AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

INCREASING CORROSION RESISTANCE OF MACHINE PARTS BASED ON NITRIDING TECHNOLOGY BY PRE-OXIDATION

https://doi.org/10.5281/zenodo.15634438

Bounazarov U.R.
Professor, Karshi State Technical University, Ph.D.

Annotatsiya

Maqolada turli xil ishlov berish rejimlarida olingan oksinitrid usulida himoya diffuziya qatlamlarining korroziyaga qarshi tajriba natijalari va ularning boshqa qoplamalar bilan qiyosiy ko‘rsatkichlari, xususan, dastlabki oksidlanish jarayoni amalga oshirilmagan holda ham nitridlash olib borilgan, shuningdek, galvanik xrom qoplamasi bo‘yicha olingan ma’lumotlar ham keltirilgan. Bundan tashqari, ish nitridlashdan oldin dastlabki oksidlanishning, shuningdek, mis sulfat eritmalarida keyingi oksidlanishning oksinitrid qatlamini olish jarayoniga va hosil bo‘lgan qoplamalarning korroziyaga qarshi chidamliligi ta’siri o‘rganilgan.

Olingan ko‘rsatkichlarni tahlil qilish shuni ko‘rsatadiki, har bir ko‘rib chiqilgan ishlov berish haroratida ma’lum bir dastlabki oksidlanish vaqti mavjud, bu esa po‘latlarning korroziyaga qarshi chidamliroq oksinitrid qoplamalarini olish imkonini beradi.

Аннотация

В статье приведены результаты экспериментов по коррозионной стойкости защитных диффузионных слоёв, полученных методом оксинитрирования при различных режимах обработки, а также сравнительные показатели с другими покрытиями. В частности, проведено нитрирование без предварительного окисления, приведены данные по гальваническому хромированному покрытию. Кроме того, в работе исследовано влияние предварительного окисления перед нитрированием, а также последующего окисления в растворах сульфата меди на процесс получения оксинитридного слоя и на коррозионную стойкость образовавшихся покрытий.

Анализ полученных данных показывает, что при каждой из рассмотренных температур обработки существует определённое оптимальное время предварительного окисления, которое позволяет получать более коррозионно - стойкие оксинитридные покрытия на сталях.

Abstract

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

This article presents experimental results on the corrosion resistance of protective diffusion layers obtained by the oxynitriding method under various treatment regimes, along with comparative indicators for other coatings. In particular, nitriding was also carried out without initial oxidation, and data are provided for galvanic chromium coatings. In addition, the study examines the effect of pre-nitriding oxidation and subsequent oxidation in copper sulfate solutions on the formation of the oxynitride layer and on the corrosion resistance of the resulting coatings.

Analysis of the obtained data indicates that at each treatment temperature considered, there is a specific optimal time for initial oxidation that enables the formation of more corrosion-resistant oxynitride coatings on steel.

Kalit so‘zlar

nitrid oksidi qatlami, oldingi oksidlanish, qoplama, ishqalanish juftlari.

Ключевые слова

оксинитридный слой, предварительное окисление, покрытие, пары трения.

Keywords

oxynitride layer, pre-oxidation, coating, friction pairs.

Introduction. Steels and protective coatings used in heavy industry and in the harshest areas of the oil and gas industry are often produced to provide various anti-friction layers. Therefore, a necessary condition for the selection of anti-friction steels and coatings is not only their wear resistance in neutral environments, but also their corrosion resistance in aggressive environments [1,2,3,4,5].

In this regard, the kinetics of electrochemical corrosion of the developed coatings was studied using the potentiodynamic method.

The corrosion resistance of nitride-oxide layers was evaluated in comparison with untreated ones. In addition, nitride-oxide coatings obtained without preliminary oxidation and coatings obtained by the chromium plating process were compared.

Corrosion resistance tests were conducted in a climate chamber in a salt spray environment. The results of the study are presented in Tables 1-3.

