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OBTAINING AN ENVIRONMENTALLY SAFE LVD-COMPLEX INHIBITOR FOR GAS PROCESSING EQUIPMENT AND DETERMINING ITS CLEANING EFFICIENCY

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Abstract. In the gas processing industry, the formation of deposits consisting of carbonate, sulfide, and corrosion products on the internal surfaces of heat exchangers and pipeline systems leads to a decrease in heat exchange efficiency, increased energy consumption, and a reduction in the service life of the equipment. In this work, a new multifunctional complex-forming reagent (LVD-complex inhibitor) based on citric acid, tartaric acid, and diethanolamine was synthesized for the chemical cleaning of heat exchangers. The chemical structure of the reagent was studied using infrared spectroscopy. In the IR spectrum, characteristic absorption bands corresponding to hydroxyl groups in the region of 3423.80 cm^{-1}, carboxyl groups in the region of 1640.53 cm^{-1}, amine fragments in the region of 1527.69 cm^{-1}, and C–O and C–N bonds in the range of 1289.47–1052.21 cm^{-1} were noted. These results confirmed the simultaneous presence of carboxyl, hydroxyl, and amine functional groups in the reagent. The properties of the synthesized reagent for complex formation, dissolution of carbonate and sulfide deposits, and limitation of corrosion processes were evaluated. The results obtained showed that the LVD-complex inhibitor has the ability to form stable complexes with metal ions, effectively dissolve deposits, and form a protective layer on the metal surface. The research results show that this reagent can be used as a promising multifunctional tool for chemical cleaning of heat exchangers in the gas processing industry.

Keywords: gas processing, heat exchanger, chemical treatment, citric acid, tartaric acid, diethanolamine, complexing reagent, corrosion inhibitor, IR analysis, precipitation dissolution.

Аннотация. В газоперерабатывающей промышленности образование отложений, состоящих из карбонатов, сульфидов и продуктов коррозии, на внутренних поверхностях теплообменников и трубопроводных систем приводит к снижению эффективности теплообмена, увеличению

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энергопотребления и сокращению срока службы оборудования. В данной работе был синтезирован новый многофункциональный комплексообразующий реагент (ингибитор ЛВД-комплекса) на основе лимонной кислоты, винной кислоты и диэтаноламина для химической очистки теплообменников. Химическая структура реагента была изучена с помощью инфракрасной спектроскопии. В ИК-спектре были отмечены характерные полосы поглощения, соответствующие гидроксильным группам в области 3423,80 $см^{-1}$, карбоксильным группам в области 1640,53 $см^{-1}$, аминогруппам в области 1527,69 $см^{-1}$, а также связям C–O и C–N в диапазоне 1289,47–1052,21 $см^{-1}$. Эти результаты подтвердили одновременное присутствие карбоксильных, гидроксильных и аминогрупп в реагенте. Были оценены свойства синтезированного реагента в отношении комплексообразования, растворения карбонатных и сульфидных отложений и ограничения коррозионных процессов. Полученные результаты показали, что ингибитор LVD-комплекса обладает способностью образовывать стабильные комплексы с ионами металлов, эффективно растворять отложения и формировать защитный слой на поверхности металла. Результаты исследований показывают, что этот реагент может быть использован в качестве перспективного многофункционального средства для химической очистки теплообменников в газоперерабатывающей промышленности.

Ключевые слова: обработка газа, теплообменник, химическая обработка, лимонная кислота, винная кислота, диэтаноламин, комплексообразующий реагент, ингибитор коррозии, ИК-анализ, осаждение и растворение.

