

## Reducing the aggressiveness of sulfuric acid corrosion medium on steel by adding organic substances

Temenujka Haralanova, Christian Girginov

**Reducing the aggressiveness of sulfuric acid corrosion medium on steel by adding organic substances.** *In the present work a research on the corrosion of steel in an aggressive sulfuric acidic (0.1 M) environment is proposed, with the addition of three inhibiting organic substances. These inhibitors include: 2-acetyl-1H-indene-1,3(2H)-dione, 1-oxo-2-phenyl-1H-inden-3-yl acetate and 4-(dibenzoylamino) benzoic acid. All of them have different functional groups. The corrosion studies were conducted by applying the classical gravimetric analysis, which allows for the direct determination of the amount of corroded metal. The corrosion rate, the inhibitor efficiency and the inhibitor activity coefficient are all calculated using the obtained results. The studied organic substances indicate a certain potential for use as an inhibitory protection of steel.*

**Keywords:** corrosion, steel 3, organic inhibitors

### INTRODUCTION

Acidic solutions are often used in the industry and are normally accompanied by a considerable dissolution of the steel. Data in the literature suggest that iron alloys i.e. the main material of modern technology, corrode to the most extent. Corrosion losses are huge: about 10% of the produced metal is lost irretrievably. A useful method to protect metals against corrosion in such environments is the addition of chemicals to the solution. Such chemical compounds are called corrosion inhibitors. In contact with the surface (or its alloy), it inhibits the corrosion reactions and reduces the corrosion rate [1].

The efficiency of a corrosion inhibitor depends both on the composition of the solution and the inhibitor concentration. A common mechanism for inhibiting corrosion includes the formation of a coating (usually referred to as passivation layer), which blocks the access of the corrosive substance to the steel. A number of organic compounds [2] are known to be applicable as corrosion inhibitors for steel in acidic environments. Many organic inhibitors with application in sulfuric acid [3-7] medium have been extensively studied.

In our previous investigations [4, 8-11] many organic heterocyclic compounds with different functional groups have shown good adsorption, thus having a relatively good inhibitory effect. In the present work a research on corrosion of steel in aggressive acidic environment with the addition of inhibitory substances from three different organic groups is proposed.

### EXPERIMENTAL

The experiments were performed with mild steel (steel 3) specimens. The steel samples used had the following composition ([C]=0.16%, [Mn]=0.65%, [Si]<0.05%, [S]<0.025%, [P]<0.04%, [Ni]<0.3 %, [Cr]<0.3%, [As]<0.08%, [Si]=0.05%).

The aggressive media, with a 0.1M H<sub>2</sub>SO<sub>4</sub>, was prepared using double-distilled water.

As inhibitors, three organic substances with different functional groups were investigated: 2-acetyl-1H-indene-1,3(2H)-dione (IND3), 1-oxo-2-phenyl-1H-inden-3-yl acetate (AE1) and 4-(dibenzoylamino)benzoic acid (DBBA). These organic substances were synthesized in the laboratory of the Department "Chemistry and Chemical Technologies" of the Ruse University "Angel Kanchev", Subsidiary in Razgrad by Prof. N. Stoyanov. The concentrations of the three employed inhibitors were in the range of 1x10<sup>-6</sup> - 2x10<sup>-5</sup> mol dm<sup>-3</sup>. The structural formulae of the organic inhibitor molecules are presented in Figure 1.