The test results showed that nitro-oxidized parts develop the least amount of corrosion spots compared to other types of treatment methods.

Research part. When comparing the anodic polarization curves obtained from steel samples of grade 38X2MYuA with each other, it was found that the magnitude of the corrosion current in the passive zone decreases by 1.5-2.0 times. Figure 1

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

shows the potentiodynamic polarization curves obtained from steel samples subjected to different oxynitriding regimes.

As can be seen from Figure 1, nitroxide coatings obtained by primary oxidation increase the corrosion resistance of steel compared to untreated steel, which is covered with a continuous film of corrosion products during the first two hours of exposure to a 3% sodium chloride solution [4,5,6,7].

It has been proven that the anodic current density of nitro-oxidized samples obtained after nitriding with initial oxidation and subsequent steam oxidation in water vapor is 1.5-5 orders of magnitude lower, depending on these cleaning methods.

Table 1

Results of corrosion tests in a salt fog chamber with 3% sodium chloride at t=26°C

T/R	Processing modes									Oxynitride layer thickness, μm	Time to first corrosion site, hours	Corrosion rate, test duration, % /hour
	Pre-oxidation			Nitriding			Next oxidation					
	τ, °C	τ, min	h, mkm	τ, °C	τ, min	h, mkm	τ, °C	τ, min	h, mkm			
1	-		-	580	2	15,1	580	30	3,0	18,1	312	5/300
2	-	-	-	580	2	15,1	580	30	3,2	18,0	547	10/1125
3	620	5	2,0	620	2	37	620	30	5,5	40,5	678	5/352
4	580	10	2,0	580	2	13,3	580	30	2,0	15,3	9	40/470
5	550	10	1,2	550	2	15,0	550	30	1,8	18,0	8	20/173
6	580	7	1,7	580	2	22,0	580	30	2,5	25,0	596	5/726
7	620	20	4,5	620	2	29,2	620	30	4,3	33,5	604	5/743
8	550	20	2,0	550	2	12,0	550	30	2,6	14,5	31	50/130
9	550	10	1,2	550	1	12,0	550	20	1,8	13,6	28	50/163
10	580	5	1,2	58	2	21,3	58	30	2,1	24,5	570	5/694

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

				0			0					
11	580	30	3,6	580	2	10	580	30	4,2	13,0	17	40/125
12	620	30	5,2	620	2	16	620	30	3,5	20,0	585	5/712
13	620	5	2,0	620	1	27,5	620	20	2,8	30,5	560	10/1142
14	580	10	2,0	580	1	16,5	580	20	2,3	19,5	16	45/120
15	580	20	3,0	580	2	17,0	580	30	2,4	19,0	320	15/570
16	620	30	5,2	620	1	13,0	620	20	5,7	18,0	18	30/112
17	550	20	2,0	550	1	10,0	550	20	2,0	13,0	7	20/85
18	550	30	2,7	550	2	5,0	550	30	2,9	8,0	9	45/70
Original sample											1,5	50/70
Hard chrome plating h=16 µm											49	50/230

It should be noted that anodic current density is a measure of the dissolution rate of a metal and, accordingly, an indicator of its corrosion resistance in a given environment. These corrosion units can be easily expressed in mm/uil, g/m2, and other units of measurement.

Table 2

Effect of hardening modes on the corrosion resistance of samples

T/R	Process erature, °C	Processing time			Number of s detected re testing, cm2	Exposure time re first appearance,
		Pre-oxidation, min	Nitrogen, hours	Oxidation after ing, min		
1	580	-	2	30	3	4
2	580	-	2	30	b/p	6
3	620	20	2	30	b/p	9
4	580	7	2	30	14	0,5
5	550	10	2	30	6	1,5
6	580	7	2	30	б/п	9,5
7	620	5	2	30	б/п	9,5
8	550	20	2	30	9	1
9	550	10	1	20	15	0,5

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

10	580	5	2	30	б/п	8
11	580	30	2	30	1	3
12	620	30	2	30	б/п	7
13	620	5	1	20	2	4
14	580	10	1	20	2	3
15	580	20	2	30	б/п	4
16	620	30	1	20	4	3
17	550	20	1	20	7	0,7
18	550	30	2	30	14	0,5

- Oxidation in $CuSO_4$ solution.

