-chemical treatment program. However, its final technological evaluation must be confirmed only by real experimental data, including corrosion rate, protection efficiency, optimal concentration, and the effects of pH and temperature.

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