EFFICIENCY OF PYRIDINE-BASED HETEROCYCLIC COMPOUNDS AS CORROSION INHIBITORS

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Annotation. This study investigated the corrosion-inhibiting properties of heterocyclic compounds obtained from pyridine and its derivatives against steel corrosion in a hydrochloric acid medium. Compositions No. 6 and No. 7 of the synthesized mixtures were tested on St.20 steel samples in a 15% HCl solution (t = 50 °C, τ = 42 h). According to the experimental results, “mixture No. 7” demonstrated a maximum protection efficiency of up to 99.5% and showed significantly higher activity compared to “mixture No. 6.” Based on the highly effective mixture, composite inhibitors were prepared using urotropine, acrylic emulsion, and thiomochelvine. Under conditions of increasing temperature from 20 to 100 °C, “composition 1” exhibited the most stable protective performance, reducing the corrosion rate by up to 20 times. The results of this study confirm the possibility of creating highly efficient, stable, and practically applicable inhibitors based on pyridine derivatives.

Keywords. Pyridine, heterocyclic compounds, corrosion inhibitor, hydrochloric acid, composite inhibitor, urotropine, acrylic emulsion, thiomochelvine, corrosion rate.

Аннотация. В данной работе исследованы ингибирующие коррозию свойства гетероциклических соединений, полученных на основе пиридина и его производных, в отношении коррозии стали в среде соляной кислоты. Составы № 6 и № 7 синтезированных смесей были испытаны на образцах стали Ст.20 в 15%-ном растворе HCl (t = 50 °C, τ = 42 ч). Согласно экспериментальным результатам, «смесь № 7» продемонстрировала максимальную защитную эффективность до 99,5 % и показала значительно более высокую активность по сравнению со «смесью № 6». На основе высокоэффективной смеси были получены композиционные ингибиторы с использованием уротропина, акриловой эмульсии и тиомочевины. В условиях повышения температуры от 20 до 100 °C «композиция 1» проявила наибольшую стабильность защитного действия, снижая скорость коррозии до 20 раз. Результаты исследования подтверждают возможность создания высокоэффективных, термически устойчивых и практически применимых ингибиторов коррозии на основе производных пиридина.

Ключевые слова. Пиридин; гетероциклические соединения; ингибитор коррозии; соляная кислота; композиционный ингибитор; уротропин; акриловая эмульсия; тиомочевина; скорость коррозии.

Annotatsiya. Mazkur tadqiqotda piridin va uning hosilalari asosida olingan geterotsiklik birikmalarning xlorid kislota muhitida po‘lat korroziyasiga qarshi

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ingibitorlik xossalari o‘rganildi. Sintez qilingan aralashmalarning № 6 va № 7 tarkiblari 15 % li HCl eritmasida (t = 50 °C, τ = 42 soat) St.20 markali po‘lat namunalari ustida sinovdan o‘tkazildi. Tajriba natijalariga ko‘ra, «№ 7 aralashma» maksimal himoya samaradorligini 99,5 % gacha namoyon etib, «№ 6 aralashma»ga nisbatan ancha yuqori faollik ko‘rsatdi. Yuqori samarali aralashma asosida urotropin, akril emulsiyasi va tiomochevina qo‘shilgan kompozitsion ingibitorlar tayyorlandi. Harorat 20 dan 100 °C gacha oshirilgan sharoitlarda «1-kompozitsiya» eng barqaror himoya xususiyatlarini namoyon etib, korroziya tezligini 20 martagacha kamaytirdi. Olingan natijalar piridin hosilalari asosida yuqori samaradorlikka ega, barqaror va amaliy jihatdan qo‘llash mumkin bo‘lgan korroziya ingibitorlarini yaratish imkoniyatini tasdiqlaydi.

Kalit so‘zlar. Piridin; geterotsiklik birikmalar; korroziya ingibitori; xlorid kislota; kompozitsion ingibitor; urotropin; akril emulsiyasi; tiomochevina; korroziya tezligi.

Introduction.

Today, the synthesis of heterocyclic compounds is one of the pressing tasks of organic chemistry, with pyridine and its derivatives occupying a special place among them. The pyridine ring is found in many natural and biologically active compounds, including heme and plant pigments, hemoglobin, chlorophyll, vitamin B12, nicotine, atropine, cocaine, various plant alkaloids, and several antibiotics.