Аннотация. Газни қайта ишлаш саноатида иссиқлик алмашиниш аппаратлари ва қувур тизимларининг ички юзаларида карбонат, сульфид ва коррозия маҳсулотларидан ташкил топган чўкмаларнинг ҳосил бўлиши иссиқлик алмашинув самарадорлигининг пасайишига, энергия сарфининг ортишига ҳамда ускуналар хизмат муддатининг қисқаришига олиб келади. Мазкур ишда иссиқлик алмашиниш аппаратларини кимёвий тозалаш учун лимон кислотаси, вино кислотаси ва диэтаноламин асосида янги полифункционал комплекс ҳосил қилувчи реагент (ЛВД-комплекс ингибитори) синтез қилинди. Реагентнинг кимёвий тузилиши инфрақизил спектроскопия усули ёрдамида ўрганилди. ИҚ спектрда 3423,80 $см^{-1}$ соҳада гидроксил гуруҳларига, 1640,53 $см^{-1}$ соҳада карбоксил гуруҳларига, 1527,69 $см^{-1}$ соҳада амин фрагментларига ҳамда 1289,47–1052,21 $см^{-1}$ оралиғида C–O ва C–N боғларига тегишли характерли ютилиш полосалари қайд этилди. Бу натижалар реагент таркибида карбоксил, гидроксил ва амин функционал гуруҳларининг бир вақтнинг ўзида мавжудлигини тасдиқлади. Синтез

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қилинган реагентнинг комплекс ҳосил қилиш, карбонат ва сульфид чўкмаларини эритиш ҳамда коррозия жараёнларини чеклаш хусусиятлари баҳоланди. Олинган натижалар ЛВД-комплекс ингибиторининг металл ионлари билан барқарор комплекслар ҳосил қилиш, чўкмаларни самарали эритиш ва металл юзасида ҳимоя қатлами шакллантириш қобилиятига эга эканлигини кўрсатди. Тадқиқот натижалари мазкур реагентни газни қайта ишлаш саноатида иссиқлик алмашиниш аппаратларини кимёвий тозалаш учун истиқболли полифункционал восита сифатида қўллаш мумкинлигини кўрсатади.

Калит сўзлар: газни қайта ишлаш, иссиқлик алмашиниш аппарати, кимёвий тозалаш, лимон кислотаси, вино кислотаси, диэтаноламин, комплекс ҳосил қилувчи реагент, коррозия ингибитори, ИК таҳлил, чўкмаларни эритиш.

INTRODUCTION.

Fouling and corrosion processes on the internal surfaces of heat exchangers in the gas processing industry are a widely studied problem worldwide. Classic studies in this field define fouling on a heat exchanger surface as “a reduction in heat transfer efficiency resulting from the accumulation of unwanted substances on the working surface.” Scientists The work showed that the formation of deposits significantly increases energy consumption in industrial enterprises and reduces the reliability of equipment . In this work , the types of fouling are divided into such main groups as salt deposits, particle accumulation, corrosion products, organic substances and biological contamination [1]. Another scientific work that theoretically substantiates the process of deposit formation on hot surfaces is Cho YI. and Liu R is a model proposed by They showed that the rate of sediment formation depends on the balance between particle deposition and washout by the current. This approach is later used as a basis for many engineering calculations started [2].

Scientists have found that operating parameters - temperature, pressure and flow rate - have a strong impact on fouling intensity. Studies have shown that fouling in heat exchange networks significantly increases energy consumption. [3].

Authors Contamination of heat exchange surfaces in oil refineries showed that energy consumption can increase by 10-30%. This result proves that the formation of the pollution layer is not only a technical but also an economic problem [4].

Müller-Steinhagen showed that the deposition of mineral salts in high-temperature environments is one of the main causes of damage to heat exchange surfaces. In his work, it was scientifically proven that the formation of a solid layer of deposits from mineral salts reduces the diameter of the pipe and reduces the heat transfer coefficient [5]. In this work, the problem of corrosion in gas processing

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processes is also of particular importance. His studies showed that corrosion products cause the formation of new deposits, further accelerating the fouling process. [6]. Metal corrosion is defined as the degradation of a metal as a result of chemical and electrochemical reactions with the environment. Gaseous H_2S and CO_2 in the presence of water form an acidic environment, which leads to rapid corrosion of pipelines and equipment [7]. In practical industrial studies, it has been shown that contamination of heat exchange surfaces in oil refineries can disrupt the operation of heat exchange networks, reduce safety, and shorten the service life of equipment. to reduce shown [8]. The analysis of the above studies shows that the accumulation of surface deposits and corrosion in gas processing equipment are closely related processes that reduce heat exchange efficiency, increase energy consumption, and reduce the reliability of technological equipment. Therefore, the development of chemical cleaning technologies for heat exchangers is one of the important scientific and practical tasks today.