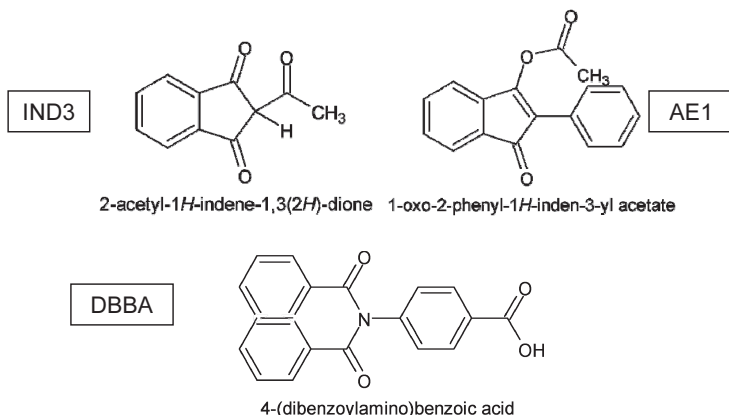


Fig. 1 Structural formulae of the organic inhibitor molecules

The corrosion studies were conducted by applying a common gravimetric method [12, 13]. This method includes exposing the clean weighed piece of metal (or alloy) to a corrosive environment for a certain time ( $t$ ), followed by cleaning, in order to remove corrosion products, and a weighing of the piece, to determine the weight loss.

Experiments were carried out at room temperature (25°C) which was maintained with an accuracy of ( $\pm 1^\circ\text{C}$ ).

#### RESULTS AND DISCUSSION

The corrosion process is characterized [14-16] by determining the corrosion rate ( $k$ ), the inhibitor efficiency ( $Z$ ) and the inhibitor activity coefficient ( $Y$ ).

The rate of corrosion ( $k$ ) is calculated as:

$$k = \frac{(m_0 - m)}{St} \left[ \text{gm}^{-2}\text{h}^{-1} \right], \quad (1)$$

where  $m_0$  [g] is the weight of the metal sample before the experiment,  $m$  [g] - weight of the specimen after exposition to corrosive media,  $S$  [ $\text{m}^2$ ] is the sample surface and  $t$  [h] - the exposure time. The dependence of the corrosion rate on concentration is plotted in Figure 2.

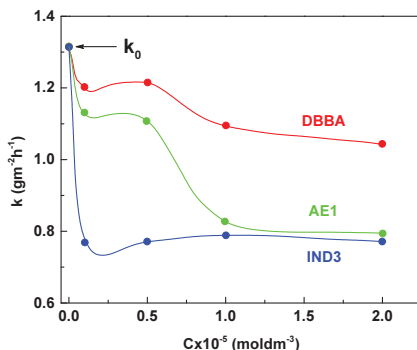


Fig. 2 Dependence of corrosion rate on organic substance concentration in 0.1 M  $\text{H}_2\text{SO}_4$  at 25 °C

The obtained results indicate that *2-acetyl-1H-indene-1,3(2H)-dione* (IND3) reduces the corrosion speed twice, at relatively low concentrations.

The inhibitor efficiency ( $Z$ ) is ascertained by the following equation:

$$Z = \frac{k_0 - k}{k_0} \times 100[\%], \quad (2)$$

where ( $k_0$ ) is the corrosion rate of the metal without inhibitor and ( $k$ ) is its corrosion rate in the presence of organic inhibitor. The obtained experimental data are presented on Figure 3.

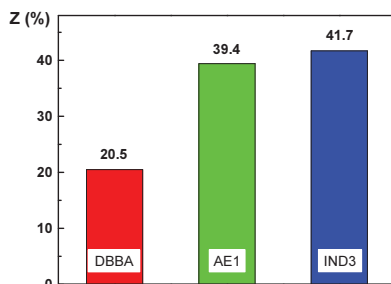


Fig. 3 Values of the inhibitor efficiency of the three studied organic substances ( $C = 2 \times 10^{-5} \text{ mol dm}^{-3}$ )

The inhibitor activity coefficient ( $Y$ ) can easily be determined from the obtained experimental data, using the corrosion rate in absence ( $k_0$ ) and in the presence ( $k$ ) of an inhibitor:

$$Y = \frac{k_0}{k}. \quad (3)$$

The calculated values for  $Y$  are given in Figure 4.

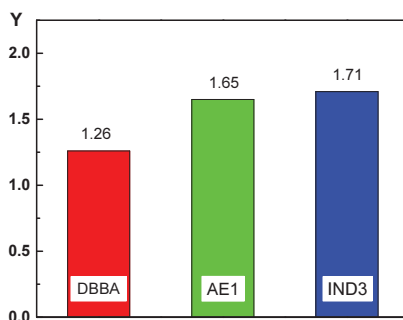


Fig. 4 Values of the inhibitor activity coefficient of the three studied organic substances ( $C = 2 \times 10^{-5} \text{ mol dm}^{-3}$ )

The results were compared with those obtained in the absence of inhibitor. As a result it can clearly be seen that all three test substances exhibit an inhibiting effect on the corrosion of steel in sulfuric acid corrosion medium. The increase in concentration of the organic substances leads to higher corrosion protection of the steel samples.