At the same time, for the purpose of obtaining heterocyclic compounds, it is important to develop the composition of multifunctional catalysts for the heterocyclization reactions of acetylene and its derivatives with ammonia and amines, and to improve the efficiency of the multistage process of producing pyridine and its derivatives.

In the global chemical industry, scientific research is being conducted on the production of nitrogen-containing heteroatom compounds and the chemistry of heterocyclic compounds. In this regard, special attention is paid to developing selective, multifunctional catalysts for the synthesis of pyridine and its derivatives, determining their structure and properties, identifying the main areas of practical application, expanding their industrial use, accelerating the production process, and testing them in practice.

To improve solubility, the resulting mixtures were treated with extraction phosphoric acid in a 1:0.25 ratio. The obtained products were tested as corrosion inhibitors in hydrochloric acid medium. To study the inhibitory properties, heterocyclization products with the highest yields, compositions No. 2 and No. 3, were selected. The effect of inhibitor concentration on the corrosion rate of St.20 steel in 15% hydrochloric acid was investigated (t = 50 °C; τ = 42 h).

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Table 1

Effect of Inhibitor Concentration on the Corrosion Rate of St.20 Steel

Inhibitor Concentration, %	Corrosion Rate, g/m²·h	Protection Efficiency, %
Mixture No. 6		
Without addition 13	13	-
0,8	2,0	41,0
1,0	1,4	43,3
1,2	2,4	47,8
1,6	3,2	63,7
2,1	4,2	83,6
2,2	4,4	87,5
Mixture No. 7		
0,8	2,0	51,0
1,0	1,4	52,2
1,2	2,4	53,6
1,6	3,2	71
2,1	4,4	98
2,2	4,46	99,5

Table 2

Effect of Temperature on the Corrosion Rate and Protection Efficiency of an Inhibitor in 15% HCl for St.3 steel in a 3% hydrochloric acid medium. The inhibitor concentration is 2.2%.

№	HCl Acid Solution	Corrosion Rate, g/m²·h	Protection Efficiency, %
Room Temperature, τ = 24 h			
1	Without Inhibitor	4,7	-
	With Inhibitor	1,4	71,0
Temperature 40 °C, τ = 4 h			
2	Without Inhibitor	46,2	-
	With Inhibitor	0,5	99,0
Temperature 80°C, τ=4 h			
3	Without Inhibitor	131,0	-
	With Inhibitor	2,0	98,0
Temperature 100°C, τ=1 h			
4	Without Inhibitor	1020	-
	With Inhibitor	4,9	99,5

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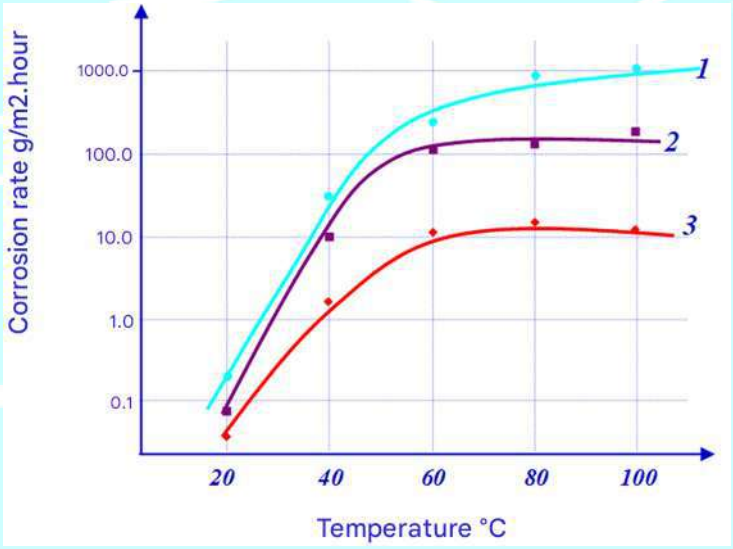
From these tables, it is evident that “mixture No. 7” is a more effective corrosion inhibitor over 42 hours at concentrations of 0.8–2.2%, protecting the metal from corrosion by up to 99.5%, whereas the protective effect of “mixture No. 6” is less than 90%.