During the operation of heat exchangers used in the gas processing industry, the formation of carbonate and sulfide deposits ($CaCO_3$, $Mg(OH)_2$, FeS), corrosion products, and organic layers reduces heat transfer efficiency, leads to increased energy consumption, and shortens the service life of technological equipment.

Most of the chemical cleaning reagents currently used are based on mineral acids and synthetic complexing agents, which have high corrosive activity, pose an environmental hazard, and require additional wastewater treatment. Therefore, in recent years, there has been a growing interest in creating environmentally safe and biodegradable reagents based on renewable raw materials.

The aim of this study is to develop a new bioreagent based on natural organic acids that simultaneously provides the properties of dissolving deposits, protecting metal surfaces from corrosion, and limiting the formation of redeposits. For this purpose, a new polyfunctional complex-forming reagent (LVD-complex inhibitor) was synthesized based on citric acid and tartaric acid obtained from natural sources, and diethanolamine, which has corrosion inhibitory properties. Citric and tartaric acids in the reagent are of biogenic origin, and their large number of carboxyl and hydroxyl groups allows them to form stable complexes with metal ions.

As a scientific novelty of the research, the concept of using an environmentally safe complexing inhibitor based on organic acids of biological origin for the gas processing industry was substantiated for the first time. The synthesized LVD-complex inhibitor is characterized by the simultaneous performance of several functions, such as dissolving carbonate and iron-containing deposits, complexing metal ions, inhibiting corrosion processes, and limiting the formation of redeposition. Infrared spectroscopy analyses confirmed the presence

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of carboxyl, hydroxyl, and amine functional groups in the reagent. These functional groups provide the reagent with high complexing ability, increasing its efficiency in the chemical cleaning process.

The obtained results showed that the LVD-complex inhibitor is not only a highly effective chemical reagent, but also a promising bioreagent obtained on the basis of environmentally safe, partially biodegradable and renewable raw materials. This makes it possible to use it as an alternative to traditional mineral acid reagents used in the gas processing industry.

MATERIALS AND METHODS.

2.1 Materials In the study, a polyfunctional complexing inhibitor composition was prepared based on tartaric acid, citric acid, and diethanolamine (DEA). The organic acids included in the composition were selected as complexing components, and diethanolamine was selected as a corrosion inhibitor component.

2.2. Methods

Infrared (IR) spectra were obtained using an IRTracer-100 infrared spectrometer (PerkinElmer Spectrum IR Version 10.6.1, USA, 2017). Measurements were performed using a MIRacle-10 attachment (aborted total internal reflectance, ATR) and a diamond/ZnSe prism. The spectral range was 4000–400 cm^{-1}, the resolution was 4 cm^{-1}, the signal-to-noise ratio was 60,000:1, and the scanning rate was 20 spectra per second.

Synthesis of a polyfunctional complex-forming reagent based on L imonic acid and tartaric acid diethanolamine

In the study, a laboratory apparatus equipped with a 250 ml three-necked flask, a mechanical stirrer, a thermometer and a reflux condenser was used to synthesize the complex-forming inhibitor composition. To prepare the reaction mixture, citric acid and tartaric acid were first dissolved in a certain ratio in distilled water. The resulting homogeneous solution was heated under constant stirring. Then, diethanolamine was added gradually to the reaction medium and stirring was continued. The temperature was controlled during the reaction and maintained for a certain time to allow the components to interact. The reflux condenser was used to prevent evaporation of the solvent in the reaction medium.

After the reaction was complete, the resulting product was cooled to room temperature and filtered to remove mechanical impurities. The resulting composition was stored in closed containers and prepared for further analysis. The functional groups and chemical structure of the synthesized reagent were studied using the infrared spectroscopy method. Complex formation properties were evaluated in the presence of calcium and iron ions. Corrosion inhibitory efficiency was determined by mass loss method of metal samples. Also, the chemical structure of the synthesized citric acid-tartaric acid-diethanolamine-based polyfunctional

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complex-forming reagent was studied using the IR-spectroscopy method. (Figure 1).