Results. All the obtained oxynitride layers are not porous, which is confirmed by the low decomposition potential in the polarization curve. Analyzing the results of polarization measurements (Fig. 1), we can conclude that the protective coatings obtained in the processing process in modes 3, 6, 7 have the highest corrosion protection properties, and the coatings obtained in mode 5 are insignificant. Comparison of the anodic polarization curves shows that corrosion resistance is achieved by treating the surface in modes 3, 6, 7, since in this case the anodic dissolution rate is 5 orders of magnitude lower than the corresponding value.

The lack of initial oxidation under the influence of water vapor during chemical-thermal treatment significantly reduces the protective properties of the oxynitride layer against the external environment. In this case, the anodic dissolution rate is 2-4 degrees lower than in the original steel, while the introduction of the initial oxidation process provided a reduction in the anodic dissolution rate by 5 degrees.

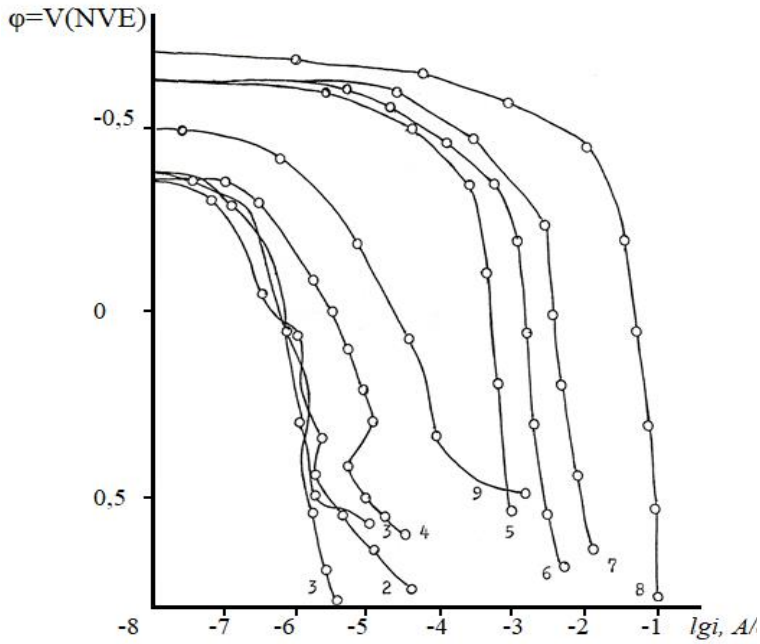

Figure 1. Potentiodynamic polarization dependences in 3% NaCl at t=25oC. 38X2MYuA steel.

1 - Hardened according to mode No. 3; 2 - Hardened according to mode No. 6; 3 - Hardened according to mode No. 7; 4 - Hardened according to mode No. 2; 5 - Hardened according to mode No. 1; 6 - Hardened according to mode No. 4; 7 -

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

Hardened according to mode No. 5; 8 - untreated steel; 9 - chrome-plated (galvanized) - h=16 μm.

It has been proven that coatings obtained by mode 2, although not undergoing initial oxidation, have better corrosion protection properties than coatings obtained by mode 1 due to steam oxidation after nitriding in a CuSO4 solution.