To obtain stable and highly effective corrosion inhibitors, compositions were prepared based on the more efficient heterocyclization product, “mixture No. 7.”

1. “Mixture No. 7” (0.6%) + urotropine (0.3%) + acrylic emulsion (0.1%) – “Composition 1”.
2. “Mixture No. 7” (0.5%) + thiomochelvine (0.3%) + copper salt (0.2%) – “Composition 2”.

The mass % of the inhibitor added to 12% hydrochloric acid is given in parentheses.

It should be noted that only hydrochloric acid corrosion inhibitors based on readily available raw materials were studied. In addition, the possibility of reducing the corrosive activity of hydrochloric acid in a hydrocarbon medium by emulsification was investigated.



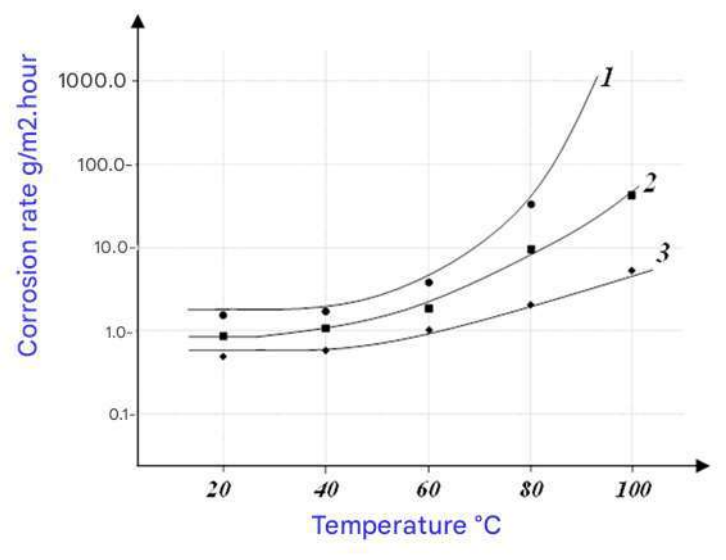
HCl (1); HCl + “Mixture No. 7” (2); HCl + “Composition 1” (3).

Figure 1. Dependence of corrosion rate on temperature

As can be seen from Figure 1, among the corrosion inhibitors studied in the temperature range of 20–100 °C, the most effective is “Composition 1.” At 90 °C in a 12% hydrochloric acid medium, the corrosion rate with “Mixture No. 7” is 130 g/m²·h (76.9%), whereas with “Composition 1” it is 17 g/m²·h (91.0%).

Compared to “Mixture No. 7”, the composition containing “Mixture No. 7,” urotropine, and acrylic emulsion offers several advantages, the main one being that it does not block the lower plastic zone during processing.

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HCl (1); HCl + Mixture No. 7 (2); HCl + Composition 2 (3).

Figure 2. Dependence of the corrosion rate of st.20 steel on temperature

As seen in Figure 2, at 90 °C, the corrosion rate of St.20 steel in a 12% HCl hydrophobic emulsion (phase ratio 75/25) is four times lower compared to the corrosion rate in the same temperature for 12% HCl when using "Mixture No. 7."

Thus, the corrosive activity of "Mixture No. 7" inhibited with hydrochloric acid decreases twentyfold when urotropine and acrylic emulsion are added at 100 °C.

Conclusion. The conducted studies confirmed that heterocyclic mixtures obtained from pyridine and its derivatives can act as effective corrosion inhibitors for steel in a hydrochloric acid medium. According to the test results, "Mixture No. 7" at a concentration of 2.2% provided a protection efficiency of up to 99.5%, demonstrating a significant advantage over "Mixture No. 6", especially at high temperatures.

Composite inhibitors prepared based on this mixture, in particular "Composition 1," showed the most stable protective performance in the 20–100 °C range and were able to reduce the corrosion rate by up to 20 times.

These results highlight the potential to develop highly effective and technologically convenient inhibitors based on pyridine derivatives, which can be applied in the chemical industry, especially for protecting metal equipment in processes involving hydrochloric acid.

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ISSN 3030-3907

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