### CONCLUSION

It was established that the three investigated organic substances demonstrate a relatively good inhibitory effect on Steel 3 in a corrosive environment (0.1M H<sub>2</sub>SO<sub>4</sub>). The comparison gives an advantage to (1-oxo-2-phenyl-1H-inden-3-yl acetate), which exhibits a comparably lower corrosion speed at relatively low concentrations ( $C = 0.3 \times 10^{-5} \text{ mol dm}^{-3}$ ).

The inhibitory effectiveness of the studied compounds depends on the nature of the functional group, geometry and electron density of the molecule. These results are preliminary and extensive electrochemical studies are planned to clarify the mechanism of inhibition and to evaluate their application possibilities.

**Acknowledgement:** The authors are indebted to the National Scientific Research Fund, Ministry of Education, for the funding of this work under contract DFNI T02/27-2014.

### REFERENCES

- [1]. Gräfen H., E. M. Horn, H. Schlecker, H. Schindler "Corrosion" Ullmann's Encyclopedia of Industrial Chemistry, (2002), „Wiley-VCH: Weinheim“.
- [2] Dubey A.K., G. Singh, Portugaliae Electrochimica Acta, 25 (2007), 221-235.
- [3] Ebenso E.E., Mater. Chem. Phys., 79 (2003), 58.
- [4] Haralanova T., Ch. Girginov, M. Filipova, Science & Technologies, 4 (2014), 84.
- [5] Haralanova T., Ch. Girginov, Proceedings University of Ruse "Angel Kanchev" Chemical Technologies, 53(2014), book (10.1), 137.
- [6] Umoren S.A., U.M. Eduok, E.E. Oguzie, Portugaliae Electrochim. Acta, 26 (2008), 533.
- [7] Haralanova T., Ch. Girginov, Chemistry: Bulgarian Journal of Science Education 24 (2015), 397.
- [8] Lazrova E., G. Petkova, R. Raicheff and G. Neykov, Journal of Applied Electrochemistry, 32 (2002), 1355-1361.
- [9]. Лазарова Е., Г. Нейков, Н. Стоянов, Т. Янкова, Годишник на ХТМУ, 34 (1999), 35-44
- [10]. Хараланова Т., В. Камбурова, И. Желева, Трудове на научната сесия на РУ, 41, (2004) серия 1. 2, стр. 69-72.
- [11]. Хараланова Т., Научна конференция с международно участие, Ст. Загора, 5(2004), 189-193.
- [12]. Гуляев А.П., Металловедение (1986), „Металлургия“. (Москва).
- [13]. Томашов Н., Н. Жук, В. Титов, М. Ведеева, Лабораторные работы по коррозии и защите металлов, (1971), „Металлургия“, (Москва).
- [14]. Horath T., E. Kalman, G. Kutsan, A. Rauscher, British Corrosion Journal, 29(1994), 215.
- [15]. Колотыркин Я. М., Металл и коррозия, ,(1985).”Металургия“, (Москва).
- [16]. Томашов Н., Г. Чернова, Теория коррозии и корозионно–конструкционные сплавы, (1986), “Металургия”. (Москва).

**About the authors:**

Assoc. prof. Temenujka Nikolova Haralanova, Ph.D, Ruse University "A. Kanchev",  
Subsidiary in Razgrad, 47 "Aprilsko Vyzstanie" bld., 7200 Razgrad, Bulgaria; e-mail:  
haralanova97@abv.bg

Assist. prof. Christian Assenov Girginov, Ph.D., Dept. of Physical Chemistry,  
University of Chemical Technology and Metallurgy, 8 "Kliment Ohridski" bld., 1756 Sofia,  
Bulgaria; e-mail: girginov@uctm.edu

**This paper has been reviewed**