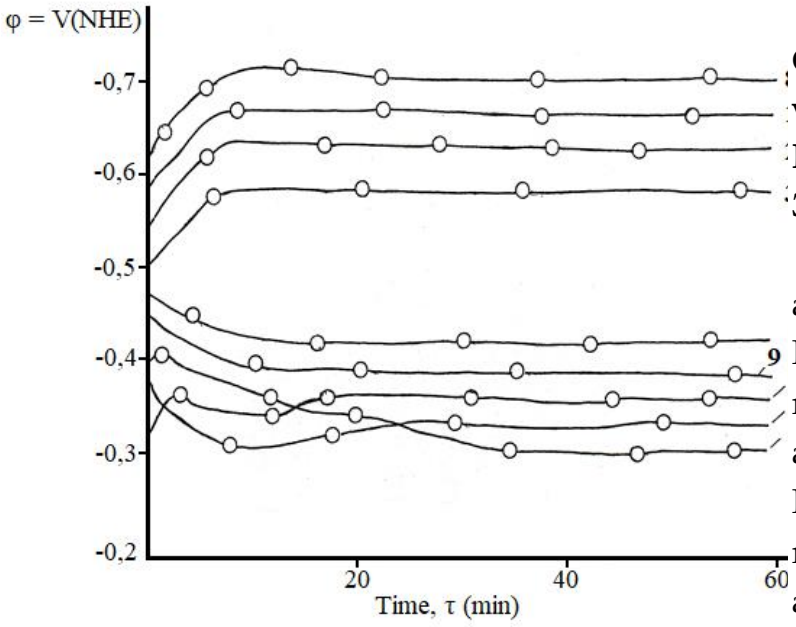

Figure 2. Corrosion potential versus time in 3% NaCl at t=25oC. 38X2MYuA steel.

1 - Hardened according to mode 5; 2 - Hardened according to mode 4; 3 - Hardened according to mode 1; 4 - Hardened according to mode 2; 5 - Hardened according to mode 6; 7 - Hardened according to mode 3; 8 - untreated steel;

9 - chrome plated (galvanized) - h=16 μm.

When analyzing the anodic polarization curves obtained for 38X2MYuA steels in modes 4 and 6, it is clear that at the initial stage of treatment in a CuSO4 solution, oxidation, respectively, anodic solution currents sharply reduced the corrosion resistance of the coating and differed by 3 orders of magnitude. The conclusions of the results obtained based on the analysis of anodic polarization curves show that the time dependence of the corrosion potential under the influence of the same solution is confirmed by measuring the indicators (Figure 2).

As can be seen from Figure 1, the initial corrosion potential of untreated 38X2MYuA steel has the most negative value, and it has been proven that the stable corrosion potentials for steel with protective coatings obtained according to modes 3, 6, and 7 shifted to positive potentials by 350-370 mV.

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

1The low protective properties of the coatings obtained in modes 4 and 5 are confirmed by a shift of the corrosion potential in the anodic direction of only 50-100 mV compared to untreated steel. Part of the corrosion tests was carried out in a salt spray chamber with spraying of 3% sodium chloride solution. The temperature in the room was 2°C. The tests were carried out on samples made of 38X2MYuA steel, hardened under various conditions. The results of the corrosion tests and the oxynitriding regimes are given in Tables 1 and 2. The results of the corrosion tests were compared with the original samples, samples with nitride-oxide layers obtained without initial oxidation, which were studied in detail in [4,5,8,9,], and coatings obtained after hard chromium plating with a thickness of 16 μm. The tests showed that the nitro-oxidized samples hardened according to regimes No. 2, 3, 6, 7, 10, 12 and 13 had the smallest corrosion spots compared to all other samples and, with increasing corrosion area, constituted a correspondingly smaller percentage. It should be noted that the values of the values obtained in nitro-oxidized samples hardened according to modes 2, 3, 6, 7, 10, 12, 13 did not increase significantly in the future. In samples hardened according to other modes, an increase in the volume of corrosion centers is observed, especially in the chrome-plated sample. If corrosion sites are present, their rapid growth also occurs.

The work also investigated the effect of the temperature-time parameters of the initial oxidation on the corrosion resistance of nitro-oxidized samples (Figures 1, 2, and 3).