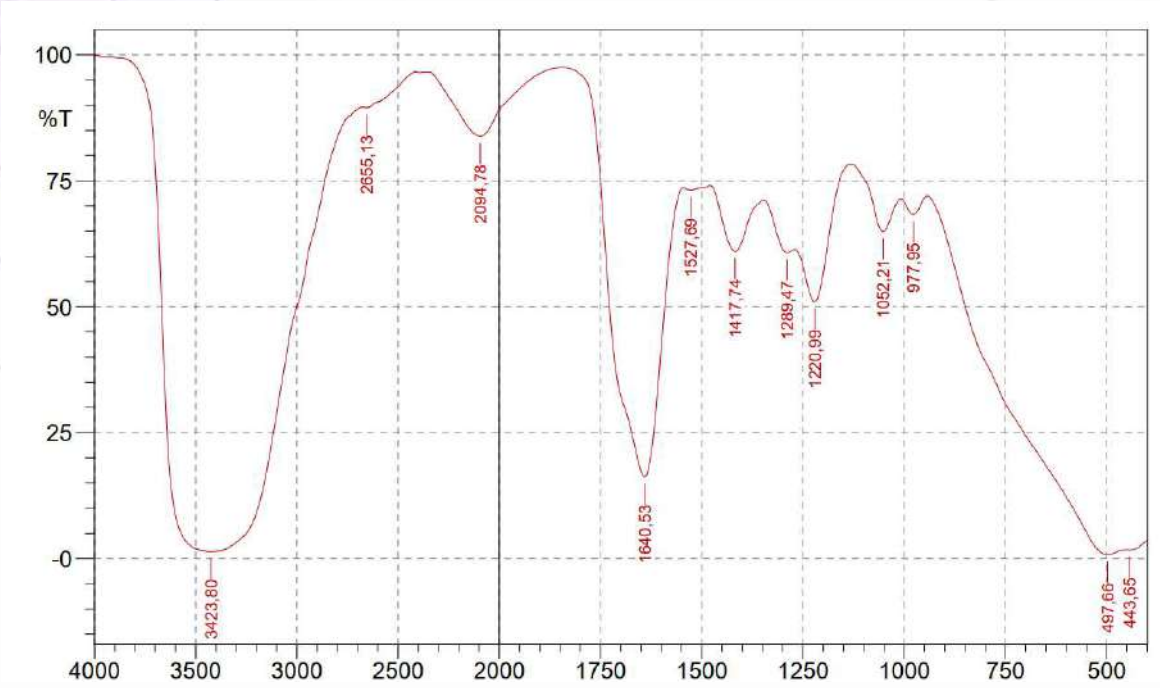


Figure 1. Synthesis of a new multifunctional complex-forming reagent (LVD-complex inhibitor) based on citric acid, tartaric acid, and diethanolamine IR spectrum

The obtained IR spectrum results confirmed the presence of carboxyl, hydroxyl and amino functional groups in the reagent.

The broad and intense absorption band observed in the spectrum at 3423.80 cm^{-1} corresponds to the valence vibrations of hydroxyl (–OH) groups. This band appeared as a broadening as a result of the formation of hydrogen bonds between the hydroxyl and carboxyl groups in citric and tartaric acids. This indicates that a large number of hydroxyl and carboxyl centers were preserved in the synthesized composition. The strong absorption line at 1640.53 cm^{-1} is explained by the asymmetric vibrations of the carboxyl groups and the effect of ion pairs formed with the amine components. This absorption is one of the main signs indicating the interaction between citric acid, tartaric acid and diethanolamine.