It was found that increasing temperature in the considered ranges has a positive effect on the corrosion resistance of the metal (Figure 3). The best results in terms of corrosion resistance in the temperature range of 550 and 580°C were achieved with a preliminary oxidation duration of 7-10 minutes (Figure 3), while the most positive results were achieved at a temperature of 620°C. After a preliminary oxidation of 5-20 minutes, it was observed that a preliminary oxidation of 30 minutes at 620°C also proved to be significantly better corrosion resistance [4,5,8,10,].

AMERICAN JOURNAL OF MULTIDISCIPLINARY BULLETIN
ISSN: 2996-511X (online) | ResearchBib (IF) = 9.512 IMPACT FACTOR
Volume-3| Issue-6| 2025 Published: |30-06-2025|

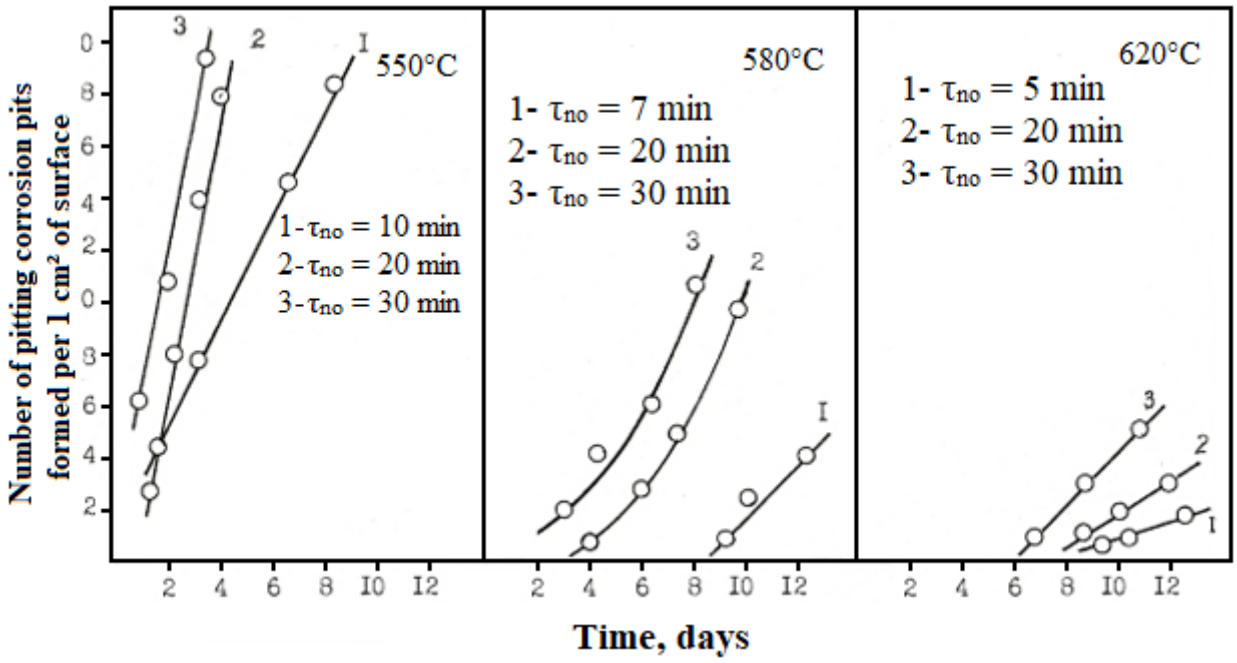

Figure 3. Dependence of the number of pits on the exposure time of 38X2MYuA steel samples in 3% sodium chloride at chemical-thermal treatment temperatures of 550, 580, 620°C. Nitriding time 2 hours, final oxidation time 30 minutes.

Thus, studies have shown that nitro-oxidation of steels, carried out under optimal conditions, significantly increases their corrosion resistance.

Discussion of the results. The high anti-corrosion properties of nitro-oxidized layers are also confirmed by the results of electrochemical studies of the samples.

The electrochemical behavior of nitro-oxidized layers was compared and evaluated with the properties of chromium coatings deposited on 38X2MYUA steel.

Thus, the results of electrochemical studies conducted in a salt spray chamber confirmed the increased corrosion protection properties of oxynitride layers formed on the surface of steels.

Conclusion. Part of the research work on increasing the corrosion resistance and extending the service life of metal coatings was carried out by spraying a 3% sodium chloride solution. The experiment was conducted at a room temperature of 2°C, and the tests were carried out under various conditions to coat and form a protective layer on samples made of hardened steel grade 38X2MYuA.

As a result, the research work showed that nitro-oxidized steel samples hardened according to regimes No. 2, 3, 6, 7, 10, 12 and 13 had the smallest corrosion spots compared to all other samples, and the corrosion area increased and, accordingly, was a smaller percentage. From the obtained research results, it

can be noted that the operational performance of the values obtained in nitro-oxidized samples hardened according to modes 2, 3, 6, 7, 10, 12, 13 is confirmed. In samples hardened according to other modes, an increase in the size of corrosion foci was observed, especially in chrome-plated samples.

REFERENCES:

1. У.Р.Бойназаров, Ж.С.Ибрагимов, Ш.Тураев. Показатели по коррозионной стойкости оксиазотированных покрытий. Академические исследования в современном технике. Журнал. 1-том. №20. С.42-47. 2023г.

2. Стульпина Г.С. Повышение коррозионностойкости инструкционных сталей методом оксиазотирования. дисс. на соиск. уч. степ, к.т.н. Москва, 1990. с.166.

3. У.Р.Бойназаров, А.А.Каримов. «Наука, техника и образование» №33 май 2016 г. Россия.

4. У.Р.Бойназаров, В.И.Юршев, Л.Г.Петрова. Изгибная прочность оксинитридных покрытий. Университетский комплекс как региональный центр образования, науки и культуры: материалы Всерос. науч.-метод. конф. (с междунар. участием), с 490-495, 23-25 янв. 2020 г., Оренбург, Россия.

5. Бойназаров У.Р., Т.Х.Раззоков. Микротвердость диффузионных нитрооксидных слоев. Журнал "Universum: технические науки". Россия. 2020 г. 26 июль.

6. Tashmurza, У. (2024). STUDУ OF THE DEGREE OF FOAMING OF ABSORBENT COMPOSITIONS USED WHEN PURIFУING GASES FROM ACIDIC COMPONENTS. *Universum: технические науки*, *9*(3 (120)), 40-44.

7. Yuldashev, T. R., Rakhimov, G. B., Bekmurodov, A. A., & Jabborov, N. X. (2024). INCREASING THE EFFICIENCУ OF CLEANING NATURAL GASES FROM SOUR COMPONENTS. *Экономика и социум*, (11-1 (126)), 626-631.

8. Yuldashev, T. R., Rakhimov, G. B., Bekmurodov, A. A., & Jabborov, N. X. (2024). METHODS OF PREVENTING FOAM IN DEVICES FOR CLEANING GAS FROM NORMIC COMPONENTS. *Экономика и социум*, (11-1 (126)), 619-625.

9. Юлдашев, Т. Р. (2023). ИССЛЕДОВАНИЕ АКТИВНОСТИ И СЕЛЕКТИВНОСТИ АБСОРБИРУЮЩИХ КОМПОЗИЦИЙ В ПРОЦЕССЕ ОЧИСТКИ ГАЗОВ ОТ КИСЛЫХ КОМПОНЕНТОВ CO2 И H2S. *Universum: технические науки*, (12-6 (117)), 62-65.

10. Юлдашев, Т. Р. (2023, November). ПОЛУЧЕНИЕ И ФИЗИЧЕСКИЕ СВОЙСТВА АБСОРБЕНТНЫХ КОМПОЗИЦИЙ НА ОСНОВЕ АМИНА И ЭФИРОВ. In *The 3 rd International scientific and practical conference "Modern research*

in science and education" (November 9-11, 2023) BoScience Publisher, Chicago, USA. 2023. 1096 p. (p. 330).