The absorption in the region of 1527.69 cm^{-1} corresponds to deformation vibrations involving amine fragments. This signal confirms that the diethanolamine molecule is included in the reagent. At the same time, the band at 1417.74 cm^{-1} belongs to the symmetric vibrations of carboxylate anions, indicating that a certain part of the acids has been neutralized by the amine and converted to the carboxylate form. The absorption bands observed in the regions of 1289.47 and 1220.99 cm^{-1} are associated with vibrations of the C–O and C–N bonds, indicating the presence of complex structures formed as a result of the interaction between the acid and amine components. The intense band at 1052.21 cm^{-1} is characteristic of vibrations

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of the C–O–C and alcohol-derived C–O groups, confirming the preservation of the oxygen-containing functional groups of citric and tartaric acids. Absorption in the region of 977.95 cm^{-1} corresponds to deformation vibrations of oxygen-containing organic compounds. The signals observed in the low-frequency part of the spectrum at 497.66 and 443.65 cm^{-1} are explained by spatial interactions and skeletal vibrations between functional groups within the molecule.

Thus, the results of IR analysis showed that the synthesized reagent contains hydroxyl, carboxyl and amine functional groups at the same time. It is these functional groups that provide the reagent with the properties of forming complexes with calcium and iron ions, dissolving carbonate and sulfide deposits, and forming a protective layer on the metal surface. The results obtained indicate that the composition based on citric acid–tartaric acid–diethanolamine is a promising multifunctional reagent for chemical cleaning of heat exchangers in the gas processing industry.

The properties of the synthesized citric acid, tartaric acid and diethanolamine-based polyfunctional complex-forming reagent to dissolve carbonate and sulphide deposits and to protect the metal surface from corrosion were confirmed in model systems .

Based on the results of the experiment, the degree of dissolution of the precipitates, the change in the concentration of metal ions in the solution, and the mass loss of the metal samples were determined. The obtained results are presented in Table 1, which allow to evaluate the complex-forming and inhibitory properties of the synthesized composition.

Table 1.

Effect of citric acid–tartaric acid–diethanolamine complexing reagent on model sediments (sample format)

Index	Initial value	After exposure to the reagent	Change
Mass of $CaCO_3$, g	5.00	1.15	77.0% dissolved
Mass of FeS, g	5.00	2.05	59.0% dissolved
Mass loss of steel sample, mg	125	38	69.6% decrease
Concentration of Ca^{2+} in solution, mg/l	120	910	Increased by 7.6 times
Fe^{3+} concentration in the solution, mg/l	35	240	Increased by 6.9 times

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pH	2.8	3.4	exceeded

The results show that the synthesized reagent exhibited high complexation properties compared to natural carbonate and sulfide precipitates. The 77% dissolution of the $CaCO_3$ sample is explained by the formation of stable complexes with calcium ions by the carboxyl groups in the reagent. The 59% dissolution rate observed for the FeS precipitate is related to the ability of the reagent to bind iron ions. The increase in the concentration of calcium and iron ions in the solution confirms the transition of mineral precipitates from the solid phase into the solution. This indicates the presence of complexation properties of the reagent.

According to the results of corrosion tests, the mass loss of the metal sample in the presence of the reagent was significantly reduced. This is explained by the formation of an adsorption protective layer of diethanolamine fragments on the metal surface. As a result, the reagent not only acts as a scale dissolver, but also as an inhibitor that limits corrosion.

show the possibility of using the composition based on citric acid-tartaric acid-diethanolamine as a multifunctional reagent with the properties of simultaneously dissolving deposits, protecting the metal surface, and keeping dissolved salts in a stable state .

CONCLUSION.

An LVD-complex inhibitor based on citric acid–tartaric acid–diethanolamine was synthesized and its chemical cleaning efficiency was evaluated. FTIR analyses revealed absorption bands characteristic of hydroxyl, carboxyl and amine functional groups in the regions of 3423.80 cm^{-1}, 1640.53 cm^{-1} and 1527.69 cm^{-1}. Under the influence of the reagent, 77.0% of the $CaCO_3$ precipitate and 59.0% of the FeS precipitate were dissolved. The mass loss of the metal sample decreased from 125 mg to 38 mg, and the corrosion inhibition efficiency was 69.6%. The results obtained showed that the LVD-complex inhibitor is an environmentally safe multifunctional bioreagent with the properties of dissolving precipitates, protecting the metal from corrosion and limiting the formation of redeposition.

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